DEMOGRAPHIC ANALYSIS OF THE BALD EAGLE IN ARIZONA

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EXECUTIVE SUMMARY

The bald eagle in Arizona has been intensively studied since 1983, and this report presents data collected from 1991 through 2003. Little information is available regarding the abundance, productivity, or survivorship of bald eagles in Arizona before the mid-1970s. In addition, there is no information on whether there was a decline in Arizona during the mid-1900s to match the nationwide trend. Therefore, any discussion of the status of the breeding bald eagle in Arizona is in terms of recent trends, not by comparison to an earlier baseline.

Here, we present a demographic analysis to bring together our multi-year data on productivity with resighting of marked bald eagles in Arizona to estimate survivorship. Together, survivorship and productivity allow us to test whether our multi-year data is adequate to formulate a demographic model precise enough to capture the positive growth documented in the bald eagle population in Arizona. As such, this analysis serves as the starting point to evaluate management practices and will provide us with guidance on how to direct and adapt our future efforts.

We used Program MARK to estimate survivorship and age-specific breeding probabilities based on 314 bald eagles banded as fledglings and 38 banded breeding bald eagles for which cohorts were not identified (i.e. bands not read). We used these age-specific estimates plus productivity values from our surveys in a Leslie matrix to create a deterministic demographic model. We estimated growth rate (λ) as well as the size of the non-breeding segment. We followed up with a sensitivity analysis to identify elements of the matrix that most influence growth. In addition, modified versions of the model were used to gauge the relative importance of delayed reproduction in females and an apparent sex ratio bias (65% male nestlings) for λ. These models do not factor in environmental stochasticity, which is the cause of non-deterministic, year-to-year variation in vital rates. Our results should be considered as a baseline from which to explore correlations between annual survivorship and fecundity rates, density-dependent effects, and the magnitude and impact of environmental stochasticity on reproduction and/or survivorship. Environmental stochasticity may raise or lower population growth rates in any given year, but the effect of increased year-to-year variability is always to dampen long-term population growth. More elaborate models would also incorporate the effects of demographic stochasticity, which is an important consideration with a species in low abundance.

Only one banded bird that fledged elsewhere has been observed breeding in Arizona, and only one fledgling banded in Arizona was later observed breeding outside this state. We disregarded these negligible occurrences in our demographic analysis, and modeled the bald eagle in Arizona as a closed population. In our model, additions to the population come only from births, and losses come only from deaths. However if the population is open, counts of breeding adult eagles will reflect losses due to emigration of juveniles, as well as addition of immigrants into the breeding segment. When we treat an open population as if it is closed, juvenile emigrants are accounted for as if they are mortalities (this decreases the apparent survivorship to breeding age). Immigrants, however, are not accounted for at all in such a demographic model. Differences between the growth rate in the number of breeders each year and in the population size based on birth and death rates (the demographic model for a closed population) were interpreted as an indication that we have incomplete understanding of factors that drive the population dynamics of the bald eagle in Arizona.

The Leslie matrix model estimated that if we saw 70 breeding birds in adult plumage (a typical value) the total population size (including fledglings and non-breeders of all ages) would be

approximately 162 bald eagles. Depending on age at first reproduction, sex ratio, and proportion of females that breed each year, the demographic models projected future annual declines ranging from 3.6 - 5.5%. These average rates and their associated confidence intervals are consistent with a stable or declining population. In contrast, simple counts of bald eagles breeding in Arizona each year indicated that the breeding segment – and by extension the non-breeding segment – has been increasing at an average rate of 4.0% per year from 1991 to 2003. The discrepancy between the demographic λ and count-based estimates might reflect incorrect assumptions about newly discovered BAs (and resulting inaccuracy in counts), idiosyncrasies of our data, survivorship estimates that are low, emigration, shifting age at first reproduction as the population expands, and/or recruitment of breeders from unmarked populations.

This analysis highlights gaps in our understanding of the biology of the bald eagle in Arizona. Compared to other studies, we estimated lower survivorship for bald eagles under the age of 4. However, some of these losses may reflect emigration, not mortality, and therefore our data describe *apparent* survivorship. The use of radiotelemetry to track young bald eagles would enable us to understand the relative importance of emigration and mortality, 2 factors that would impact the number of Arizona-fledged bald eagles that eventually breed in Arizona. Understanding pre- and non-reproductive bald eagles (emigration, specific types of mortality) is one step in evaluating our best options for continuing management. Another step requires assessing the relative contribution of different vital rates (e.g., birth, death, immigration, emigration) to population growth rates. Our sensitivity analysis indicated that there would be a larger impact on population growth from increasing survivorship of bald eagles over age 5 than from an equivalent increase in pre-reproductive survivorship or in productivity. However, we cannot evaluate whether a management focus on survivorship of bald eagles over age 5 would be effective until we develop a better understanding of specific factors that affect vital rates, specifically adult survivorship.

The bald eagle in Arizona is one of the most studied; nonetheless, this analysis points to parameters that must be more clearly understood in order to reconcile the increasing number of observed breeders with the relatively low observed productivity and survivorship. As part of our analysis, we estimated the size of the non-breeding segment (pre-reproductive and non-breeding, reproductively mature birds) for bald eagles in Arizona. Our monitoring does not lead to direct estimates of survivorship of non-breeding adults (floaters). Therefore we used survivorship rates for same-aged breeders. Demands on breeders are different from those on floaters, so it would have been preferable to estimate survivorship separately for breeders and same-aged floaters. The size of the breeding population in Arizona makes this segment particularly important for describing population stability, and we think future work should be directed at understanding the role of floaters. The increase in number of breeders and breeding areas leads to further questions: Is the increase in breeding areas due to an increase in the number of breeding bald eagles and/or to a shift in habitat use? If the latter, what changes have occurred in the role of environmental factors that previously limited the number of breeding areas in Arizona? These questions cannot be answered at the scale of the breeding area, but require consideration of factors at the landscape and watershed scales. Because non-breeding bald eagles spend time in seasonal migration across North America, questions about factors influencing their survivorship would also have to be pursued at larger geographic scales.

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INTRODUCTION

The bald eagle (*Haliaeetus leucocephalus*) is the common North American representative of sea eagles, a genus of fish predators occurring on all but two continents (Brown and Amadon 1989). However, bald eagles do not prey upon fish exclusively and supplement their diet with waterfowl, shorebirds, mammals, and carrion. Historically widespread across North America, the species began a significant decline in the late 1800s due to the combined effects of shooting for feather collection, habitat modifications following European settlement, loss of large bison herds that supplied carrion, and extensive predator control measures (U.S. Fish and Wildlife Service 1999). The Bald Eagle Protection Act of 1940 (16 U.S.C. 668-668d) reduced purposeful killing of bald eagles, but subsequent widespread use of the insecticide dichloro-diphenyl-trichloroethane (DDT) nearly brought the species to extinction before it was banned as a pesticide in the United States in 1973 (U.S. Fish and Wildlife Service 1999).

The above description of the species' decline is not based on information from Arizona, but reflects factors affecting the species across their range, with the relative importance of each factor varying regionally. In Arizona before the 1970's, there was no direct information about the size and condition of the breeding population and no understanding of any threats. Before the era of dam construction in the early 1900s, only 1 breeding pair was mentioned in any reports from the period (Mearns 1890). This inability to reconstruct the historical range and densities of bald eagles in Arizona affects our ability to quantify long-term trends or to identify their causes. Some factors that were documented to affect the species elsewhere may have impacted the bald eagle in Arizona historically. It is likely that riparian, nesting, and foraging habitat of bald eagles in Arizona were affected to a greater extent than those in northern and eastern parts of the continent by water development projects (Rubink and Podborny 1976; Hunt et al. 1992). Introduction of non-native fish that utilized the water column differently from native species probably affected the availability of prey (Rubink and Podborny 1976). One possible source of decline was widespread use of DDT, as residues of dichloro-diphenyl-dichloroethylene (DDE, a metabolite of DDT) persist at harmful levels in waterfowl and some fish in cotton-growing regions of Arizona (King et al. 1997). We do not know the extent to which waterfowl overhunting, or ingestion of lead and other contaminants in waterfowl and fish might have impacted the species in Arizona. Although many activities around nesting bald eagles are now strictly regulated and killing of bald eagles has been illegal since the 1940's, current harassment and killing of bald eagles in Arizona continues to decrease nest success (Rubink and Podborny 1976; Grubb and King 1991; Hunt et al. 1992) and survivorship (Hunt et al. 1992).

Due to lack of historical background, the focus of this demographic analysis is not on whether there was a decline in the Arizona population to match the trend nationwide, or even whether there were harmful impacts, and if so, whether these impacts have been removed. Instead the question addressed here is whether the current population can sustain or increase itself. Attempts have been made since the 1970's to estimate the size and status of the bald eagle population in Arizona. A non-breeding segment exists (consisting of pre-reproductives and non-breeding, reproductively mature birds), but has been difficult to characterize (Hunt et al. 1992).

The Arizona population of bald eagles appears to meet the assumptions of a closed population, i.e., without immigration or emigration (see Methods). In Arizona, breeding areas (BAs) are primarily located along the Gila, Salt, and Verde rivers (Fig. 1). These more densely populated drainages have also recruited to and from BAs along the Agua Fria and Bill Williams rivers. The only known immigrant into Arizona pioneered a BA (Luna) in the White Mountains. Based on resighting of banded individuals, BAs in the White Mountain area of the state (San Francisco and Little Colorado rivers) have not recruited to or from these primary drainages. This single occurrence of immigration does not conflict with treating the population as closed, since there has been effectively no immigration or emigration. Because the bald eagle in Arizona occupies a limited number of BAs, a more complete description of population status would consider the role of year-to-year variability in mortality and reproductive rates (environmental stochasticity), as well as how small-population effects (e.g. loss of genetic variability and ability to recover from stochastic population decreases) might affect population stability. In this report, we bring together data and calculations to describe vital rates (e.g. birth, death, immigration, emigration), and end with a simple population dynamics model that will be the basis for future, more realistic demographic models which incorporate environmental and demographic stochasticity.

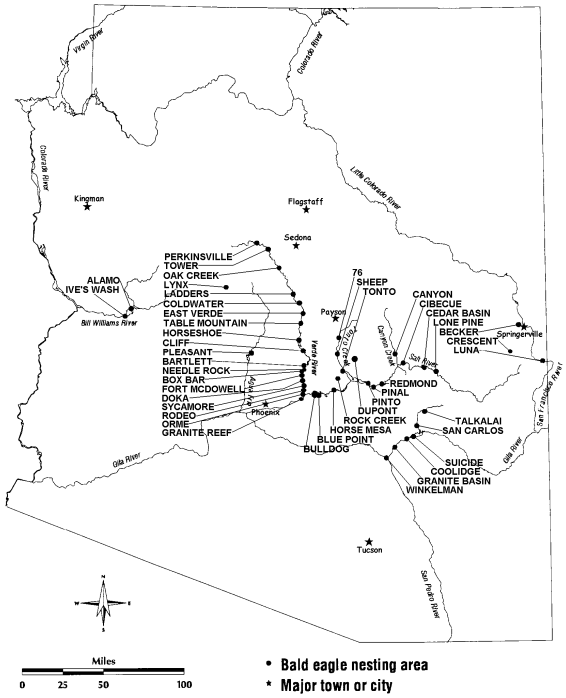


Figure 1. Known Arizona bald eagle BAs as of 2003.

HISTORY OF EFFORTS TO DESCRIBE STATUS

The first in a series of studies on breeding bald eagles in the United States was initiated just before passage of the Endangered Species Act of 1973 (16 U.S.C. 1531-1544). The U.S. Fish and Wildlife Service (USFWS) instituted surveys nationwide in 1972 to assess the distribution of the species, estimate population size, and collect productivity information. The status report for the southwestern region estimated that 90% of potential habitat in Arizona had been surveyed by helicopter or on foot in 1975, and the number of breeders was estimated at 18 birds, with 5 fledglings annually (Rubink and Podborny 1976).

This report led to studies by Robert Ohmart and colleagues at Arizona State University. Their work on the breeding bald eagles in Arizona from 1977 through 1982 included the first banding efforts to describe site fidelity and identify natal origin of breeders (Hildebrandt and Ohmart 1978; Ohmart and Sell 1980; Haywood and Ohmart 1980, 1981, 1982, 1983; Hildebrandt 1981).

The Arizona Bald Eagle Nestwatch Program (ABENWP) was initiated and coordinated by the U.S. Forest Service (USFS) from 1978-1985, by USFWS from 1986-1990, and by the Arizona Game and Fish Department (AGFD) since 1991. While coordinated by AGFD, contractors for the program monitored 10-15 BAs near high-use recreational areas, educated the public about the breeding bald eagles, collected behavioral data, and alerted wildlife biologists when intervention could rescue a failing reproductive effort. In addition, seasonal closures have been enacted at some BAs in high-use recreational areas to reduce any detrimental effects on the breeding cycle.

Intensive nationwide survey and monitoring efforts that began in the 1970's resulted in USFWS classification of the bald eagle as endangered in 43 states, including Arizona, and as threatened in 5 others (USFWS 1982). The Southwestern Bald Eagle Recovery Plan (USFWS 1982) was formulated, and a research project was initiated by Teryl Grubb (USFS) from 1983-1985 (Grubb 1986). During this project, intensive monitoring began in order to describe, among other things, productivity and population trends of bald eagles in Arizona, and included opportunistic banding of nestlings. This study created the basic banding protocol for the subsequent, 4-year effort by Hunt et al. (1992) that included laying out goals, timing, locations for surveys, banding, and in-depth monitoring. The latter was a contracted study to describe impact of water development projects on bald eagles in Arizona (Hunt et al. 1992). The resulting research provided description of movements within the breeding population, estimates of age at first reproduction, pair-bond duration, survivorship of breeding bald eagles, and tenure of individual birds in the breeding population (Hunt et al. 1992). USFWS (1991 and 1992), Mesta et al. (1992), and AGFD (1993 to present) continued with the protocol as modified by Hunt et al. (1992).

The bald eagle was subsequently downlisted to threatened status (USFWS 1995), and later delisted (USFWS 1999, 2007). Delisting criteria were established in 4 separate regional recovery plans, but not for the Southwestern Region (USFWS 1999).

DEMOGRAPHIC ANALYSIS

This study was initiated to guide management efforts to continue the recovery of bald eagles in Arizona, and has generated a comprehensive data set used to describe population dynamics of the species. We created models to explore the relative importance of different stages of bald eagle life history in maintaining or increasing this population. Recovery and delisting criteria for other regions were all couched in terms of demonstrating that population numbers, productivity levels, and/or number of subpopulations reflect the ability of the bald eagle to avoid complications of small-population effects. Our description of the status of bald eagles in Arizona addresses the first 2 of these demographic concerns. We also discuss aspects of bald eagle biology that are most sensitive to threats and/or management.

As a simple assessment of population growth rate, we can estimate the replacement rate of the breeding segment. If the numbers are steady or increasing each year, we can make an initial assessment that the population is not in crisis. To test this assessment, and to examine the limiting parameters of a species' biology, we need to examine the species' life history in detail.

These detailed analyses are a critical aspect of demographic analyses. Reconstructing elements of a species' life history can test our understanding of the biology of a species, allow us to evaluate its resilience in the face of random or catastrophic environmental perturbations, estimate rates of population decline or growth, and describe the relative merits of different management options. In addition, development of demographic models can reveal population parameters that limit population growth, and provide direction for management based studies. In recent years, there has been increasing demand for demographic analyses to test the effectiveness of management activities. One example is a population viability analysis (PVA), illustrated in Fig.

2, which provides a conceptual framework for demographic analysis and subsequent management.

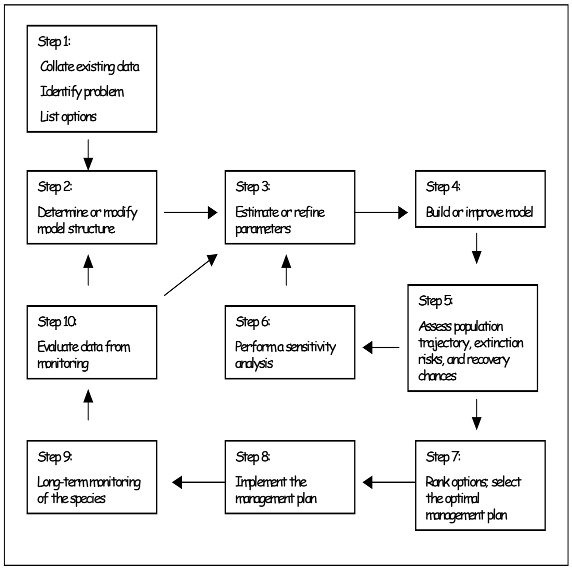


Figure 2. Components of a typical population viability analysis used to describe current status and guide recovery management (modified from Akçakaya et al. 1997).

Some biologists have also applied this tool to endangered species to predict extinction risk (Step 5 in Fig. 2). Analyses that attempt to project extinction risk usually consider the relationship between specific identified threats and population dynamics. This connection differentiates PVAs from other types of demographic analysis. However, Beissinger and Westphal (1998) identified major limitations in developing PVA models. Most PVA models cannot be validated, and projections usually do not incorporate future changes in habitat quality or quantity. Data sets are usually too short to capture the range of environmental variability, including uncommon but powerful catastrophes and bonanzas. Even when the data are accurate and threats well known, stochasticity inherent to all biological processes can generate large errors, especially in forecasting extinction risk (Taylor 1995, Ludwig 1999). Complex, biologically realistic models may not capture reality because demographic data, the main inputs of the models, are often inaccurate, imprecise, or variable due to environmental stochasticity and catastrophes.

Noting the caveats and recommendations of Beissinger and Westphal (1998), we used a simple, single population model for bald eagles in Arizona, built in a deterministic (Leslie matrix) form, to describe current population growth rates. Beissinger and Westphal (1998) also recommended estimation of relative extinction risk rather than absolute extinction risk. Therefore, we used variants of our original model to explore the impact on population growth rate from apparent sex ratio bias and variation in the proportion of females breeding in each age class. We performed an elasticity analysis to evaluate the influence of certain elements of the matrix (e.g. age-specific fertility or survivorship) on population dynamics.

Long-term data sets, especially for a long-lived species like bald eagles, are necessary to provide accurate estimates of parameters like birth and death rates. We report rates from earlier studies (Grubb 1986; Ohmart and Sell 1980; Haywood and Ohmart 1980, 1981, 1982) that formed the basis for the current study. This study collected data in Arizona from 1991 to 2003, reporting, in some cases, on bald eagles banded during the earlier studies (Hunt et al. 1992, Mesta et al. 1992). Our annual survivorship estimates only reflect the period 1993 to 2003, so we only used productivity data from the same years. We interpret vital rates with the highest elasticities as those parameters that are most sensitive to accurate estimation, and that have more impact on population growth rate if they experience a small increase or decrease (Beissinger and Westphal 1998, Morris and Doak 2002).

The scope and depth of empirical data available to us is more extensive than what is typically available for an endangered species. On the other hand, our data span a period during which habitat quality and quantity as well as human interactions with bald eagles may have changed dramatically. Rather than attempting to describe and model all of this information, our goal in this report is to develop a model for population dynamics as a platform to discuss the current understanding of population dynamics, and to illustrate how different management options may affect the population. As such, our report addresses the first 6 steps of Fig. 2. Regarding Step 5, we describe the population trajectory for a closed population. Pending increased banding and resighting efforts in surrounding states to document possible immigration and emigration, we defer assessing the extinction risks to the next round of analysis. Our analysis provides an initial understanding of how well the biology of bald eagles in Arizona matches this environment, and whether the observed birth and death rates match the observed population increase. At this time, we are using this analysis to guide future information gathering, but postpone consideration of management changes (i.e., the 7th step in Fig. 2) until we develop better understanding of factors that limit expansion of the bald eagle in Arizona.

METHODS

STUDY AREA

We collected data at bald eagle BAs along lakes, rivers, and reservoirs throughout central Arizona (Fig. 1). In 2003, these BAs extended from Winkelman in the south, to near Clarkdale in the north. Most bald eagle BAs are in central Arizona between elevations of 329 m (1080 ft) and below 1341 m (4400 ft). They are found within the riparian areas of the Sonoran Riparian Scrubland and Sonoran Interior Strands as described in Brown (1994). Representative riparian vegetation includes Fremont cottonwood (*Populus fremontii*), Goodding willow (*Salix gooddingii*), Arizona sycamore (*Platanus wrightii*), and introduced salt cedar (*Tamarix* spp.). Surrounding uplands include the Sonoran Desertscrub biome-Arizona Upland subdivision, Interior Chaparral biome, and Great Basin Conifer Woodland biome. These areas are commonly vegetated with blue palo verde (*Cercidium floridium*), mesquite (*Prosopsis* spp.), ironwood (*Olyneya tesota*), saguaro (*Carnegia gigantea*), teddy bear cholla (*Opuntia bigelovii*), juniper (*Juniperus* spp.), and pinyon pine (*Pinus edulis*).

Six BAs were located outside of Sonoran Riparian Scrubland areas (Brown 1994). The Becker BA is within the Plains and Great Basin Grassland biome where they nest in an isolated patch of Fremont cottonwoods. Lower Lake Mary, Luna, and Lynx are in Rocky Mountain and Madrean Montane Conifer Forest where riparian vegetation includes narrow-leaf cottonwood (*Populus angustifolia*), thin-leaf alder (*Alnus tenuifolia*), Bebb's willow (*Salix bebbiana*), and coyote willow (*S. exigua*) (Brown 1994). Dupont and Rock Creek are located in patches of Rocky Mountain and Madrean Montane Conifer Forest surrounded by Interior Chaparral, consisting mainly of pinyon–juniper woodland, shrub live oak (*Quercus turbinalla*), and pointed (*Arctostaphylos pungens*) and pringle manzanita (*A. pringlei*).

DATA COLLECTION

Breeding Area Status and Productivity

We used monthly occupancy and reproductive assessment (ORA) and nest survey flights to estimate the number of breeders and to describe productivity as a function of occupancy. These flights were conducted at most known BAs and within suitable habitat statewide to describe BA breeding status, monitor the breeding cycle, estimate age of nestlings, and to detect new BAs. When ORA flights were not adequate to gauge breeding or occupancy status, the BA was surveyed from the ground. In addition, any known BA outside of the ORA flight routes was monitored from the ground. For instance, BAs in the White Mountains were monitored by ABENWP contractors (Luna BA), or by local AGFD or USFS personnel (Becker BA).

We used helicopter flights throughout the breeding season to classify BAs as unoccupied, occupied, or active based on operational definitions (Appendix A) derived from Postupalsky (1974, 1983) and Steenhof and Kochert (1982). Since 1982, Arizona has also participated in nationwide surveys for wintering bald eagles (e.g. Driscoll et al. 2002). Flight paths for the annual winter counts traversed most of the major waterways including those with known Arizona BAs. Winter count flights were scheduled each year for the first full week in January. Since these flights coincided with early breeding activity in Arizona, they were also used as our first ORA flight. Each month of ORA flights lasted a consistent number of flying days, with a predetermined set of river systems on each day. January flights included 4 days to allow for counts of wintering birds. Flights during the first week in February, and during the third week of both March and April covered 2 days. One day covered BAs on the Verde, Bill Williams, and Agua Fria rivers; the other day covered the Salt, Gila, and San Carlos rivers. Flights during these months were different than in January as they contained no official bird tallies. Biologists used reported sightings of bald eagle pairs, spacing between known BAs, and knowledge of suitable nesting areas to target searches for active nests within and outside the known BAs. By May, the occurrence of late and second breeding attempts was minimal. Therefore, flights during the third week in May and June rarely involved more than 1 flight day to document the status of nests that were active in April.

ORA flights were spaced to monitor each phase of the breeding attempt: incubation, hatching (up to 2 weeks of age), nestling (2-8 weeks), pre-fledging (8-12 weeks), and post-fledging (after 12 weeks). We used observed incubation and hatching dates, in conjunction with a development guide (Carpenter 1989), to estimate the age of nestlings. If fledglings were not observed during the last ORA flight or by ABENWP contractors, we nonetheless classified a breeding attempt as successful if nestlings were known to have lived to at least 8 weeks of age and we found no evidence of later death. We occasionally reversed our determination if, in a subsequent year, a ground visit revealed the nestling had died in or near the nest, or if a banded nestling presumed dead was later identified alive. Classifying nestlings as successful fledges once they reached 8 weeks of age likely overestimated fledging success; however, daily monitoring by the ABENWP at many nests tempered these estimates by enhancing documentation of nestling mortality. We used survey data to calculate occupancy rate, BA success rate, productivity, and fledging rate per hatchling from 1993 through 2003. Data for the 6 preceding years were taken from Hunt et al. (1992) and Mesta et al. (1992).

Banding and Resighting

To estimate survivorship of bald eagles, we banded nestlings and identified them upon return as breeders (Appendix B). From 1977 through 1982, researchers initiated the first banding efforts to describe site fidelity and identify natal origin of breeders (Hildebrandt and Ohmart 1978; Ohmart and Sell 1980; Haywood and Ohmart 1980, 1981, 1982, 1983; Hildebrandt 1981). From 1983 through 1985, Grubb (1986) conducted a genetic analysis of Arizona bald eagles during which nestlings were banded opportunistically.

From 1977 to 1985, biologists used USFWS aluminum bands engraved with 8-digit numeric codes to band nestlings (Haywood and Ohmart 1980, 1981, 1982, 1983; Hildebrandt and Ohmart 1978; Hildebrandt 1981; Grubb 1986). However, engraved codes could rarely be read from a distance, so individuals were usually identified through band recoveries or the time-consuming process of capturing birds. In this report, we refer to these birds as 'single-banded.' Various attempts were made to increase the visibility and readability of the USFWS bands (Hildebrandt 1981; Grubb 1986). These attempts had limited success.

Beginning in 1987, Hunt et al. (1992) modified banding techniques to increase identification from a distance (Hunt et al. 1992; Mesta et al. 1992; this study). Under this protocol, attempts were made to band every nestling at accessible BAs with a USFWS band as well as a color-anodized aluminum visual identification (VID) band engraved with a unique symbol. From 1987 to 2003, 83% of known fledglings have been banded (Table 2, Appendix C; Hunt et al. 1992, Mesta et al. 1992). Nestlings were not banded if the process would harm the nest, nestlings, or the climbers.

Since 1993, we collected resighting data during the breeding season, and were most successful at active nests, which were visited regularly by breeders. Identification of breeders at BAs that were not active was less likely as their presence was less predictable. Most resighting was accomplished with Questar® spotting scopes (15x – 210x) from a distance sufficient to read the symbol, but far enough to avoid disrupting normal behaviors. Exact distance depended on topography, weather, temperature, legibility of the band, and tolerance of individual birds to human activity. Breeders tended to remain within the BA year-round, so if a VID band could not be read with a spotting scope, trapping attempts were made during the non-breeding season and were occasionally successful.

Identification rates of banded breeders reflected the successful use of colored VID bands for distance resighting. Some birds were not identified before they were replaced at territories, and project priorities limited the time available to identify single-banded individuals. We used a life-table survival analysis to describe median time to identify individuals based on whether they were single-banded or also carried a VID band. VID banding reduced time needed to identify birds (Wilcoxon statistic=23.3, df=1, $P < 0.0005$; Fig. 3). Median time to identify single-banded birds (through trapping or reading the numeric code) was 7.0 yrs; for VID-banded birds it was less than one full breeding season at only 0.6 years. During its first breeding season, there was an 88% chance a VID-banded bird would be identified, compared to 17% for single-banded birds (Fig. 3). By the end of their fourth year on a BA, all VID-banded birds were identified.

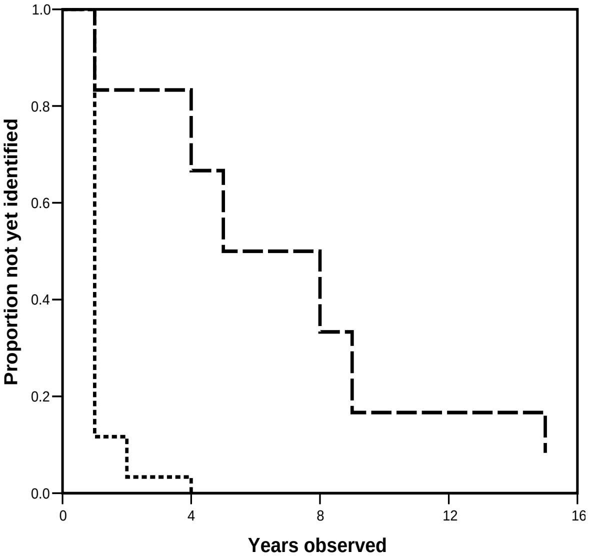


Figure 3. Proportion of unidentified banded birds after the indicated years of residence in a BA. Separate curves for birds banded only with a USFWS band (dashed line; N_{single}*=6) or with a VID band (dotted line;* N_{VID}*=60). Censored cases, for which the band was not read before the bird left the BA, are included in the above totals (*N_{single}*=5,* N_{VID}*=58).*

The inability to identify every banded breeder in each BA annually (Appendix B) created gaps in our understanding of survivorship and breeding tenure. We used the following guidelines to associate identities with breeders:

1. For the mark-resight analysis, the following assumptions were related to the premises that banded birds had fledged in Arizona, and the identity of those with unread bands is best assumed to be that of identified banded birds of the same sex that occurred in the same BA in adjacent years. Because we never extrapolated these identities past the last year a band was actually read, this procedure did not affect survivorship estimates, but increased estimated resighting rates. These identities were used for *Level 1* analyses.
   a. Same-color-banded, same-sex birds from contiguous years were considered the same bird. For example, the male seen in 1993 at the Tower BA had a purple band, but its symbol could not be read. We assumed that this male was the same as the purple-banded male present at the BA in 1994, when the band was read. Of 190 instances between 1987 and 2003 when we were able to read same-color bands in consecutive years, replacements only occurred 5 times.
   b. If a band's symbol could not be read, but the cohort could be identified, the bird was included in the age-specific mark-resight analysis. The color of nestling bands were always blue except in 1988 and 1989, when they were green and purple, respectively. In 1987, the blue bands were 19 mm tall and contained a single engraved symbol, compared to the blue 25 mm bands with two engraved symbols used after 1991.
   c. Once a single-banded bird was trapped and identified, we equated these birds with the [unidentified] single-banded ones that had occupied the same BA in previous years. Single-banded males trapped, identified, and then VID-banded in 1988 (Cliff and Blue Point BAs) were considered identical with those that had occupied the BAs since 1984 (Cliff) and 1983 (Blue Point). At Blue Point, the BA was apparently unoccupied in 1987, but the trapped bird in 1988 was from the 1979 cohort, consistent with the near-adult single-banded male that first arrived in 1983 (Grubb 1986).
   d. The same single-banded male was observed at the Pinal BA from 1987 through 2003. The band was first read in 2002. Although there were intervening years during which banding status could not be ascertained, and 1 year when the BA was apparently unoccupied, we assumed the identity of the bird had not changed over this period. We assume that ownership of the BA did not change after the BA was unoccupied in 2001, since the identified male was a nestling banded in Arizona in 1981 and it is unlikely that he deferred breeding until 2002. In addition due to VID banding since 1987, it is unlikely that a single-banded male would coincidentally be replaced at the same BA where another single-banded male had been in residence.

   e. The single-banded subadult plumage male that arrived at Sheep BA in 1994 was an Arizona male fledgling single-banded in 1991. Because VID-banding had been in use in Arizona since 1987, this bird's banding and plumage is consistent with the only single-banded Arizona fledgling in 1991 (one VID band short during banding).

2. To describe breeding tenure (length of reproductive period and duration of pair bonds), we did not need to identify birds sufficiently to assign their cohort. The following rules were used for determining which unbanded or unread banded birds at a BA were the same across years:
   a. If the plumage of an unbanded resident bird changed from adult to near-adult or subadult, or from near-adult to subadult, it was assumed to be a different bird. Similarly, if USFWS bands were on different legs, we identified these as separate birds. At the Pinto BA, we identified a replacement between unread single-banded birds because the 1992 male was banded on the right leg, while the 1993 male was banded on the left.
   b. Unbanded birds were identified as those from previous years if the first time we observed the bird was unequivocally the first year it occupied the territory, and the last time was the latest date it could have occupied the BA. Thus, we excluded birds if they were present when a BA was discovered unless it was a pioneering effort. We also excluded birds from analysis if the BA had been occupied in previous or following years, but no ground survey had determined the occupant's banding status. We identified a bird's last year of tenure if the BA was unoccupied the following year, or if we documented replacement by a banded bird or by an unbanded one of a different plumage.

Most banding was done on nestlings; however, to calculate age-specific survivorship estimates, it was necessary to have information from additional birds that could be used to estimate annual survivorship of only the oldest age class. For this purpose we used 8 breeders banded between 1987 and 1990 (Hunt et al. 1992) as well as 30 single-banded birds from earlier cohorts (Haywood and Ohmart 1980, 1981, 1982, 1983; Hildebrandt 1981; Grubb 1986). Because we did not identify 19 of these single-banded birds or their cohorts, we could not calculate the proportion of a cohort that survived to age 4. However, we could use these birds to estimate annual survivorship of older breeders, since this did not require cohort information.

We used resighting information to determine if bald eagles occupied an alternate BA once replaced at the first BA and to describe age at first reproduction. We also describe the typical reproductive period of a bald eagle's life, using survival analysis (Fox 1993) to estimate duration of the breeding stage and length of pair bonds, and treating years as intervals during which the pair bond survived or was severed. We calculated median length of pair bond and tenure; since some birds occupying BAs in 2003 will certainly return, means would have provided estimates that were biased low.

Plumage and Age

Known-age breeders were used to describe age-specific plumage for the first sighting of each bird (Fig. 4.). Plumage of resighted breeders was also classified as adult ('Definitive and Basic IV'), near-adult ('Basic III'), or subadult ('Basic II') following McCollough (1989). All banded subadult birds were 3 years old (N=2), and all but 1 of 18 4-year old birds were in near-adult plumage. However, other near-adult birds were as young as 3 and as old as 6, so this plumage is not a reliable predictor of age. Including birds of unknown age, 4 breeders (2.5%) were in subadult plumage and 35 (21.9%) in near-adult plumage.

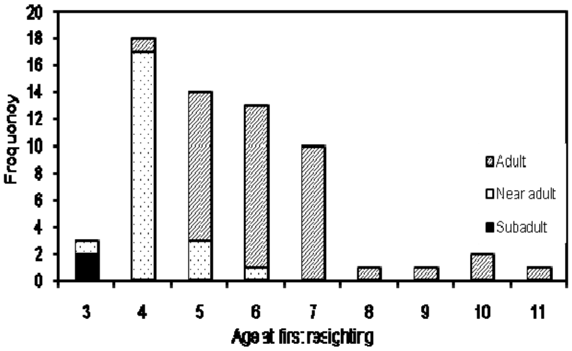


Figure 4. Age-specific plumage for first resighting of banded birds.

In this report, we use the terms 'juvenile' and 'adult' to refer to bald eagles with specific plumages. 'Pre-reproductive' and 'mature' refer to the reproductive maturity of specific birds. In addition, some reproductively mature individuals have occupied BAs ('breeders') while others deferred reproduction. We refer to these as 'floaters,' and use 'non-breeders' to describe both pre-reproductives and floaters (Fig. 5).

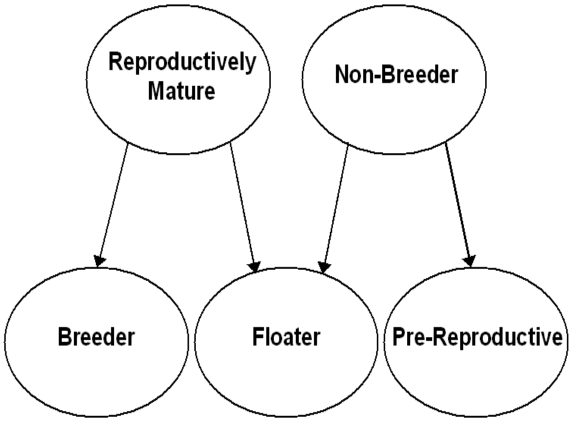


Figure 5. Relationship of terms describing reproductive maturity and breeding status in this report.

Sex Determination

While banding nestlings, we measured the tarsus laterally, classifying those with measurements greater than 12.5 mm as females (Hunt et al. 1992). This measurement correctly classified all but 1 of 50 nestlings that were later autopsied or sexed when they returned to breed (Table 1).

Table 1. Estimate of sex ratios of bald eagle nestlings in Arizona 1987 to 2003. The last two columns were used to estimate error rates for sexing nestlings.

Tarsus lateral measurement (mm)[1]	Number Fledged	Sex Determined upon Breeding[2]	
		M	F
10	8	1	
10.5	26	1	
11	41	3	
11.5	19	3	
12	12	2	
12.5	19		
13	35	1	2
13.5	1		1
14	16		1
14.5	7		1
15	2		1
F[3][4]	30		13
M[3][4]	47	19	
Total	263	30	19

[1] Sexing protocol followed Hunt et al. (1992), Mesta et al. (1992), and Driscoll et al. (1993).

[2] Adults that returned to breed (N=38 plus one that was not sexed as a nestling) or non-breeders that were recovered dead (N=1) could also be sexed behaviorally or by autopsy.

[3] Measurements of nestlings before 1994 not available

[4] Two additional nestlings from the period pre-1994 were not sexed.

DEMOGRAPHIC MODELING

A model is a simplified description of a complex process. The demographic models used here simplified the description of population dynamics by using average birth and death rates instead of using rates for each individual female. The models also assumed that bald eagles were subject to the same dynamics throughout Arizona with factors affecting their vital rates remaining stable over the period of this study. These assumptions were applied to survivorship and population growth estimates, and we treated productivity but not survivorship as if there were no upward or downward trends in these rates. Using data from 1991-2003, we estimated population parameters to create deterministic demographic models to project population growth rate (λ; number of individuals in year(t+1)/number in year(t)). Deterministic models assume that all individuals have the same average productivity and survivorship, so they reflect less biological intricacy than stochastic ones. Stochastic models, which create separate productivity and survivorship rates for each modeled female each year, are based on average rates as well as reasonable estimates of variance for these rates. The deterministic models should, nonetheless, compute similar though consistently larger λ than stochastic ones, capture effects of deterministic factors that consistently increase or decrease population growth, and have the advantage of leading easily to sensitivity analysis. This modeling approach allowed us to focus on major parameters influencing bald eagle population dynamics.

Survivorship and Resighting Estimation

Our analysis considered information on birds that were resighted starting in 1991. Obviously, birds resighted that year were banded in previous years by other biologists, so we also assessed survivorship of these earlier cohorts into the study period. Depending on their age and banding status, we used different sets of individuals in the analyses to describe productivity, survivorship, and reproductive life history. We classified juvenile bald eagles from cohorts since 1987 as either banded or unbanded. Both groups were used to estimate fledging success. Banded juveniles were also used to estimate average age at first reproduction, sex ratios of nestlings and breeders, and to calculate age-specific survivorship. Although single-banded birds provided information about reproductive life history and lifespan, only 12 of 23 single-banded breeders have been identified (Hunt et al. 1992; this study), and therefore we could not estimate the proportion of any of these early cohorts surviving to breeding age. We therefore used cohorts beginning in 1987 (first year of VID banding) to describe annual survivorship of young birds. We assumed that survivorship of older birds did not change significantly with age, so all birds known to be 8 or older, plus single-banded birds and the banded immigrant were used to estimate annual survivorship after 7 years of age. Therefore, our most detailed models for estimating survivorship included a composite estimate of survivorship from fledging to age 4 (annual survivorship could not be directly estimated since juveniles are not resighted at breeding areas), then annual estimates of survivorship to age 5, 6, and 7. A final survivorship estimate described probability of surviving one more year for any bird over age 7.

We used Program MARK (White and Burnham 1999) to estimate survivorship assuming a geographically closed population with resighting of live birds. The program aids development of a series of models to describe survivorship and resighting rates. If bald eagle survivorship varies with age or sex, but a particular model does not include these variables, our estimate will be biased. Conversely, the more predictors we use to fit the model, the less bias. However, using the same data to estimate more parameters means that the variance of our estimates increases. To choose the model that minimized both variance and bias, we used Akaike's criterion to compare the information content of different models (Anderson and Burnham 1999a, b).

Because resighting only occurred at BAs, we could not directly estimate resighting or survivorship rates before age 4. However, because we began resighting bald eagles as 4-year-olds, we are able to estimate the proportion of fledglings that survive to be 4 years old and return to breed. We assumed that mortality was spread equally among years 1-4 so that we could estimate the annual survivorship for the first 4 years. The actual percentage of fledglings that survives to age 4 represents the compound survivorship over those four years, times the proportion that did not emigrate (which we assumed to be 100%). To perform this calculation using Program MARK, we fixed survivorship at 1 and resighting rate at 0 for the first 3 years of each cohort. Consequently, the survivorship estimate at age 4 returned by Program MARK is the survivorship estimate for the entire period from fledging to age 4. For demographic models that required age-specific survivorship, we assumed that survivorship was equal across these ages and estimated it as the fourth-root of the survivorship (Φ) estimate from fledging to age 4:

$$\Phi_{\text{fledgling-to-4}} = (\Phi_{\text{fledgling-to-1}}) * (\Phi_{\text{1-to-2}}) * (\Phi_{\text{2-to-3}}) * (\Phi_{\text{3-to-4}})$$

$$\text{Where: } \Phi_{\text{fledgling-to-1}} = \Phi_{\text{1-to-2}} = \Phi_{\text{2-to-3}} = \Phi_{\text{3-to-4}} = \Phi_j$$

$$\text{So, } \Phi_{\text{fledgling-to-4}} = \Phi_j^4$$

All models used the above approach to estimate juvenile survivorship, but models differ in how adult survivorship and resighting were treated. Models were developed to test whether these estimates were improved by considering differences by age, sex, and over different time periods. Resighting rates might vary, for instance, depending on year-to-year differences in project funding or on experience level of project biologists. *A priori*, we created 5 intervals to test time effects on resighting: the study period for Hunt et al. (1992; 1987-1990), new effort by a single researcher (1991-1992), a period of 2 researchers with 1 of them in training each year (1993-1995, 2002), a period of intensive resighting work from the same group of 3 trained personnel (1996-1998, 2003), and a final period during which only a single trained person conducted surveys and monitoring (1999-2001). We used annual intervals to test for possible year-to-year differences in survivorship, since food availability might vary on this scale, and there was no *a priori* reason to create longer time intervals. We also tested for a gradual (linear) increase in survivorship to mirror ongoing long-term management. A similar trend was possible in resighting rates because bald eagles and BAs became more familiar over the study period, which might have led to more efficient identification. We tested for effects of all combinations of these factors on survivorship, and for effects of all combinations of age and time on resighting rate. Because we identified birds in breeding pairs, and assumed equal opportunities to resight both members within the BA, we did not test for sex-specific differences in resighting rates. Although Stalmaster (1987) reported females incubate for longer periods than males, a behavior that could affect the resighting rate between sexes, Hunt et al. (1992) stated this behavior was variable, and reported two instances to the contrary. We did, however, model sex-and-age-specific differences in resighting rate, to test for later age-at-first reproduction in females.

These models correspond with various hypotheses about breeding biology of Arizona bald eagles. For instance, to test the hypothesis that young, reproductively mature bald eagles (e.g. 5, 6, and 7 year olds) were more likely to be floaters than old reproductively mature bald eagles (e.g. 10+ years old), we compared the efficiency of models with and without age-specific resighting rates. Further, if females began breeding at a later age, younger females should have a lower resighting rate than same-aged males. Due to observed male sex-ratio bias in nestlings and banded breeders, we predicted that males in this monogamous species (= equal sex ratio of breeders in any year) would suffer higher mortality and/or have lower resighting rates (more likely to be floaters) in at least one breeder age class. We tested this idea with models for sex-specific and sex-by-age-specific survivorship as well as sex-by-age-specific resighting rates. For survivorship estimates, we considered the possibility that females might have consistently higher survivorship than males (additive model) or that female survivorship might only be higher for some age classes.

Because some bald eagles deferred reproduction for up to several years, there was variability in age at first reproduction. To test for differing age at first reproduction and differing survivorship between sexes, we estimated annual survivorship and resighting rates for bald eagles aged 5 through 7. Because we had no reason to predict age-specific survivorship differences in older birds, we assumed survivorship rates were similar for those over age 8, and created a single age class for this group plus single-banded birds and those that could not be aged. Similarly, because breeding bald eagles do not normally leave their BAs to become floaters (Stalmaster 1987), we assumed that resighting rates for breeders were uniform; and due to sample-size considerations (with fewer observations of older birds) assumed most living bald eagles were breeders by age 8. We created 1 age class to estimate resighting rates for unaged birds on BAs, plus all birds age 8 and older.

Mark-resight data can be analyzed under the following assumptions (White and Burnham 1999): 1) Every banded animal present in the population at time (i) has the same probability of resighting (p_i). 2) Every banded animal in the population immediately after time (i) has the same probability of surviving to time (i +1). 3) Bands are not lost or missed. 4) All samples are instantaneous, relative to the interval between occasion (i) and (i +1), and each release is made immediately after the sample.

Regarding bald eagles in this study: 1) Resighting rate (p_i) was a function of our ability to identify all breeding birds, but also depended on whether the bird was breeding that year or not. Some birds in each age class were non-breeders, so $p_i = 0$. Breeding birds had a finite probability of resighting. These situations require multistrata models (Hestbeck et al. 1991), which estimate transitions between strata (non-breeding/breeding) for each age class in addition to survivorship and resighting rate for each stratum. Our dataset is not amenable to estimating survivorship or resighting rate for non-breeders since this stage was rarely resighted. For this reason and to use our relatively small dataset to test models with parameters of most interest, we used Jolly-Seber models for capture-recapture (Jolly 1965; Seber 1965). Carothers (1979) demonstrated that errors in survivorship estimates due to violation of the assumption of equal catchability are usually quite small compared to variance estimates (this would indicate that bias is small). We assumed we identified breeders at all occupied BAs each year; however, due to logistical and time constraints, this was not the case. Breeders were more likely to be identified if ORA flights indicated breeding activity at the BA. Some BAs consistently had more breeding activity than others, so these BAs (and birds that occupied them in consecutive years) would be ground surveyed more often. This could have reduced survivorship estimates. 2) Survivorship estimates were based only on breeding birds, and may not accurately estimate age-specific survivorship for floaters. Because we understand little about the biology of floaters, we cannot predict whether their survivorship might be lower or higher than that of breeders. 3) It is unlikely that marks are lost (see Methods, Data Collection, Banding and Resighting). However, some bands were not read the first year they were seen, so some of the recently sighted birds had bands but were not identified. This had the effect of underestimating survivorship; however, because few birds were involved (see below), the effect was probably small. 4) Although we monitored during the entire breeding season and banded during the pre-fledging period, we assumed that all subsequent nestling mortalities were documented, and all breeders alive during that time survived to the post-fledging period. In situations where breeders died during the breeding season (non-instantaneous observation), we treated the bird as being alive through the post-fledging interval because it had potentially contributed to production of that year's cohort.

Based on the relative geographic isolation of BAs in Arizona from those in nearby states and Sonora, bald eagles in Arizona have been treated as a closed population. That is, all previous analyses as well as ours assume that bald eagles that fledge in Arizona do not emigrate and breed outside the state, and bald eagles that fledge elsewhere do not immigrate and subsequently breed in Arizona. Since 1977, there has been only 1 confirmed (banded) male immigrant (from Texas) and 1 confirmed female emigrant (to California). The ability to detect movements among populations depends on banding and survey intensity in other states and/or countries. To be conservative and in the absence of contrary information, we proceeded to model the Arizona bald eagle population as a closed population, but also present a brief analysis of the level of banding and resight activities in other states. If there was significant emigration and/or immigration, population growth rates (λ) based on a closed population could be used to interpret the Arizona population as a growing or shrinking subset of a larger metapopulation. Also, emigration would lead to lower *apparent* survivorship estimates for birds 4 and younger. That is, if a model does not account for emigration but it actually occurs, then estimates of mortality for the affected age classes will also include losses due to emigration. We will interpret our results as if they might describe either a closed population or one with significant levels of emigration and/or immigration.

Estimating Number of Non-breeders

Although biologists have been aware of the existence of floaters due to the rapid replacement of breeders during the breeding season, there has been no attempt to quantify their contribution to population dynamics in Arizona. Mark-resight analysis allowed us to estimate the proportion of non-breeders in each age class. Once banded as nestlings, non-breeders were not observed in subsequent years, due to the method of resighting birds at breeding areas. However, we also did not resight breeders every year, and many apparently did not occupy a BA as soon as they were physiologically able to breed. All of these elements contributed to resighting rates less than 1. Thus, resighting rates were lower due to non-breeders, but also due to incomplete identification of breeders. Although ORA flights were carried out at most BAs each year, we usually only followed up with ground surveys at BAs that were nesting successfully as a time-saving measure. We estimated decreases in resighting rates due to non-breeding status by assuming all banded birds were sighted each year between the first and last year they were identified, as long as surveys confirmed breeding activity. This meant that if a banded bird was identified in two separate years, but in the intervening years there had been failed breeding attempts, with no ground surveys to ascertain the breeders' identities, we assumed the same banded bird had occupied that BA. When reporting our analyses, we refer to this as our *Level 2* assumption (see the Banding and Resighting section).

The Level 2 assumption did not appreciatively affect survivorship estimates since it did not operate outside the period when each bird had been identified, but increased the effective resighting rate within that period. Thus, Level 2 resighting rates provided an estimate of the proportion of each age class that attempted to breed by at least occupying a BA. We report resighting rates for all age classes. In reporting population size and structure, we subdivided age classes into breeder and non-breeder components.

A Deterministic Matrix Population Model

The matrix population model was age-structured, with seven year-classes and a final class for birds 8 and older. The model assumed post-hatching censusing and calculated the number of birds as a simple function of age-specific fertility and survivorship schedules (Caswell 1989; Donovan and Welden 2002). The model generated a stable age distribution, for which the proportion in each age class remains stable over time, and a summary estimate of λ. However, these models do not account for variability in life history parameters (environmental stochasticity), so they reflect average effects of consistently operating factors, and each individual is subjected to the same average fate (no demographic stochasticity). We calculated age-specific fertilities as the proportion of females breeding from each age class, times the average number of hatchlings for occupied BAs. Therefore, fertilities take into account failure of a certain proportion of birds in an age class to occupy a BA, failure of some territorial pairs to nest, and failure of some eggs to hatch. Our estimate of nestling survivorship to age 1 includes fledging success, which has been influenced by management practices to increase this parameter (e.g. ABENWP monitoring, and life-saving interventions by biologists). Two modifications were made to compare our original model with one assuming males comprise 65% of nestlings, and another assuming females delay reproduction according to the schedule characterized by our data. These models reflect best estimates from our empirical data but are not the focus of our analysis, since we only have limited data to assess the technique for sexing nestlings, and our capture-recapture analysis did not support different ages at first reproduction for males and females.

To explore our demographic model, we used elasticity analysis (Caswell 1989; Donovan and Welden 2002) to calculate the sensitivity of λ to changes in specific matrix elements (fertilities and survivorships). The elasticity of any element is the proportional change in λ for a 1% change in that element.

POPULATION GROWTH RATE (λ) CALCULATED FROM NUMBER OF BREEDERS OCCUPYING BAS

Assuming a stable age structure, one estimate of λ could be calculated using a simple ratio of any stage or age class from one year to the next. We used counts of breeders (bald eagles occupying known breeding areas) since 1991 to describe one such stage class (Appendix A). We assumed each occupied BA held only 1 breeder unless the BA was active or we observed 2 breeders at the same time. We took into account exceptions, such as when a single male was involved in nesting attempts with 2 females at 2 different BAs.

From 1991 to 2003, the number of known BAs increased from 28 to 47, with a corresponding increase in the number of breeders at occupied BAs. This increase in number of BAs might reflect 1) pioneer efforts by pairs to create new or to reoccupy historical BAs, or 2) discovery of existing BAs which were occupied in the past but remained undetected in the intervening time. Because bald eagles have been known to modify large nests of golden eagles, great blue herons, osprey, and so on (Hunt et al. 1992; Beatty et al. 1995), we monitored several large nests along Arizona's riparian areas during the ORA flights. We used evidence from these surveys to document both pioneering behavior and the reoccupation of historical BAs. From 1991 to 2003, we have described 19 BAs as either pioneer efforts or reoccupied historical BAs, while three BAs were in existence before their discovery (Table 2). We documented territorial bald eagles in some areas for many years before nesting activity was initiated (e.g. Perkinsville). For analysis purposes, we did not consider these birds as breeders. However, once we recorded an active nest, we considered the pioneer effort a BA, and considered any subsequent occupying birds to be breeders.

We report count-based estimates of λ only for 1991 through 2003, years within our analysis framework when we were monitoring BAs to count breeders. The geometric mean of annual λs is the unbiased estimator for λ (Morris and Doak 2002) and is the approximation for λ when counts are taken at equal intervals (e.g., annually; Morris et al. 1999). If newly discovered BAs were unoccupied the previous year, the estimate of λ would be accurate. However, if those BAs were occupied before 1991 but unobserved, the estimate of λ would reflect survey effort, not a true increase in population numbers. For this reason, we calculated λ using 3 methods: 1) Reflecting the first scenario, we used all breeders seen in a given year compared to all breeders seen in the previous year. 2) Reflecting the second scenario, we used only breeders at previously identified BAs, excluding those at new BAs to compare to the previous year's count of breeders. 3) The third method assumed that we were able to identify pioneer efforts or the first year of activity at a reoccupied historical BA. Thus, breeders at recently discovered BAs (Talkalai, Dupont, and Oak Creek BAs) were excluded from counts for the first year the BA was discovered.

Table 2. Recorded breeding activity for bald eagle BAs in Arizona 1983 to 2003[1].

Breeding Area	First year[2]	First status	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03
Alamo	1988	Pioneer					O	S1	S1	S2	S2	S2	S1	S1	S2	F	F	F	F	S1	F	S1	O
Ash	1984	Existing		S1	S2	U	U	U	U	U	U	U	U	U	U								
Bartlett	1964	Existing	F	F	S1	S1	F	S2	S2	F	F	S1	S1	S1	S2	S2	F	S2	S1	F	F	F	S1
Becker	1999	Pioneer																	F	O	O	O1	U
Blue Point	1971	Existing	S3	S2	S1	U	S3	S2	F	O	S2	S2	S2	S2	S2	S2	S3	F	S1	F	S1	S2	F
Box Bar	1996	Reoccupied													O	F	F	S2	F	S2	S2	S1	S1
Bulldog	2003	Pioneer																					S2
Camp Verde	1992	Reoccupied										F	O1	U	U	U	U	U	U	U	U	U	U
Canyon	1986	Existing				S1	S1	S1	S1	S2	F	S1	S1	F	O	O	O1	O	O	O	U	U	U
Cedar Basin	1978	Existing	F	F	F	F	F	F	F	F	O1	F	F	F	O1	F	F	F	O	O1	O1	O1	U
Chino	1985	Existing			S2	F	F	U	U	U	U	U		U	U	U	U						
Cibecue	1973	Existing	F	S3	S1	S1	F	O	S1	F	S2	F	F	S1	S1	O	O	O1	S1	O1	O	F	F
Cliff	1984	Pioneer		F	S2	F	O	S2	F	O	O	F	O	F	O	O1	O1	O	O	O1	O	O	O
Coldwater	1998	Reoccupied																F	F	F	F	S2	S1
Coolidge	1985	Existing			F	S1	S2	S2	O	O	S1	S1	S2	F	S2	F	S2	F	F	F	F	F	S1
Crescent	2003	Pioneer																					F
Doka	1998	Pioneer																S1	S2	S2	S2	S2	S1
Dupont	1997	Existing															F	S1	O1	F	O	U	F
East Verde	1973	Existing	F	S1	S2	S2	S1	S2	S2	F	F	S1	S1	F	S1	S1	F	F	S2	O	F	F	O
Fort McDowell	1968	Existing	S3	S3	S3	S2	S1	F	S2	F	S1	F	S2	F	F	O	S2	F	S1	S2	S2	S2	F
Granite Basin	1999	Pioneer																	F	O	F	O1	O1
Granite Reef	2002	Pioneer																				S2	F
Horse Mesa	1982	Existing	F	F	F	S2	S2	S1	F	S2	S3	F	S1	F	S1	S2	S1	F	S1	S1	S1	S1	S2
Horseshoe	1975	Existing	S1	S2	S2	F	S3	S1	F	S2	F	F	O	F	F	S1	S2	F	S2	S2	S2	S2	S1
Ive's Wash	1987	Pioneer					S1	S1	S1	F	S2	S2	S1	S1	S1	F	F	O	O	O1	O1	O1	O
Ladders	1972	Existing	S2	F	S2	S2	F	S2	S2	F	S2	S2	F	S2	O	S1	F	S3	S2	O	S1	S2	S2
Lone Pine	1984	Existing		F	F	S1	F	S2	O	F	S1	F	F	F	O	F	F	O1	S2	F	S1	F	O
Luna	1994	Pioneer												S1	S1	S2	S3	S1	S1	S1	F	S2	S1

[1] S(number) = successful(number fledged), F = Failed, O = occupied, O1 = occupied with only one bald eagle confirmed, U = unoccupied, blank=BA not discovered or was designated historical.

[2] BAs were not designated until an active nest was observed. For completeness, the table reflects observation of bald eagles in the area or at nests before this date.

Table 2. Continued.

Breeding Area	First year	First status	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03
Lynx	2002	Pioneer																				F	F
Mule Hoof	1974	Existing	U	U	U	U	U	U	U	O	O1	O1	U	U	U	U	U	U	U	U	U	U	
Needle Rock	2002	Reoccupied																				S1	S1
Oak Creek	2002	Existing																				S2	S1
Orme	1987	Existing				S1	S2	S1	O	S1	S1	S1	S1	S2	F	F	S2	S1	S1	O	S1	S2	S1
Perkinsville	2000	Reoccupied							O	O	O	O	U	U	U	U	O	O1	U	S1	S1	F	S2
Pinal	1979	Existing	S1	S1	S1	U	S2	F	S1	S2	S1	F	S1	S1	F	F	F	O1	O	S1	U	S1	F
Pinto	1989	Pioneer							F	O2	F	F	S1	F	S2	S3	F	O	S2	O	S2	F	O
Pleasant	1984	Existing		F	F	U	O	U	O	O	O	F	S1	S2	S2	F	S2	S1	S1	S2	S2	S1	S1
Redmond	1974	Existing	S2	F	S2	S1	S2	S1	F	S1	F	O	O	F	S1	F	F	S1	F	S1	S1	F	O1
Rock Creek	2002	Reoccupied																				S1	F
Rodeo	2000	Pioneer																		F	F	S1	F
San Carlos	1995	Pioneer													S2	S1	F	S2	O1	F	O1	F	O1
76	1982	Existing	S1	S2	S1	S1	F	S2	O	S1	S1	S1	F	S2	F	S1	S2	S2	S1	S2	S2	O1	O
Sheep	1983	Pioneer	F	O	O	F	F	F	O	O	U	O	O	F	O	S2	O	O	S1	F	F	S2	F
Suicide	1999	Pioneer																	S2	S3	S2	F	S3
Sycamore	1997	Pioneer															F	S1	S2	F	S2	S1	S2
Table Mountain	1988	Existing						F	F	F	S1	F	S2	S1	S2	S1	S1	F	S1	F	F	O	F
Talkalai	1994	Existing												F	F	F	O	O	F	F	S1	S2	O
Tonto	1992	Pioneer										F	S2	S1	S1	S2	S2	S1	S2	F	S1	S2	F
Tower	1993	Reoccupied											S1	F	F	S2	S1	S2	S2	S2	S1	S2	S1
Winkelman	1996	Pioneer													O	F	F	O	U	U	U	U	U

[1] S(number) = successful(number fledged), F = Failed, O = occupied, O1 = occupied with only one bald eagle confirmed, U = unoccupied, blank=BA not discovered or was designated historical.

[2] BAs were not designated until an active nest was observed.

RESULTS

From 1987 to 2003, the status of a minimum 500 nestlings were documented in Arizona (Table 3). Of these, 124 (24.8%) died before fledging, including 23 that died between 8 weeks of age and fledging. Two hundred twenty-five banded and 62 unbanded nestlings fledged, after which we have no further information on their fate. Eighty-nine banded fledglings had a known fate, subsequently returning to breed in Arizona (*n*=50) or California (*n*=1), or were known to have died before breeding (*n*=38). We have records for at least 152 breeders in the population: 59 that were banded as nestlings during the study period, 11 that were banded as nestlings before 1987 and their bands were read by various means, at least 62 unbanded breeders (only some replacements can be detected, so this is a minimum estimate), and 19 unidentified single-banded (from before 1987) or post-juvenile-banded birds (most were banded in 1987 and 1988).

Table 3. Status of nestling and breeding bald eagles in Arizona, 1987 to 2003.

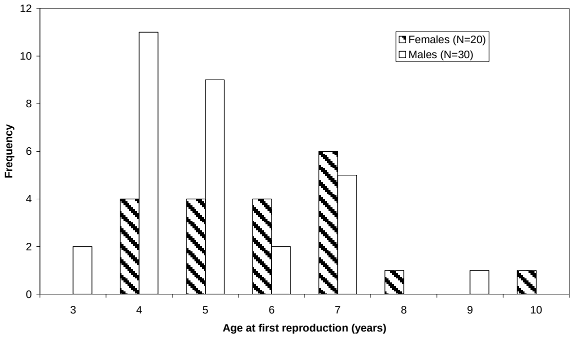
Status	Count			
Fate of nestlings	500			
Dead before fledging		124		
Unbanded fledglings		62		
Banded fledglings		314		
Unknown			225	
Known dead before breeding			38	
Bred in Arizona			50	
Bred in California			1	
Identity of breeders	152			
Unbanded (minimum estimate)		62		
Banded		90		
Fledged in Arizona between 1987-2003			59	
Unidentified				9
Cohort identified				50
Fledged before 1987 (single- or post-juvenile banded)			30	
Unidentified				19
Cohort identified				11
Fledged in Texas			1	

INPUTS FOR SIMULATION MODELS

Age at First Reproduction

Fifty identified nestling-banded birds returned to Arizona to breed during the study period. We observed that few of the youngest adults were females (Fig. 6) so we compared age at first reproduction for known-aged males and females. Females occupied a BA for the first time 0.97 years later than males on average (*t*=2.286, *df*=48, *P*=0.027). Average age at first reproduction for females was consistent with an average age of 6 (*t*=0.000, *P*=1.000), but not 5 (*t*=2.874, *P*=0.010); whereas for males it was consistent with age 5 (*t*=0.130, *P*=0.897), but not 6 (*t*=-3.778, *P*=0.001).

P-values were not adjusted for multiple tests on a single set of data. These comparisons analyzed resighted birds without adjusting for resighting probability and without considering the age of



males and females that are alive but have not yet returned to breed. On the basis of this first comparison, we built survivorship/resighting models to test whether this larger dataset also indicated a different age at first reproduction for males and females (see “Survivorship Estimates from Program MARK and Literature,” below). In that larger analysis, the most parsimonious models did not support sex-specific differences in age-at-first-reproduction (see below).

Figure 6. Age at first reproduction for nestling-banded birds in Arizona, 1987-2003. Bar heights between sexes should not be compared, because sample size differed.

Breeding Success and Nestling Sex Ratios

Occupancy rate between 1987 and 2003 averaged 90.1%, with 48.7% of occupied BAs fledging young (Table 4). There were 0.746 fledglings on average per occupied BA (i.e. productivity) (Table 5). The number of occupied BAs since 1987 has increased steadily with the number of known BAs. In contrast, the number of successful BAs has increased at a more gradual overall rate and is similar to the higher variability seen in the number of active BAs (Fig. 7).

Table 4. Status summary for breeding areas in Arizona, 1983-2003.

Year[1]	BAs	Occupied	Active	Successful	Occupancy Rate	Activity Rate	Success Rate
1983	14	12	12	7	0.86	1.00	0.58
1984	18	17	16	8	0.94	0.94	0.47
1985	20	19	18	13	0.95	0.95	0.68
1986	21	16	16	11	0.76	1.00	0.69
1987	23	21	19	11	0.91	0.90	0.52
1988	25	21	20	15	0.84	0.95	0.71
1989	26	23	17	9	0.88	0.74	0.39
1990	26	24	17	9	0.92	0.71	0.38
1991	26	23	19	13	0.88	0.83	0.57
1992	28	26	23	10	0.93	0.88	0.38
1993	29	26	21	16	0.90	0.81	0.62
1994	31	27	27	13	0.87	1.00	0.48
1995	32	28	22	15	0.88	0.79	0.54
1996	33	30	26	14	0.91	0.87	0.47
1997	35	32	27	12	0.91	0.84	0.38
1998	36	34	24	14	0.94	0.71	0.41
1999	39	36	29	21	0.92	0.81	0.58
2000	41	38	27	13	0.93	0.71	0.34
2001	41	36	29	19	0.88	0.81	0.53
2002	46	41	34	23	0.89	0.83	0.56
2003	47	42	31	18	0.89	0.74	0.43
Mean 1987-2003	33.2	29.9	24.2	14.4	0.900	0.818	0.487

[1] 1983-1985 data from Grubb (1986). 1986-1990 data from Hunt et al. (1992)

Males represented 65% of banded nestlings since 1987; this percentage has varied from 41% to 76% over this period, based on tarsus measurements of an average of 20.2 nestlings sexed each year (n=343) (Table 5). Female nestlings outnumbered males only in 2002.

Table 5. Productivity and nestling sex ratio summaries for bald eagles in Arizona, 1983-2003.

Year[1]	Breeding areas			Nestlings per occupied BA	Nestlings at 6-8 weeks				Fledglings		
	Occupied	Active	Successful		Banded males	Banded females	Proportion Males	Total banded and unbanded	Total	Per nestling	Per occupied BA (productivity)
1983	12	12	7	--	--	--	--	--	13	--	1.08
1984	17	16	8	--	--	--	--	--	15	--	0.94
1985	19	18	13	--	--	--	--	--	22	--	1.22
1986	16	16	11	--	--	--	--	--	17	--	0.89
1987	21	19	11	1.10	12	6	0.67	23	20	0.87	0.95
1988	21	20	15	1.24	12	7	0.63	26	23	0.88	1.10
1989	23	17	9	1.00	8	4	0.67	23	13	0.57	0.57
1990	24	17	9	0.63	6	5	0.55	15	13	0.87	0.54
1991	23	19	13	1.00	12	9	0.57	23	20	0.87	0.87
1992	26	23	10	0.77	7	7	0.50	20	14	0.70	0.54
1993	26	21	16	1.12	14	8	0.64	29	21	0.72	0.81
1994	27	27	13	1.00	14	6	0.70	27	18	0.67	0.67
1995	28	22	15	1.04	14	6	0.70	29	23	0.79	0.82
1996	30	26	14	1.10	18	8	0.69	33	23	0.70	0.77
1997	32	27	12	0.94	19	5	0.79	30	23	0.77	0.72
1998	34	24	14	0.79	13	5	0.72	27	21	0.78	0.62
1999	36	29	21	1.11	16	10	0.62	40	31	0.78	0.86
2000	38	27	13	0.97	17	7	0.71	37	23	0.62	0.61
2001	36	29	19	1.03	16	5	0.76	37	28	0.76	0.78
2002	41	34	23	1.12	12	17	0.41	46	37	0.80	0.90
2003	42	31	18	0.83	13	5	0.72	35	25	0.71	0.60
Mean (1987-2003)	29.9	24.2	14.4	0.987	13.1	7.1	0.650	29.4	22.1	0.756	0.746
Total (1987-2003)	--	--	--	--	223	120	--	500	376	--	--

[1] 1983-1985 data from Grubb (1986). 1986-1990 data from Hunt et al. (1992).

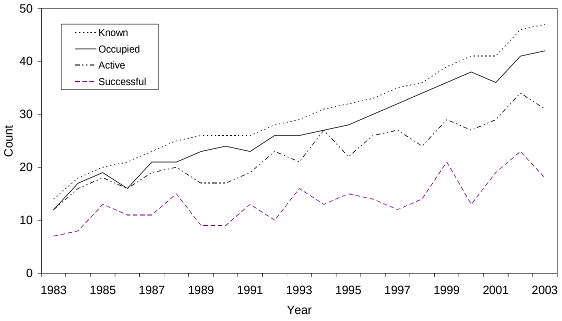


Figure 7. Changes in the number of known, occupied, active, and successful BAs in central Arizona, 1983-2003.

Survivorship Estimates from Program MARK and Literature

Surveys only resighted breeding birds. Since most bald eagles do not reproduce until at least age 4, annual survivorship from fledging to age 4 was based on resighting at older ages, with resighting rates of these juvenile bald eagles close to 0. This scenario was expected to inflate variance estimates and reduce fit of the models. In fact, the global model fit the data poorly (χ^2=344.3, df=1, P<0.0005). Examination of lack-of-fit for subsets of the data indicated that inability to resight birds before age 4 explained the overall lack-of-fit. The global model showed no lack-of-fit for older, known-aged birds or for data from breeder-banded birds. We adjusted for this idiosyncrasy in 2 steps. 1) For the first 3 years after fledging we fixed parameter estimates for resighting and survivorship rates at 0 and 1, respectively. 2) To compensate for variance inflation in the data, for computations and model choice we adjusted the Akaike criterion statistic by a variance inflation factor of 4.95.

Of the 48 models developed (Table 6), the most parsimonious one modeled resighting rate as an increasing function of age (fewer young adults breed; more older adults breed), but estimated annual adult survivorship as independent of age equal ([$\Phi_{.}\ p_{\text{ageL}}$]). Model weights ($w_i$) are the relative likelihoods for each model given the data (Burnham and Anderson 2001). The model weights were normalized so that all models for the same dataset sum to 1, so the model weights indicate the relative support for each model.

Level 1 data reports resighting history using band information only without accounting for the defined assumptions (see Methods). This first model {$\Phi_{.}\ p_{\text{ageL}}$} fit Level 1 data 1.44 (=0.174/0.122) times better than the {$\Phi_{\text{ageL}}\ p_{\text{ageL}}$} model, which estimated survivorship and resighting rates as a function of age. The best 12 models for Level 1 include the best set for Level 2 data, although their rank by weight differs.

Considering Level 1 data only, and summing model weights for the appropriate models, those models that included age as a predictor of survivorship, with or without other factors, were supported 48% of the time (Table 7). Models that included sex as a predictor were supported 18% of the time, which indicated a larger dataset might distinguish survivorship rates for males and females of the same age. Survivorship models that included time received stronger support (31% of the relative support), so the capture-recapture analysis may indicate an important linear trend as the study continues.

Level 2 resighting histories were built with the assumption that between the first and last times a bird was seen at a BA, all confirmed occupancies at that BA also involved that bird. Although resighting rates usually include a component due to survey effort level, the intended effect of using Level 2 assumptions was that age- and/or sex-specific resighting rates would primarily reflect recruitment rate as breeders. As expected, comparison of model weights (Table 7) indicated that resighting rates for Level 2 models were less influenced by increasing survey experience (reflected in the variable “time”) than were Level 1 models, and models that used age structure to estimate resighting rates were even more predictive under Level 2 than under Level 1 models.

Table 6. Summary of model testing for banded bald eagles in Arizona. Models are described by parameters used to predict survivorship (Φ) and resighting rate (*p*), and the 12 most parsimonious are ordered by the corrected quasi Akaike criterion value (QAIC) for Level 1 analysis; the favored model has the lowest QAIC and the highest weight. For reference, the constant and global models are reported at the bottom in italics.

Model[1]	Parameters estimated	Original data (Level 1)			Assume residency for years between positive identifications of same banded bird (Level 2)		
		QAIC	ΔQAIC[2]	Model weight	QAIC	ΔQAIC[2]	Model weight
Φ(.) p(ageL)	5	685.0	0.0	0.174	545.6	0.0	0.248
Φ(ageL) p(ageL)	7	685.7	0.7	0.122	548.7	3.1	0.054
Φ(T) p(ageL)	6	685.7	0.7	0.121	546.6	1.0	0.149
Φ(T) p(ageL+T)	6	686.3	1.4	0.088	546.8	1.2	0.135
Φ(ageL+T) p(ageL)	7	686.6	1.6	0.076	548.8	3.2	0.049
Φ(ageL+T) p(ageL+T)	7	687.0	2.0	0.064	547.8	2.2	0.083
Φ(sex+ageL) p(ageL+T)	8	687.4	2.5	0.051	549.8	4.2	0.031
Φ(sex+ageL) p(ageL)	8	687.5	2.5	0.049	550.5	4.9	0.021
Φ(sex) p(ageL+T)	7	687.5	2.5	0.049	548.5	2.9	0.058
Φ(sex) p(ageL)	8	688.6	3.7	0.028	551.5	5.9	0.013
Φ(sex+ageL+T) p(ageL)	7	688.8	3.8	0.026	549.5	3.9	0.036
Φ(sex+ageL+T) p(ageL+T)	8	688.8	3.8	0.026	549.7	4.1	0.032
Φ(.) p(.)[3]	*4*	*689.4*	*4.5*	*0.019*	*557.4*	*11.8*	*0.001*
*Φ(sex*age*time)p(sex*age*time)*	*248*	*831.5*	*146.5*	*0.000*	*699.0*	*153.4*	*0.000*

[1] Parentheses indicate factors allowed to vary in each model: age=year classes for eagles over 4 years old; ageL=linear change with age over 4 years old; time=separate groups each year for survivorship, intervals of similar survey effort (see text) for resighting rate; T=linear change in either rate with time. For example, the third model estimated survivorship as a linear function of survey year but not as a function of age or sex. Resighting rates for that model were calculated as a linear function of age.

[2] Difference between QAIC for each model and the best model.

[3] All models, including the constant model, set survivorship to ages 1 to 3 at 1 and resighting rates for these ages at 0; all models also estimate survivorship and resighting rate separately for 4-year-olds.

Table 7. Favored models with original data (Level 1) and by assigning further 'resightings' for years between positive identifications of the same bird at the same BA (Level 2).

	Sum of model weights	
	Level 1	Level 2
Models that estimate survivorship using …		
Age structure only	0.243	0.202
Age structure and any other factors	0.482	0.427
Sex only	0.054	0.049
Sex and any other factors	0.178	0.160
Time only	0.165	0.185
Time and any other factors	0.306	0.330
Models that estimate resighting rates using …		
Age structure only	0.549	0.741
Age structure and any other factors	0.875	0.908
Time only	0.000	0.000
Time and any other factors	0.326	0.167
Sex and any other factors	0.000	0.000

The relative importance of age structure was slightly less for Level 2 survivorship models than for Level 1, whereas the relative importance of including a trend over time in these models was increased. Because survivorship estimates for the same models differ very little between the Level 1 and 2 data, we proceeded with Level 2 estimates. Survivorship before age 4 was estimated as slightly higher and after age 4 it was slightly lower than for Level 1 models, but the difference was less than 1% for each age class. We favored Level 2 models because they allowed us to provide an initial estimate of the proportion of non-breeders in any age class.

Model weights indicated that breeder age and a decreasing time trend might influence survivorship estimates, while age contributes most to estimates of resighting rates (Table 7). Because sex was not supported as a predictor of survivorship in the best model, model averaging (White and Burnham 1999) was used to generate sex-specific survivorship estimates (Table 8). The model-averaged parameter estimates show only a slightly higher survivorship rate for females compared to males, but the pattern is probably too small to be biologically relevant.

Table 8. Sex- and age-specific survivorship and resighting rate estimates (95% CI) using model averaging on Level 2 data in Program MARK.

To age	Survivorship estimates		Resighting rate estimates
	Females	Males	
1[1]	1	1	0
2[1]	1	1	0
3[1]	1	1	0
4[2]	0.29 (0.131,0.535)	0.28 (0.130,0.514)	0.23 (0.065,0.576)
5	0.94 (0.642,0.992)	0.93 (0.638,0.992)	0.45 (0.190,0.736)
6	0.93 (0.668,0.987)	0.92 (0.666,0.986)	0.70 (0.484,0.852)
7	0.91 (0.729,0.978)	0.90 (0.730,0.971)	0.87 (0.729,0.948)
8 and older	0.88 (0.764,0.973)	0.87 (0.759,0.936)	0.95 (0.850,0.988)

[1] Parameters for birds younger than 4 were fixed in each model, not estimated.
[2] Because survivorship for ages 1 through 3 was fixed at 1, the survivorship estimate at age 4 is survivorship from fledging to age 4.

For demographic modeling, we used survivorship estimates from the most parsimonious, age-specific capture-recapture model (Table 9). Demographic models required annual survivorship estimates for each of the earliest age classes, but we could only create a direct estimate of survivorship from fledging to age 4. Previous studies (Table 10) indicated considerable variability in survivorship estimates and in the shape of the mortality schedule. We experimented with the effect of partitioning survivorship to age 4 to reflect patterns seen in other studies (Table 10), but these experiments with annual survivorship patterns indicated no effect on population growth estimates or sensitivity analysis. Therefore, for simplicity, we assumed equal annual survivorship over the first 4 years. Using Program MARK, we estimated 27.9% survivorship from fledging to age 4 (Table 9), which we translated into 72.7% annual survivorship for the first 4 years (Table 10).

Table 9. Age-specific resighting and survivorship estimates (95% CI) from Program MARK using Level 2 data.

Age	Annual survivorship to age	Resighting rate at age
1[1]	1	0
2[1]	1	0
3[1]	1	0
4[2]	0.28 (0.147,0.466)	0.22 (0.066,0.534)
5	0.88 (0.785,0.936)	0.44 (0.201,0.714)
6		0.70 (0.513,0.841)
7		0.88 (0.745,0.944)
8 and older		0.95 (0.852,0.987)

[1] These parameters were fixed in each model, not estimated.
[2] Because survivorship for ages 1 through 3 was fixed at 1, the survivorship estimate at age 4 is survivorship from fledging to age 4.

Table 10. Age-specific survivorship estimates for bald eagles across their range.

Study	Population status	Annual survivorship to age …[1]									Last age class limits
		Nestling to fledging	1	2	3	4	5	6	Last age class	Fledging to 4[2]	
This study		0.75	0.73	0.73	0.73	0.73	0.88	0.88	0.88	0.28	7+
Driscoll et al. (1999)		0.84	0.84						0.84	0.50	1+
Hunt et al. (1992)		0.84								0.39	
Stalmaster (1987)[3]		0.85									
Grier (1980; low)	Declining		0.30	0.70					0.70	0.10	2+
Grier (1980; moderate)[4]	Declining		*0.60*	*0.80*					*0.80*	*0.31*	2+
Grier (1980; stationary)[4]	Stationary		*0.60*	*0.85*					*0.85*	*0.37*	2+
Grier (1980; high)[4]	Expanding		*0.70*	*0.90*					*0.90*	*0.51*	2+
Brown and Amadon (1968)			0.22	0.44	0.39	0.76	0.68			0.03	
McCollough (1986; pre-feeding)			0.54	0.79	0.91				0.91	0.31	3+
Harmata et al. (1999)			0.87	0.85	0.64	0.71	0.60	0.67		0.34	
Buehler et al. (1991)	Expanding		1.00	0.92	0.75	0.83	0.83	0.83	0.83	0.57	4 to 6
Bowman et al. (1995)	Expanding		0.71	0.95	0.95	0.95			0.88	0.61	5+
Gerrard et al. (1978; wing marks)			0.37	0.62	0.83						
Gerrard et al. (1978; bands)			0.53	0.51	0.74						
Wood (1992)			0.63	0.84	0.94						
Jenkins (1996)	Expanding		0.77	*0.80*	*0.84*	*0.88*	*0.91*		0.95		5+
McClelland et al. (1996)			0.91								

[1] Mortality estimates for pre-reproductives may actually include emigration. Numbers in italics were not arrived at empirically.

[2] This is the product of annual survivorship for each of the 4 annual age classes from fledging to age 4.

[3] A summary of work through the early 1980s

[4] Hypothetical but often-cited values from an earlier demographic analysis

Final Inputs To Each Simulation Model

Where possible, we used data from this study to provide parameter estimates for simulations, which are in Table 11. Table 12 is the resulting Leslie matrix for our primary model, assuming equal sex ratios and similar age at first reproduction for males and females. One other model was built assuming later age at first reproduction for females. Our sex ratio estimates based on tarsus measurements indicate a male-biased sex ratio in nestlings. No other analysis to date has assumed male-biased sex ratios, so for comparison a third model simulated a population producing 65% male nestlings. For all models, we used an initial population size of 200 eagles.

Table 11. Parameters for input in the matrix demographic analyses.

Parameter	Proportion of females that breed	
	Same as males at each age	Defer reproduction relative to males
Proportion age 3 females that breed (occupy a BA)	0.0	0.0
Proportion age 4 females that breed	0.22	0.21
Proportion age 5 females that breed	0.44	0.42
Proportion age 6 females that breed	0.70	0.63
Proportion age 7 females that breed	0.88	0.90
Proportion females age 8 and older that breed	0.95	0.95
Nestling sex ratio (% males)	0.50 or 0.65	
Nestlings per occupied BA	0.995	
Survivorship of hatchlings through fledging	0.750	
Survivorship of fledglings through age 1	0.73	
Survivorship age 1 to age 2	0.73	
Survivorship age 2 to age 3	0.73	
Survivorship age 3 to age 4	0.73	
Survivorship age 4 to age 5	0.88	
Survivorship age 5 to age 6	0.88	
Survivorship age 6 to age 7	0.88	
Annual survivorship after age 7	0.88	
Initial population size	200	

Table 12. Leslie matrix for deterministic model assuming 50% of nestlings are female.

	F(h)	F(1)	F(2)	F(3)	F(4)	F(5)	F(6)	F(7)	F(8+)
Nestlings	0	0	0	0.000	0.080	0.193	0.306	0.382	0.416
1	0.546	0	0	0	0	0	0	0	0
2	0	0.728	0	0	0	0	0	0	0
3	0	0	0.728	0	0	0	0	0	0
4	0	0	0	0.728	0	0	0	0	0
5	0	0	0	0	0.877	0	0	0	0
6	0	0	0	0	0	0.877	0	0	0
7	0	0	0	0	0	0	0.877	0	0
8+	0	0	0	0	0	0	0	0.877	0.877

ESTIMATES OF λ AND ELASTICITY ANALYSIS

Based on our vital rate estimates and resulting deterministic demographic models, the population is projected to be declining at a rate of 3.6 to 5.5% per year (Table 13). Count based ratios comparing numbers of breeders in 1 year to the number in the previous year indicate the breeding segment of the population in Arizona is expanding at an average rate of 4.0% yearly (Tables 13 and 14). These trends rely on our ability to census all breeding birds each year. In some cases, however, we counted breeders occupying newly discovered but previously existing

BAs (Table 4; evidence that BAs were previously existing might include presence of more than 1 nest in the breeding area). If we treated these breeders as new recruits, we potentially confounded search effort with growth (if the breeding area was in existence prior to 1991) resulting in an overestimate of the replacement rate. Conversely, censuring the data to only include previously existing breeding areas effectively negates the possibility to detect true growth (new breeding areas). Consequently when we limited the estimate of λ to breeders at previously existing territories, the replacement rate was slightly less than 1, with a 95% confidence interval that includes 1. Taking these biases into account, our best count based estimates of λ are derived from counts of breeders at previously existing breeding areas and breeders at pioneered or re-occupied historical breeding areas resulting in a 4.3% yearly increase (Table 14).

Table 13. Estimates of λ from different models.

Estimate type	Model	λ
Breeding Segment	Ratio of all eagles at BAs current year to previous year (counts taken from Table 1 and reported in Table 14)	1.040
	Ratio of eagles at BAs current year to previous year; newly identified BAs not included	0.984
	Ratio of eagles at BAs current year to previous year; Newly identified BAs with Existing status not included	1.043
Deterministic	Nestling sex ratio 50% males; MARK-estimated age-specific survivorship	0.964
	Nestling ratio 50% males; females defer reproduction 1 year later than males	0.963
	Nestling sex ratio 65% males; MARK-estimated age-specific survivorship	0.945

Table 14. Estimate of λ based on number of birds occupying BAs in central Arizona.

Year	Counts of breeders			Males at 2 BAs[1]	Occupied BAs where 2 breeders Not confirmed	Replacement rate (λ)		
	Total	Previously existing BAs	Previously existing or pioneered BAs			All breeders	Previously existing BAs	Previously existing or pioneered BAs
1987	41	37	39	0	1	1.024	0.927	1.026
1988	42	38	40	0	0	1.048	1.024	1.100
1989	44	43	44	1	1	1.068	1.068	1.068
1990	47	47	47	1	0	0.915	0.915	0.915
1991	43	43	43	1	2	1.163	1.070	1.163
1992	50	46	50	1	1	1.020	0.980	1.020
1993	51	49	51	0	1	1.098	1.020	1.059
1994	56	52	54	0	0	0.982	0.946	1.019
1995	55	53	55	0	1	1.073	1.000	1.073
1996	59	55	59	0	1	1.051	0.983	1.017
1997	62	58	60	0	2	1.048	0.984	1.083
1998	65	61	65	0	3	1.062	0.969	1.062
1999	69	63	69	0	3	1.029	0.986	1.029
2000	71	68	71	0	5	0.958	0.958	0.958
2001	68	68	68	1	3	1.118	0.971	1.059
2002	76	66	72	1	5	1.013	0.961	1.069
2003	77	73	77	1	4			
Mean	62.0	54.4	56.9	0.4	1.8	1.040[2]	0.98[2]	1.043[2]
Lower limit CI						1.005	0.959	1.010
Upper limit CI						1.080	1.012	1.081

[1] Note that in 7 different years, 1 male occupied BAs with 2 different females, so breeder count is odd.

[2] Geometric means.

Elasticity analysis (Table 15) indicated how short-term changes in individual parameters could change a population decline from 3% per year to 0% per year. Nestling survival to age 1 would have to increase 49.7% (to 81.7% survival from the current 54.6%). Alternatively, fertilities would need to increase by the same proportion. Pre-reproductive survivorship of each age class from 1 to 4 could change 12.5% and have the same effect, or annual survivorship of the oldest class could change only 4.7%, from 87.7% to 91.8%. Thus, a smaller change in adult survivorship would have a more dramatic impact on persistence than would a larger change in nestling survivorship, but this analysis does not address the tractability of managing to change any of these vital rates. For instance, management to improve survivorship of nestlings may be more feasible than management to improve adult survivorship. Elasticity analysis describes potential for population increases (or declines), but does not weigh the costs of achieving these changes.

Table 15. Elasticities for comparing possible management impacts on persistence of the bald eagle population in Arizona. A 1% increase in the estimate for each parameter would have the effect of bringing the population growth rate, λ, closer to even (1.0) by the percentage indicated in the table.

Parameter	Estimated % change in (1-λ)	Some associated management options
Survival of nestlings to 1 year	6.0	Decrease mortality factors including: effects of development/projects, falling from nests, human disturbances, Mexican chicken bugs, and monofilament entanglement. Increase quality of prey base and riparian habitats to support successful fledging.
Survival to age 4	23.9	Describe habitat use by pre-reproductives and decrease mortality from electrocution, lead poisoning, shooting, and starvation.
Survival after age 4	64.0	Understand habitat use by non-breeders and decrease mortality from shooting, lead poisoning, and monofilament entanglement.
Fertilities	6.0	Decrease egg failure from heavy metals, organochlorines, and human disturbance. Increase quality of prey base and riparian habitats, and number of suitable BAs.

Elasticities indicated that increased age at first reproduction for females would have a small impact on survivorship; this is also observed by comparing λ for models that differ only in age at first reproduction for females (Table 13). These comparisons predicted a decrease in λ of about 0.1% if females begin breeding at age 6 on average instead of age 5. Similar comparisons of λ for models that differ only in sex ratio indicate that when the sex ratio is biased in favor of males, λ would be almost 2% lower than if the sex ratio were equal.

Age Structure

We used the primary deterministic model to illustrate the expected age structure currently (Fig. 8). We used the resighting rate estimates to divide each age class into breeders, pre-reproductives, and floaters (if at least 4 years old). The proportion of birds in adult plumage (for simplicity, assume these are all birds older than 5) in any year is estimated to be 48.7%. Some of these birds will be floaters, and not occupying BAs. This means that if we identify 70 adult-plumage birds occupying BAs in any given year, we predict we will also find 2 near-adult breeders, there will be 33 nestlings (20.1% of the population), and 58 individuals will not be seen at all, since these birds are pre-reproductives (26.4%) or floaters (9.7%).

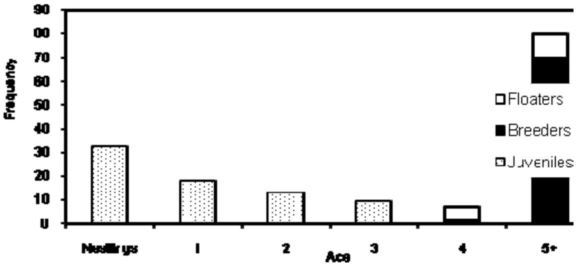


Figure 8. Age distribution using survivorship estimates from mark-resight data and assuming a stable age distribution with 70 adult plumage birds (5 years of age or older) occupying BAs.

OTHER ELEMENTS DESCRIBING REPRODUCTIVE BIOLOGY

Breeding Tenure and Pair Bonds

Between 1987 and 2003, at least 83 unique breeding pairs were identified along with their first year of breeding. This is a minimum estimate of the total number of breeding pairs, because replacement of unbanded birds was only documented when the BA was unoccupied the following year, when the bird was known to die, or when it was replaced by a banded bird or one with a different plumage. Also, survival analysis of pair bond duration could not be applied to pairs that were not identified during the first year together (left-censored data). Median pair duration was 4.9 years, and we assumed the bond was severed due to the death of 1 member. Due to incomplete documentation of replacement of unbanded birds, this is a maximum estimate.

In contrast, individual breeders remained at a BA a median of 9.8 years (59.4% cases were right censored, with unknown total length of tenure because they are still in residence); there was no difference in tenure of males and females (Gehan statistic, *df*=1, *P*=0.167; means were 10.7 and 9.0, respectively). Again, these are maximum tenure estimates since replacement of an unbanded individual by another could often not be detected. Because the typical bald eagle's tenure lasted longer than the pair bond, a bald eagle was likely to have more than 1 mate in its lifetime.

Dispersal Distances from Natal Area to Breeding Area

Dispersal distances for 21 females and 35 males from their natal to their first breeding area are plotted in Figure 9. Females have been reported to disperse farther than male bald eagles in 1 other population (Harmata et al. 1999). In our study, females traveled farther than males to breeding areas (t-test assuming unequal variances on square-root transformed distances, *t*=3.397, *df*=29.8, *P*=0.002), with females traveling an average of 109.7 km and males traveling 45.1 km. With the possible exception of a female that dispersed 428 km, these distances do not indicate that emigration from the region is a simple extension of this type of sex-specific, within-region dispersal.

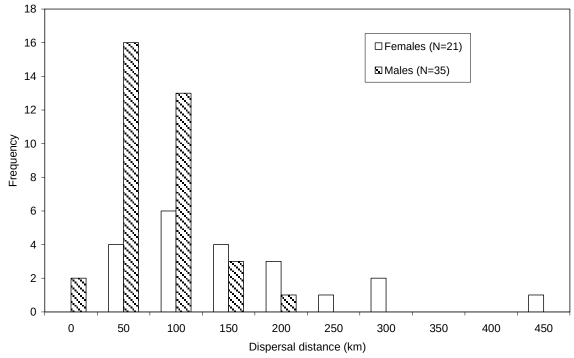


Figure 9. Dispersal distance from natal BA to first known breeding BA.

DISCUSSION

Our dataset and analysis are extensive and intensive. Life history theory provides one context for interpreting the individual vital rates we have estimated. If the breeding population in Arizona was isolated during its evolution, we expect the suite of life history characteristics (and the associated vital rates) to have unique features related to the unique environment of river corridors in the Sonoran Desert. Current birth and death schedules, however, are difficult to associate with evolutionary environments due to extreme habitat modification in recent times. In addition, some vital rates measured today reflect direct intervention to manage population dynamics. In Arizona, for instance, most management focuses on enhancing survival of nestlings at BAs. Consequently, our productivity estimates reflect those efforts.

The set of life history traits describe current population dynamics, reflecting stable, increasing, or decreasing populations. Our analyses do not definitively answer whether the population of bald eagles in Arizona is stable, but do identify gaps in our data which limit our ability to accurately predict population stability through demographic models. For instance, does immigration into Arizona explain the increase of breeding adults that has been observed? Is the population age structure at equilibrium? Finally, is the isolation and relatively low abundance of bald eagles mirrored in its genetic pool and if so, how do these factors contribute to stochastic events that affect population growth? In the sections below, we discuss individual vital rates in comparison to results from other studies, the sensitivity of population dynamics to each of these rates, and resulting focus for future study and management.

COMPARISON OF LIFE HISTORY PARAMETERS TO OTHER STUDIES

Reproductive Rates

In Table 16, we report productivity data for studies to date in Arizona, other studies from across the species' range, and information from Stalmaster (1987), who summarized range wide data collected by the early 1980s. Variable methods were used to measure productivity and studies occurred over different time periods, so exact comparisons between studies were difficult. Studies outside Arizona typically computed productivity based on 2 or 3 flights per breeding season to count the number of *nestlings* that attained 8 weeks of age (Fraser et al. 1983; Postupalsky 1974; Steenhof and Kochert 1982). However, our study and Driscoll et al. (1999) used 6 ORA flights to describe breeding activity, usually continuing past the 8-week stage. Consequently, we were more likely to document mortality of *nestlings and fledglings* beyond 8 weeks of age, which resulted in lower productivity and nest success estimates than would be obtained under the conventional protocol. Specifically, an average 1.4 nestlings (6%) died each year between 8-weeks of age and fledging. If we included these birds, estimated productivity increases to 0.80.

Table 16. Bald eagle productivity estimates across North America[1].

Study area	Average # BAs Monitored per year	Productivity (Fledglings per occupied BA)	Success per Occupancy	Years	Study
Wisconsin	254	1.28	0.76	1983-1988	Kozie and Anderson 1991
Aleutian Islands, AK	23/island	0.67-1.24[3]	0.48-0.86[3]	1993-1994	Anthony et al. 1999
Colorado/Wyoming	9.4	1.21	0.63	1981-1989	Kralovec et al. 1992
Florida	40	1.21		1985-1988	Wood and Collopy 1993
Chesapeake	145	1.18	0.69	1981-1990	Buehler et al. 1991
Arizona	15.0	1.18	0.65	1981-1985	Grubb 1986
Arizona	22.3	1.00	0.50	1987-1990	Hunt et al. 1992
Nationwide	--	0.92	0.58	Pre-1986	Stalmaster 1987
Washington	173	0.85	0.66	1981-1985	McAllister et al. 1986
California	10	0.81	0.56	1970-1991	Jenkins 1996
Arizona	8.8	0.80	0.52	1975-1980	Grubb et al. 1983
Interior Alaska	231	0.77	0.52	1989-1994	Steidl et al. 1997
Arizona	33.2	0.75[2]	0.49	1991-2003	This study
British Columbia	26.0	0.70	0.48	1992-1996	Elliot et al. 1998
Arizona	25.4	0.69[2]	0.45	1987-1993	Driscoll et al. 1999
Minnesota	22.3	0.68	0.51	1973-1993	Grim and Kallemeyn 1995

[1] Stalmaster (1987) summarized most studies that were completed by the early 1980s; his summary statistics are included here plus information from studies begun by the early 1980s, and from all reported periods of study in Arizona.

[2] Note that extended observation protocols resulted in improved mortality estimates of young-of-year over 8 weeks old; these studies would have reported higher survivorship using protocols in place elsewhere.

[3] Per active breeding area

Conversely, intensive management, introduced in 1978 with the establishment of the first BA closure, has probably increased bald eagle productivity in Arizona. This management increased in intensity over time with such practices as daily monitoring and education by the ABENWP, establishment of 17 BA closures, and efforts of biologists to intervene in bald eagle life-threatening situations. Those practices have directly helped save 42 (13.4% of 314) banded fledglings from 1987-2003, and indirectly saved an undetermined number through closures, ABENWP monitoring, and education of recreationists. Without these efforts, we can assume that natural productivity in Arizona since 1978 would be considerably lower than what we have documented.

Compared to earlier studies in Arizona, we estimated a similar rate of nest success, but lower productivity than Grubb (1986) and Grubb et al. (1983), and higher productivity than Driscoll et al. (1999), a report that included data from early years of our study. These discrepancies were not due to changes over time, with our data reflecting higher productivity in later years. Rather, the difference in reported productivity between our study and that of Grubb (1986) and Grubb et al. (1983) could be attributed to an increase in monitoring efforts and management within the BAs (as described above). Discrepancies with Driscoll et al. (1999) arose because under our more conservative operational definition of occupied BAs, we reported fewer breeding pairs each year. Because ORA flights are not generally suited to identifying territorial (occupancy) behavior unless the BA is active, surveyors often use other sources of information for assessing BA occupancy. For instance, if the area was used historically for breeding and if bald eagles were present during the breeding season, the area might be considered an occupied BA. However, in addition to breeders, Arizona hosts non-breeders as well as wintering bald eagles from other states that occasionally remain late into the breeding season. Therefore, we only defined a BA once recent breeding activity was confirmed (Appendix A). Until the BA was defined, it would not be considered occupied. Applying our standards to observations from 1987 through 1993, we recognize 2-4 fewer BAs per year than reported in Driscoll et al. (1999), and calculated a productivity rate of 0.77 fledglings/occupied BA for the years 1987 through 1993, closer to the rate for the whole period through 2003.

In general, bald eagles in Arizona had lower nest success than bald eagles elsewhere, but this has not resulted in depressed productivity compared to other regions. The occupancy rate of known BAs in Arizona was about 90% (Table 4). This is higher than typical rates reported by Stalmaster (1987), who speculated that high occupancy rates indicate populations are large enough to saturate available BAs. In this case, further growth of the breeding segment would be limited by lack of available habitat, which would possibly promote an increase in the non-breeding floater segment and/or emigration.

By themselves, productivity estimates are difficult to interpret. Research on bald eagles in Alaska (Hansen 1987) and Spanish Imperial eagles in Spain (Ferrer and Donazar 1996) have contributed to speculation that population saturation and the occurrence of an increasing floating population could cause lower productivity through intraspecific competition for food resources (see also Hunt 1998). These potential mechanisms of population regulation in bald eagles (or other recovering species) are problematic, because lowered productivity could indicate population decline or, alternatively, a recovered population. At this point, we are merely laying out our basic estimates, and note that mechanisms such as habitat saturation, density dependence, or continuing external threats to productivity cannot be assumed at this point. Low productivity levels by themselves should not be used to interpret the species' status in Arizona.

Survivorship

In Table 10, we summarize results from range wide studies of survivorship to date. Our rate of nestling deaths (25%) is similar to that reported by Driscoll et al. (1999) for Arizona during the period 1987-1993, and higher than the 15% level in range wide studies examined by Stalmaster (1987). However, additional monitoring flights and daily observation by ABENWP undoubtedly documented more mortalities than if the typical protocol had been followed (Driscoll et al. 1999). Thus, our rate of nestling deaths probably reports lower (but more accurate) survivorship than a less intensive monitoring protocol would capture. Conversely, Arizona bald eagle management practices to increase productivity have been in place since the late 1970s and our estimates reflect increased survivorship due to very active management at the nest.

Pre-reproductive survivorship reported here is generally lower than those reported elsewhere, but pre-reproductive survivorship should be considered *apparent* survivorship. That is, our estimate could include losses due to emigration as well as mortality. However, there is currently only a single confirmed report of emigration (to a BA in Southern California), so we conservatively continue to treat Arizona bald eagles as a closed population until and unless more direct evidence is acquired (see discussion below).

Grier (1980) and Stalmaster (1987) identified adult survivorship as a key element in maintaining bald eagle population numbers (i.e. more influential than productivity rates). Our sensitivity analysis also identified adult survivorship as the most important or "sensitive" factor in estimating growth. Although population growth rate is a function of interrelationships between many vital rates, the relatively important role of adult survivorship should be considered when comparing and interpreting survivorship rates in Arizona to those in other populations that have been characterized as expanding, declining, or stable.

Driscoll et al. (1999) reported demographic values for birds in Arizona, including 14 nestling-banded breeders, based on studies from 1987 through 1993. Since then, we have detected 35 more that have returned as breeders. Due to the low number of resightings, Driscoll et al. (1999) estimated breeder survivorship by counting all known replacements of banded and unbanded breeders as deaths. Because some replacements of unbanded birds go undetected, their 84% annual survivorship estimate was biased high, but is similar to our estimate of 87.7%. Compared to other studies, we report relatively high survivorship in young breeders and low survivorship in older breeders. As in other studies, we lack information on relative survivorship of breeding and non-breeding same-aged bald eagles.

ADDITIONAL INPUTS TO MODEL POPULATION DYNAMICS

Sex Ratios and Age at First Reproduction

Sex ratio of available breeders may vary year to year, especially in a small population. Our analysis showed a male-biased sex ratio among nestlings, based on a protocol developed by Hunt et al. (1992). In our study, this measurement correctly classified all but 1 of 50 nestlings that were later autopsied or sexed when they returned to breed (Appendix D). The misclassified nestling was a male with a 13 mm tarsus, which was originally classified as a female. It is unlikely that misclassification errors explain our reported male-bias in nestlings, which would arise if the predominant errors were due to true females misclassified as male nestlings.

No other study has reported skewed sex ratios in nestling bald eagles. Bortolotti (1984) reported 53 males in a sample of 103 nestlings (51.5% males), and Harmata et al. (1999) reported 50.9% males in 218 nestlings. However, skewed sex ratios have been noted in other raptors (Krackow 1993) including golden eagles (Edwards et al. 1988). Skewed sex ratios in raptors are usually investigated for insight into evolution of sex ratios, but we are focusing on potential to affect population dynamics by reducing ability to form monogamous pairs.

In a monogamous species, adult sex ratios consistently different from 1 will depress the replacement rate (Lacy 2000). Any shift in number of potential breeding pairs can impact other parameters such as productivity, which can affect the viability of the population (Brook et al. 2000, Lacy 2000). If the biased nestling sex ratio has an adaptive basis in monogamous bald eagles of the Southwest, we predicted males would suffer greater mortality than females, or would occur at higher frequency in the floating population. However, we did not detect an important difference in survivorship, resighting rates, or tenure between males and females. In Northern California, males and females also had similar tenures (Jenkins and Jackman 1993).

Furthermore, our direct estimates of age at first reproduction (t-tests on birds that actually bred) indicate that males return to breed (occupy a BA) at age 5, while females typically are not reproductive until age 6. The mark-resight analysis answers this same question in a more thorough fashion by incorporating uncertainty about the fate of birds that do not return to breed, and suggests that we do not have sufficient information to accept this difference. Bowman et al. (1995) assumed that faced with lack of available breeding areas, Alaska bald eagles begin breeding on average at age 8, and Harmata et al. (1999) estimated reproduction began at age 6. Delayed first reproduction in females compared to males has not been reported in other bald eagle studies. Our conclusion is that age at first reproduction appears to be the same for males and females in Arizona, but we should continue modeling possible differences as more years of data become available.

UNDERSTANDING POPULATION GROWTH RATE ESTIMATES

Our estimates of λ based on the number of breeders support the interpretation of a growing population (Table 14), but the demographic models predict that Arizona-fledged bald eagles do not have the recruitment, reproductive, and survivorship rates to maintain their numbers (Table 13). Although the differences in percentage appear small, their effects can be quite large. For example, a 50% reduction of the initial population size would result if a 3% decline were sustained for 23 years; a 3% increase sustained over the same number of years would result in population doubling. Population growth rate reflects multiplicative effects. The discrepancy between the demographic λ and count-based estimates might reflect incorrect assumptions about newly discovered BAs (and resulting inaccuracy in counts), idiosyncrasies of our data, survivorship estimates that are low, emigration, shifting age at first reproduction as the population expands, and/or recruitment of breeders from unmarked populations (Fig. 10). Some of these possibilities have been discussed elsewhere in this report; here, we consider them in more detail.

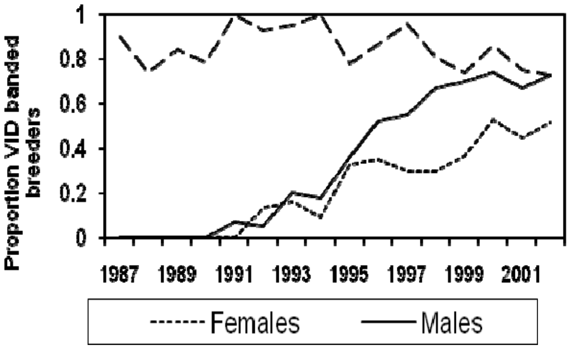


Figure 10. Proportion fledglings banded each year and proportion breeders that were banded. Note that banded fledglings were not resighted until they were at least 3 years old.

Is the Arizona Population Closed?

Only a well-designed study to estimate emigration and immigration rates would be able to address whether the population in Arizona is best treated as open or closed. No past studies have addressed this question. Because most recent work has theorized that Arizona bald eagles form a closed population (e.g. Hunt et al. 1992), our models described population dynamics as if there was no immigration from or emigration into other states. Failure to sight Arizona fledglings breeding elsewhere may be a consequence of low levels of monitoring in other states. Similarly, it is possible that immigrants have contributed to the breeding population in Arizona, but were not detected because of low banding efforts in states that are potential sources of breeding bald eagles in Arizona. Banding information from other western states indicates that California and Texas were the only surrounding states capable of contributing significant numbers of unbanded immigrants during this study (Table 17). Colorado, which had a large number of BAs also had a very intensive banding effort, so immigrant breeders were more likely to have been detected and identified.

Table 17. Bald eagle banding and resighting information in states and countries surrounding Arizona.

States/regions	Banding years	Number banded per year	Number of occupied BAs
Baja California	-	0	< 6
California	1958-2000	0-26	>151
Colorado	1976-2001	0-31	42
Nevada	1983, 1988,1989, 1993	1	3-4
New Mexico	1975-1988	1	3-4
Sonora	1988-present	1-4	3-6
Texas	1957-1991	0-25	17-35 (currently ~110)
Utah	1964-1994	0-9	2-4

Sonora, Mexico, is also a possible but unlikely source of recruits to the breeding population in Arizona. In 2001, a 14-year-old banded bald eagle from Arizona was seen during the breeding season at El Novillo Reservoir in Sonora (approximately 120 km east of Hermosillo); however, no BA has been identified there. Banded nestlings from Mexico have been reported in Arizona and other states along their northern migration, but there are no reports of them breeding north of Sonora (R. Mesta, USFWS, pers. comm.). The possibility of exchange of breeders between Arizona and Sonora suggests the need for closer attention directed at Sonoran bald eagles. Nonetheless, the small number of BAs, combined with high nestling and pre-reproductive mortality rate make it unlikely that fledglings from Sonora have been a significant source of breeders in Arizona in recent history (R. Mesta, USFWS, pers. comm.).

While confirming immigration into Arizona will be difficult due to the lack of banding effort in surrounding states, it is also possible that fledglings from undetected BAs within Arizona have recruited into this population. At least 4 existing BAs were discovered during our study. Production in these 4 BAs cannot account for all of the recruitment of unbanded breeders; however, this may be one important source of unbanded breeders. Due to the intensive survey effort in Arizona, it is unlikely that there are enough undetected BAs to account for all observed unbanded breeders.

Because banding effort in Arizona has been relatively constant since 1987, if the Arizona population is closed, we expect the proportion of banded breeders to level off eventually. Figure 10 contrasts the proportion of known fledglings banded each year (average approximately 80%) with the proportion of observed breeders that were VID banded. These values are apparently still converging and therefore not conclusive. However, the rate of return for females is slower than that for males. This difference is consistent with the possibility females are delaying age at first reproduction. Although immigration by females could cause this slower convergence, female dispersal from natal to breeding areas has been shown elsewhere to be greater than that of males (Harmata et al. 1999). In Arizona, females tended to travel farther from their natal sites than males to establish a breeding area (Fig. 9). However, on average those females only traveled 72.4 km farther, which is still consistent with local (i.e. Arizona) dispersal and is not necessarily the same as emigration from the area altogether. This topic requires a better understanding of the dispersal process than our data can support.

Undetected Population Segments Described in the Analysis

Another possible source of breeders could come from the pool of adults that are floaters. When we compared counts of breeders from one year to the next, we were not actually comparing counts of all breeding age birds. Resighting rates indicated that in addition to the 70 or so breeders each year, there was a group of over 20% as many floaters (Fig. 8). In any given year, some will replace breeders, fill vacancies, establish new BAs or reoccupy historical BAs, while others will continue to defer breeding for up to several years (up to 13 years old in the current study). A recent increase in the recruitment rate of breeders from the floating segment could explain some of the discrepancy between population growth calculated from breeder counts (improving status) and from vital rates across all segments of the population (declining status). If this hypothesis is correct, then the proportion of floaters has been changing, with higher numbers in the past and a lower number more recently.

Our estimate of the number of floaters is indirect and based on assumptions about reproductive behavior of bald eagles that are consistent with other studies (Brown 1969; Hunt 1998; Kenward et al. 1999; Newton and Rothery 2001; Arnold et al. 2002). Of the 59 identified banded breeders in our study, very few (3) moved from one BA to another. We therefore assumed bald eagles do not change BAs, and tenure at the BA with which they are first associated captures the beginning and end of their phase as a breeder. Also, our estimate of the number of floaters relies on our ability to accurately describe the age at first reproduction for each resighted, known-age banded bird. Of 49 such birds, 43 were seen their first year on the BA, 2 may have been there for 1 year before they were seen, 3 for 2 years, and 1 may have been present for as many as 6 years. Our assumptions seem reasonable, but the estimate of the proportion of adults that are floaters may nonetheless be inaccurate due to sample size and the possibility that floaters have been recruited into the breeding segment at variable rates, with greater recruitment in recent years. Changes in the recruitment rate of the breeding population might reflect stabilization from a past age structure reflecting rates and sources of mortality which are now under management. It is unlikely that a managed population would maintain the same population dynamics and age structure while it recovers. Nonetheless, our analysis puts a shape on an otherwise invisible segment of the population, and allows us to begin considering its importance.

Contrary to populations elsewhere, it is not uncommon for subadult and near-adult bald eagles to breed in Arizona. Hunt et al. (1999) speculated that occurrence of subadult and near-adult breeders may indicate a small or non-existent floater segment in the population, enabling occupancy by young birds that otherwise would not successfully defend a BA. To the contrary, we estimated that about 20% of birds over 4 years of age were floaters despite the fact that we also documented both subadult (N=4) and near-adult (N=35) breeders. In addition, Driscoll et al. (1999) proposed that Arizona birds in near-adult plumage should be considered competent breeders. The reported near-adult nest success rate of 0.49 supports this idea as it is comparable to the overall success rate for the population (Table 3).

Our estimated age structure predicted that 22.5% of the population consisted of pre-reproductives, a segment of the population that was not directly examined. We estimated that 27.9% [CI 14.7%, 46.6%] of fledglings survived to age 4. Assuming there is negligible emigration, which would otherwise lower the apparent survivorship estimate, this rate is relatively low compared to pre-reproductive survivorship in other studies. Our sensitivity analysis indicated that a moderate change in pre-reproductive survivorship could have a significant impact on population growth rate (Table 14). Alternatively, if there is considerable emigration to other regions, increasing pre-reproductive survivorship may have little impact on recruitment in Arizona. These considerations illustrate the necessity of a study to monitor or describe behavior and survival of pre-reproductives.

GAPS IN OUR UNDERSTANDING OF THE BALD EAGLES IN ARIZONA

This report provides a glimpse into aspects of the bald eagle's lifecycle in Arizona that had not previously been quantified. In analyzing our data, estimating vital rates, and creating demographic models, we identified several areas where our understanding of the bald eagle in Arizona could be improved. These gaps in our understanding include the need for additional analysis on our current data which include the exploration of density-dependent influences, environmental stochasticity, and spacial relationships. Some gaps in our understanding require continued monitoring in order to provide the sample sizes necessary to adequately refine our estimates of vital rates and create more accurate demographic models. Finally, some gaps will necessitate a change in priorities to collect different types of data currently not represented in our data. By addressing many of these gaps in understanding, we hope to resolve the apparent conflicts between our demographic models and simple count based λ estimates.

Further Analysis on Current Data

Our dataset is suitable for further exploration in many areas. For example, an analysis on environmental stochasticity and its effects on reproductive and survivorship rates would provide a better understanding of this population's stability. As the number of breeding areas continue to increase and breeding areas become spatially compressed, we will need to analyze the influence of density-dependent factors and their effect on the population. Future studies could also explore environmental variation on a spatial scale investigating their influences on the population dynamics of Arizona bald eagles. Finally, one of the benefits of performing a demographic analysis is that we can compare relative outcomes of investment in different types of management in the short- or long-term (Fig. 2). Recovery actions in Arizona to date have focused on increasing productivity by protecting breeding bald eagles from human interference, but we have not adequately explored the influence of these and other management options on the population. These and other analyses may provide insight into more complex aspects of the bald eagle population in Arizona and guide future management.

Estimates Requiring Larger Sample Sizes

The accuracy of our models is contingent upon reproductive and survivorship rates that were both accurate and remained constant over the period of study. Elasticities indicate which vital rates most affect the outcome of population models, and therefore point to estimates that require better parameter estimation, or more study. As additional years of data are included in future analysis, more accurate and representative estimates alone may bring our demographic model closer to count based λ estimates. For example, our analysis is sensitive to post-fledging survivorship rates. Therefore, our estimates would be more accurate if they were based on resighting more birds. Likewise, because survivorship estimates for pre-reproductives and bald eagles over age 8 were low, identifying and measuring the specific contributors to mortality should be given priority. In addition, we have made no attempt to quantify the extent to which factors limiting mortality and reproduction have declined, remained constant, or increased in intensity. We do not expect that these factors have remained constant over a period where the numbers of breeders nearly doubled from 46 to 80 breeders. With additional years of data, we need to analyze how these rates have changed over time.

Analysis Requiring Additional Types of Data Collection

For territorial birds, simple description of breeder replacement rates is inadequate to describe population status (Hunt 1998). Understanding the connection between breeders and floaters and their mutual link to habitat availability is necessary to characterize current population dynamics. In populations approaching stable age structure, in those with age structures shifting due to management practices, and in populations at equilibrium, the proportion of floaters can be a measure of the population's buffering capacity in the face of year-to-year environmental and demographic stochasticity as floaters can provide a minimum number of breeders, even in years with low recruitment. However, in a declining population, the buffering capacity of the floating segment may serve to mask the decline. Our indirect estimates of the floater population would be greatly improved with a concentrated effort to track and monitor these floaters. In addition, non-breeders apparently migrate annually across large regions, but we have no information on migration-related or region-specific sources of mortality and how these can impact eagles that breed in the Southwest.

Demographic models, alone, cannot necessarily capture the status of a population. For example, they do not account for risks associated with genetic characteristics of the population. Nonetheless, although genetic models have made important contributions for managing endangered species in the wild (Hedrick and Miller 1992; Haig et al. 1993), their application has been limited because the currencies of genetics (e.g. loss of heterozygosity and expression of deleterious recessive alleles) are not easily translated into extinction rates. Genetic characteristics can, however, be used to guide both regulatory and management decisions.

RECOMMENDATIONS

This analysis assumed that within age classes, survivorship for breeders and floaters was the same. A management project will have to be developed focusing on direct observations and resighting of floaters.

Because we only resighted banded birds at breeding areas, we were unable to directly estimate annual survivorship of juveniles. This particular information gap highlights our general lack of information on biology of pre-reproductives in Arizona. This gap could be addressed by developing a management project with elements of increased effort to identify banded birds in wintering concentrations, and with use of telemetry technology to determine the age at, and cause of, mortality.

The annual effort to identify breeders contributes to estimates of adult survivorship, tenure at a BA, duration of pair bonds, and age of senescence. Currently, efforts are being made to identify successful breeders, but to reduce possible bias; effort should be made to get to BAs earlier to identify unsuccessful breeders as well. Bald eagles are more difficult to locate and identify once their breeding effort fails.

The sensitivity of our demographic analysis to estimates of adult survivorship supports the need to accurately estimate survivorship. The size of the current sample was sufficient to develop age-specific but not sex-and-age-specific survivorship rates. Therefore, we need to continue our marking and resighting efforts.

We have been able to band most fledglings in each cohort, but not all BAs are currently accessible to biologists. As currently accessible nests are abandoned or fall, it becomes increasingly important to gain access to other, currently unavailable nest locations.

Although current management practices increase fledging success, we realize that this does not have the same potential to benefit the population as would as reducing mortality after the first year. However, until further work can illuminate factors limiting the Arizona population, we argue that limitations on productivity must continue to be a focus of management. Additionally, these localized efforts are logistically easier, while our ability to manage adult mortality from diffuse sources is less certain.

To investigate the dynamic relationship between breeding bald eagles in Arizona and those of surrounding regions, we should start with a better understanding of current banding efforts across the potential historic range. These efforts might enable us to identify and later quantify immigration into and emigration out of this population. After determining out-of-state breeding areas of most interest for such an effort, we should investigate the possibility of interstate cooperation to perform these studies.

Our first suggestion for focusing effort within Arizona is to concentrate on identifying any banded breeders, and on banding all possible fledglings on the Bill Williams River, and at the Luna and Becker BAs. The BAs along the Bill Williams River seem to recruit strongly from that same drainage and are closest to California. The origin of breeders in this drainage could inform us both about possible immigration and about difficulties of colonizing new drainages within Arizona. Since the only known immigrant into Arizona was breeding at the other White Mountain BA at Luna, it is important to identify these bald eagles each year to document immigration or connection to other Arizona BAs as a source or recipient of Arizona fledglings as breeders.

Future analyses will need to develop a logistic regression model to describe relative effects on nest success (odds of fledging at least 1 eaglet) from: nest substrate (tree, snag, cliff), nest orientation, number of low-flying planes, hikers, boaters, nest height, and type of foraging area (reservoir, regulated river, unregulated river). A similar but inconclusive analysis was performed by Hunt et al. (1992) using discriminant analysis. These analyses can serve 2 functions: 1) To identify factors that have relatively predictable impacts on nest success, and 2) To identify management impacts to specific BAs. The latter function allows us to quantify the probable impact of closure areas around specific nests, so the benefits of such closures can be weighed.

Increasing public education to prevent mortality from incidental shooting, entanglement in monofilament, lead poisoning, etc., is needed to reduce the human induced causes of mortality. Heightened awareness to the cause of bald eagle mortality will bring consideration, understanding, and respect for the species' plight in Arizona. These losses are preventable, and this recommendation can be implemented, but it requires public support.

The bald eagle in Arizona has relatively low productivity and adult survivorship. Earlier recognition of these rates led to recommendations by other biologists (Bednarz 1999; letter to Jody Millar, USFWS) to defer delisting of the bald eagle in Arizona. However, there is literature that predicts lower vital rates as a population approaches carrying capacity due to effects of density dependence. We therefore recommend that the level of density-dependent effects be estimated for the Arizona population.

We recognize that our best information addresses the demographic status of this breeding population, not its genetic status. For instance, we have little information about heterozygosity and any developmental effects of homozygosity in Arizona bald eagles. Hunt et al. (1992) examined the level of genetic variability and heterozygosity in Arizona and found them comparable to bald eagles in other regions. However, they cautioned against interpreting the results due to the low number of individuals and the few loci examined. The current study did not examine the 'genetic status' of bald eagles in Arizona. Although we documented 3 cases of incest between parents and offspring (89F01 and 92J02) or siblings (89J11 and 94J12, 94J06 and 94J07), we do not know the level that inbreeding naturally occurs in a bald eagle population. Speculation exists that inbreeding may reduce the fitness of the individual by a reduction in productivity (Newton 1979; Hunt et al. 1992). Incestuous relationships are reported in other species of raptors, but minimal information exists on its effects to reproductive success. It is possible that productivity in Arizona is not increasing at the same rate as occupancy due in part to the occurrence of inbreeding depression. Only future genetic study will enable us to assess this link.

We began the analysis with models to test whether females began to breed after males, whether males have lower survivorship at any age, and whether survivorship has important connections to year-to-year variation in environmental effects. Although age structure differentiated resighting (breeding likelihood) rates, the differences due to sex-specific age differences were not important for describing either survivorship or resighting rate. Larger sample sizes will make it easier to detect meaningful effects that are perhaps smaller in magnitude than the age-specific effect on resighting rates.

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APPENDIX A: RAPTOR REPRODUCTIVE STATUS CRITERIA

[Known] Breeding Area (BA): An area containing one or more nests within the range of one mated pair of birds. Operationally, a BA is recognized only after an active nest has been documented. Once a BA is established, we consider it a BA whether it is occupied by bald eagles in a given year or not, until/unless it is designated historical.

Occupied BA/Nest: An occupied BA must have an occupied nest, which is any nest, where at least one of the following activity patterns was observed during the breeding season:

a. Young were raised.
b. Eggs were laid.
c. One adult sitting low in the nest, presumably incubating.
d. Two adults present on or near the nest.
e. One adult and one bird in immature plumage at or near a nest, if mating behavior was observed (display flight, nest repair, coition).
f. A recently repaired nest with fresh sticks, or fresh boughs on top, and/or droppings and/or molted feathers on its rim or underneath.

Active Nest: One in which eggs have been laid. Activity patterns (a), (b), and (c) above are diagnostic of an active nest.

Unoccupied BA/Nest: A nest or group of alternate nests at which none of the activity patterns diagnostic of an occupied nest were observed in a given breeding season. BAs must be existing as occupied before they can be recognized and classified as unoccupied.

Successful BA/Nest: An occupied nest from which at least 1 young fledged during the breeding season under consideration. We classified nests as successful if at least 1 young was raised past 8 weeks of development.

Failed BA/Nest: An occupied nest from which no young fledged due to any cause.

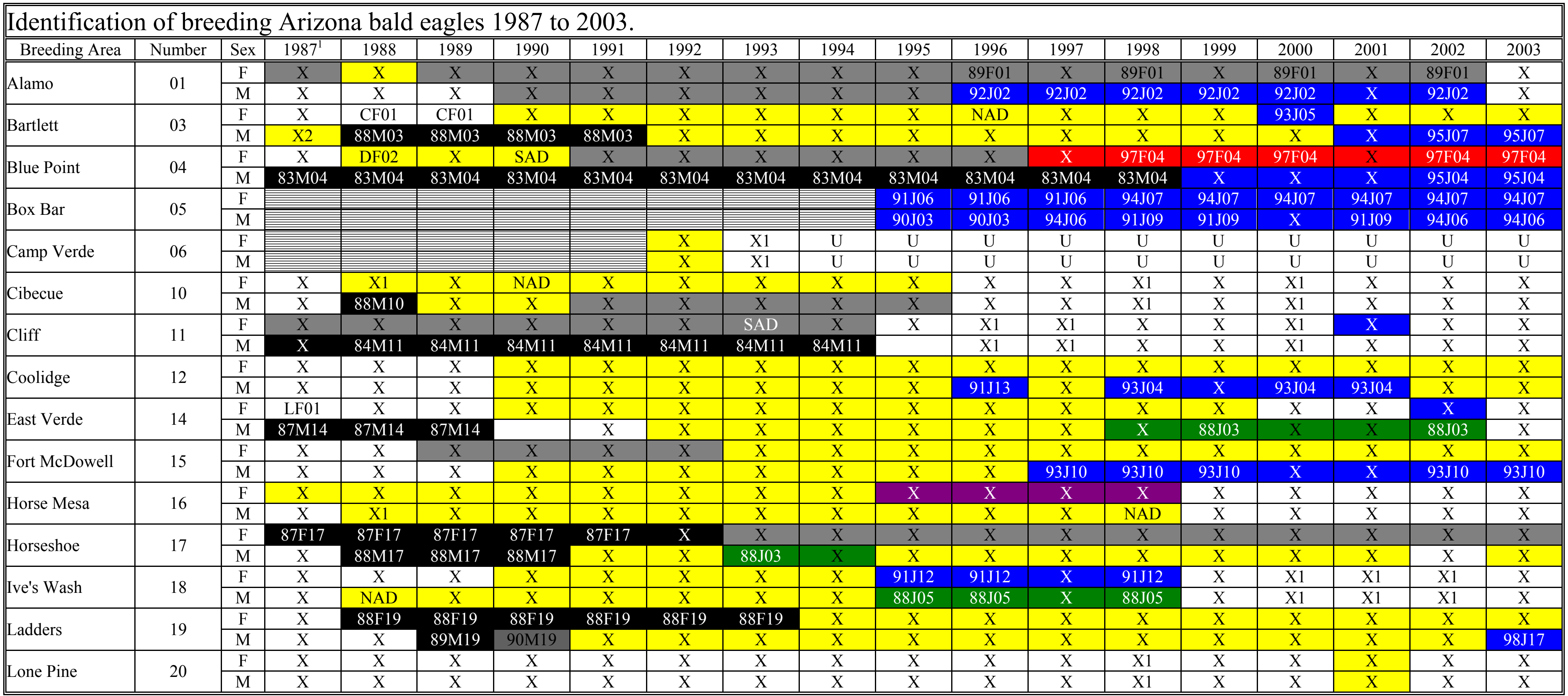
Historical BA: A BA that has remained unoccupied for 10 consecutive years. Given that some records of breeding occupancy are sparse in the literature before 1973, this term also applies to any BA recorded not showing signs of occupancy since that time.

Reoccupied Historical BA: A Historical BA, which shows signs diagnostic of being active. Due to intensity survey effort and BA location, a reoccupied historical BA can be discovered reoccupied the first year of activity, or may have been active prior.

Pioneer Effort: The occupancy of a new nest, in previously undocumented breeding habitat, where there is no evidence of prior activity. These occur in areas monitored before discovery due to 1) the presence of a large nest built by another or unknown species, or 2) the observed suitability of the habitat.

Existing BA: A BA that shows signs of prior occupancy (for example multiple large nests) and/or signs of prior activity (for example prey remains below an existing nest) upon discovery.

APPENDIX B: ADULT IDENTIFICATION CHRONOLOGY



Identification of breeding Arizona bald eagles 1987 to 2003.

Breeding Area	Number	Sex	1987[1]	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Alamo	01	F	X	X	X	X	X	X	X	X	X	89F01	X	89F01	X	89F01	X	89F01	X
		M	X	X	X	X	X	X	X	X	X	92J02	92J02	92J02	92J02	92J02	X	92J02	X
Bartlett	03	F	X	CF01	CF01	X	X	X	X	X	X	NAD	X	X	X	93J05	X	X	X
		M	X2	88M03	88M03	88M03	88M03	X	X	X	X	X	X	X	X	X	X	95J07	95J07
Blue Point	04	F	X	DF02	X	SAD	X	X	X	X	X	X	X	97F04	97F04	97F04	X	97F04	97F04
		M	83M04	83M04	83M04	83M04	83M04	83M04	83M04	83M04	83M04	83M04	83M04	83M04	X	X	X	95J04	95J04
Box Bar	05	F									91J06	91J06	91J06	94J07	94J07	94J07	94J07	94J07	94J07
		M									90J03	90J03	94J06	91J09	91J09	X	91J09	94J06	94J06
Camp Verde	06	F						X	X1	U	U	U	U	U	U	U	U	U	U
		M						X	X1	U	U	U	U	U	U	U	U	U	U
Cibecue	10	F	X	X1	X	NAD	X	X	X	X	X	X	X	X1	X	X1	X	X	X
		M	X	88M10	X	X	X	X	X	X	X	X	X	X1	X	X1	X	X	X
Cliff	11	F	X	X	X	X	X	X	SAD	X	X	X1	X1	X	X	X1	X	X	X
		M	X	84M11	84M11	84M11	84M11	84M11	84M11	84M11		X1	X1	X	X	X1	X	X	X
Coolidge	12	F	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		M	X	X	X	X	X	X	X	X	X	91J13	X	93J04	X	93J04	93J04	X	X
East Verde	14	F	LF01	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		M	87M14	87M14	87M14		X	X	X	X	X	X	X	X	88J03	X	X	88J03	X
Fort McDowell	15	F	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		M	X	X	X	X	X	X	X	X	X	X	93J10	93J10	93J10	X	X	93J10	93J10
Horse Mesa	16	F	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		M	X	X1	X	X	X	X	X	X	X	X	X	NAD	X	X	X	X	X
Horseshoe	17	F	87F17	87F17	87F17	87F17	87F17	X	X	X	X	X	X	X	X	X	X	X	X
		M	X	88M17	88M17	88M17	X	X	88J03	X	X	X	X	X	X	X	X	X	X
Ive's Wash	18	F	X	X	X	X	X	X	X	X	91J12	91J12	X	91J12	X	X1	X1	X1	X
		M	X	NAD	X	X	X	X	X	X	88J05	88J05	X	88J05	X	X1	X1	X1	X
Ladders	19	F	X	88F19	88F19	88F19	88F19	88F19	88F19	X	X	X	X	X	X	X	X	X	X
		M	X	X	89M19	90M19	X	X	X	X	X	X	X	X	X	X	X	X	98J17
Lone Pine	20	F	X	X	X	X	X	X	X	X	X	X	X	X1	X	X	X	X	X
		M	X	X	X	X	X	X	X	X	X	X	X	X1	X	X	X	X	X

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[1] 1987-1990 information from Hunt et al. 1992.

[2] U = BA was visited and found unoccupied, X = Two birds occupied the BA but not identified, X1 = Only one bird could be confirmed in the BA, because only nest reconstruction was seen or only one bird was seen at any one time. Blank or stippled cells indicate the BA was not visited.

[3] Band color and identification: White cells = ORA information only; banded or unbanded status of birds could not be confirmed. Yellow cells = Confirmed unbanded birds, Gray cells = USFWS but no VID band, All other cell shading = corresponds to Visual Identification (VID) band color (blue, black, red, purple, green). If the VID or USFWS band was read, the bird's identity is indicated in the cell. Birds identified by band year, followed by age/sex at banding (J=banded nestling, F=banded adult female, M=banded adult male), then BA number at the time of banding. Information on subadult (SAD) or near-adult plumage (NAD) reflects a change in plumage and therefore replacement.

Appendix B. (Continued).

Breeding Area	Number	Sex	1987[1]	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Luna	21	F								94F21	94F21	94F21	X	94F21	94F21	X	X	94F21	94F21
		M								94M21	94M21	94M21	94M21	94M21	X	94M21	X	94M21	94M21
Orme	23	F	X	X	NAD	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		M	X	NAD	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Perkinsville	24	F			NAD	X	X	X	U	U	U	U	X	X1	U	94J13	94J13	94J13	94J13
		M			NAD	X	X	X1	U	U	U	U	X	X1	U	96J15	96J15	96J15	96J15
Pinal	25	F	87F25	87F25	87F25	87F25	87F25	87F25	87F25	87F25	X	90J05	90J05	X1	X	X	U	90J05	90J05
		M	X	X	X	X	X	X	X	X	X	X	X	X1	X	X	U	87M25	87M25
Pinto	26	F		87F26	87F26	87F26	87F26	87F26	87F26	87F26	87F26	87F26	87F26	X	91J08	X	X	X	X
		M		X	X	X	X	X	X1	X	88J04	88J04	88J04	X	94J04	X	X	X	X
Pleasant	27	F	X1	U	X1	X	X	NAD	X	X	X	X	X	X	X	X	X	X	X
		M	X1	U	X1	NAD	87J04	87J04	87J04	87J04	87J04	87J04	87J04	87J04	87J04	87J04	87J04	87J04	87J04
Redmond	28	F	X	X	X	X	X	X	X	X	X	X	X	X	X	89J02	X	89J02	X1
		M	X	88M28	88M28	88M28	88M28	X	X	87J05	87J05	87J05	87J05	87J05	87J05	87J05	87J05	87J05	X1
San Carlos	29	F									89J12	89J12	X	89J12	89J12	X	X1	X	X1
		M									90J04	90J04	90J04	90J04	X1	X	X1	X	X1
76	30	F	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X1	X
		M	X	X	X	X	X	X	X	X	X	88M30	88M30	88M30	88M30	88M30	88M30	X1	X
Sheep	31	F	X	X	X	X	U	88J11	88J11	88J11	88J11	88J11	X	X	88J11	88J11	88J11	88J11	88J11
		M	X	NAD	X	X	U	X	X	SAD	X	91J14	X	X	94J12	94J12	94J12	94J12	94J12
Table Mountain	32	F	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		M	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Talkalai	33	F								X	88J10	88J10	X	X	X	X	88J10	88J10	X
		M								X	X	X	X	X	X	X	X	X	X
Tonto	34	F						87J15	87J15	87J15	87J15	87J15	87J15	87J15	87J15	87J15	87J15	87J15	87J15
		M						X	87J18	87J18	87J18	87J18	87J18	87J18	87J18	87J18	87J18	87J18	87J18
Tower	35	F							X	X	X	X	X	X	X	X	X	X	X
		M							X	89J08	89J08	89J08	89J08	89J08	89J08	89J08	89J08	89J08	89J08
Winkelman	36	F									X	91J08	X	X	U	U	U	U	U
		M									X	92J07	X	X	U	U	U	U	U
Dupont	37	F											X	X	X1	X	X	U	X
		M											88J07	88J07	X1	X	X	U	X

[1] 1987-1990 information from Hunt et al. 1992.

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Appendix B. (Continued).

Breeding Area	Number	Sex	1987[1]	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Becker	38	F											X	X	X	X	X	X1	U
		M											X	X	X	X	X	X1	U
Sycamore	39	F											90J02	90J02	90J02	X	X	X	X
		M											92J06	92J06	92J06	X	X	92J06	92J06
Doka	40	F												X	X	X	X	X	X
		M												94J05	94J05	94J05	94J05	94J05	94J05
Coldwater	41	F												X	X	X	X	X	X
		M												92J07	92J07	X	X	X	X
Granite Basin	42	F													X	X	X	X1	X1
		M													X	X	X	X1	X1
Suicide	43	F													X	92J13	92J13	92J13	92J13
		M													X	93J09	93J09	93J09	93J09
Rodeo	44	F														95J??	95J??	95J??	97J14
		M														X	X	X	X
Lynx	46	F																95J09	95J09
		M																X	98J??
Granite Reef	47	F																X	X
		M																X	X
Needle Rock	48	F																X	X
		M																98J06	98J06
Oak Creek	49	F																X	96J14
		M																X	X
Bulldog	58	F																	X
		M																	X
Crescent	59	F																	X
		M																	X

[1] 1987-1990 information from Hunt et al. 1992.

[2] U = BA was visited and found unoccupied, X = Two birds occupied the BA but not identified, X1 = Only one bird could be confirmed in the BA, because only nest reconstruction was seen or only one bird was seen at any one time. Blank or stippled cells indicate the BA was not visited.

[3] Band color and identification: White cells = ORA information only; banded or unbanded status of birds could not be confirmed. Yellow cells = Confirmed unbanded birds, Gray cells = USFWS but no VID band, All other cell shading = corresponds to Visual Identification (VID) band color (blue, black, red, purple, green). If the VID or USFWS band was read, the bird's identity is indicated in the cell. Birds identified by band year, followed by age/sex at banding (J=banded nestling, F=banded adult female, M=banded adult male), then BA number at the time of banding. Information on subadult (SAD) or near-adult plumage (NAD) reflects a change in plumage and therefore replacement.

APPENDIX C: BANDING TABLES

Bald eagle nestlings banded from 1977 to 1982 in Arizona by Robert Ohmart as reported by Hunt et al. (1992).

Natal Area	Bird Number[1]	Sex	USFWS Band	Breeding Area	First Year Breeding	Age of Death	Comments
1977							
Fort McDowell	---	---	629-04451				
	---	---	629-04452			0	
Bartlett	---	M	629-04453	Cibecue	?	12	
	---	---	629-04454			3	
East Verde	---	---	629-04455				
	---	---	629-04456				
1978							
Fort McDowell	---	---	629-04457				
	---	---	629-04458				
Cibecue	---	---	629-04459[2]				
	---	---	629-04461[2]				
Bartlett	---	---	629-04460			0	
1979							
Bartlett	85F01	F	629-04462	Alamo	1987	8	Replaced.
Fort McDowell	83M04	M	629-04463	Blue Point	1983	19	
	89F01	F	629-04464	Alamo	1989		
Pinal	---	---	629-04465				
	---	---	629-04466				
Redmond	84M11	M	629-04467	Cliff	1985		
1980							
East Verde	---	---	629-04468				
	---	---	629-04469				
Bartlett	---	---	629-04470				
1981							
Bartlett	---	---	629-04471			0	
	87F26	F	629-04472	Pinto	1988	16	Replaced.
Redmond	87M25	M	629-04473	Pinal	1987		
	---	---	629-04477				
Pinal	---	---	629-04474				
Fort McDowell	---	---	629-04475				
	---	---	629-04476				
1982							
Redmond	---	---	629-04478				
	---	---	629-04480				

[1] AGFD bird number.
[2] USFWS band placed on left leg.

Bald eagle nestlings banded from 1983 to 1985 in Arizona by Teryl Grubb as reported by Hunt et al. (1992).

Natal Area	Bird Number[1]	Sex	USFWS Band	Breeding Area	First Year Breeding	Age of Death	Comments
1983							
Pinal	---	---	629-14551				
Fort McDowell	---	---	629-14552				
	88M30	M	629-14553[2]	76	1988	18	Replaced.
Horseshoe	---	---	629-14554				
Redmond	---	---	629-14556				
	---	---	629-14557[2]				
1984							
Blue Point	---	---	629-14558				
	88M03	M	629-14559	Bartlett	1988	7	
East Verde	97F04	F	629-14560	Blue Point	1997		
Horseshoe	---	---	629-14561				
	90M19	M	629-14562	Ladders	1990	6	

[1] AGFD bird number.
[2] USFWS band placed on left leg.

Appendix C. Continued.

Natal Area	Bird Number[1]	Sex	USFWS Band	Breeding Area	First Year Breeding	Age of Death	Comments
1984 continued							
Cibecue	---	---	629-14563				
	---	---	629-14564				
	---	---	629-14565				
1985							
Ladders	---	---	629-14566				
Bartlett	---	---	629-14567				
Ash	---	---	629-14568				

[1] AGFD bird number.

Bald eagle nestlings banded from 1987 to 1990 in Arizona by Hunt et al. (1992).

Natal Area	Bird Number[1]	Sex	USFWS Band	VID Symbol[2]	Breeding Area	First Year Breeding	Age of Death	Comments
1987								
Orme	87J01	M	629-15184	Z				
	87J02	F	629-15185	Y				Sighted 1989.
Fort McDowell	87J03	M	629-15186	X				Sighted 1988.
Horse Mesa	87J04	M	629-15187	W	Pleasant	1991		
	87J05	M	629-15188	V	Redmond	1994		
Coolidge	87J06	M	629-15189	U				
	87J07	M	629-15190	S				
Ladders	87J08	M	629-15191	R			0	
	87J09	M	629-15192	P			0	
Blue Point	87J10	M	629-15193	O			0	
	87J11	M	629-15194	N				
	87J12	F	629-15195	M				
Horseshoe	87J13	F	629-15196	K	California			Breeding Temecula, Ca.
	87J14	M	629-15197	H			3	
	87J15	F	629-15198	G	Tonto	1992		
Redmond	87J16	F	629-15199	→				
	87J17	M	629-15200	Backwards 2				
Pinal	87J18	M	629-26451	Backwards 3	Tonto	1993		
	87J19	?	629-26452	Backwards 4				
East Verde	87J20	F	629-26453	Backwards 5				Sighted 1987.
1988								
Alamo	88J01	F	629-26457	①				
Ladders	88J02	M	629-26462	②			0	
	88J03	M	629-26468	③	Horseshoe/ East Verde	1993		
Orme	88J04	M	629-26469	④	Pinto	1995	9	Replaced.
Ive’s Wash	88J05	M	629-26464	⑤	Ive’s Wash	1995		
Cliff	88J06	F	629-26465	⑥				Sighted 2002.
	88J07	M	629-26466	⑦	Dupont	1997		
Coolidge	88J08	M	629-26467	⑧				
	88J09	M	629-26473	Circle A				
76	88J10	F	629-26471	Circle B	Talkalai	1995		
	88J11	F	629-26472	Circle C	Sheep	1992		
Blue Point	88J12	M	629-26473	Circle D			0	
	88J13	M	629-26474	Circle E			0	
	88J14	F	629-26475	Circle G			0	
Horseshoe	88J15	M	629-26476	Circle H				
Lone Pine	88J16	M	629-26477	Circle K				
	88J17	M	629-26478	Circle M				
Redmond	88J18	F	629-26479	Circle N			0	
	88J19	F	629-26480	Circle P			0	
1989								
Alamo	89J01	M	629-32602	Diamond 1				
Ive’s Wash	89J02	F	629-32603	Diamond 2	Redmond	1999		
	89J03	M	629-32604	Diamond 3			0	
Fort McDowell	89J04	F	629-32605	Diamond 4				
	89J05	F	629-32624	Diamond 5				

[1] AGFD bird number.

[2] VID color bands: 1987=blue, 1988=green, 1989=purple.

Appendix C. Continued.

Natal Area	Bird Number[1]	Sex	USFWS Band	VID Symbol[2]	Breeding Area	First Year Breeding	Age of Death	Comments
1989 continued								
East Verde	89J06	M	629-32625	Diamond 6				
	89J07	F	629-32626	Diamond 7				
Ladders	89J08	M	629-32627	Diamond 8	Tower	1993		
	89J09	M	629-32628	Diamond A				
Pinal	89J10	M	629-32629	Diamond B				
Bartlett	89J11	M	629-32630	Diamond C				
	89J12	F	629-32631	Diamond D	San Carlos	1995		
1990								
Alamo	90J01	F	629-32653	1/A				
	90J02	F	629-32654	1/B	Sycamore	1997	10	Replaced
Horse Mesa	90J03	M	629-32655	1/C	Box Bar	1995	6	Replaced.
	90J04	M	629-32656	1/E	San Carlos	1995		
Horseshoe	90J05	F	629-32657	1/G	Pinal	1995		
	90J06	M	629-32658	1/H				
Pinal	90J07	F	629-32659	1/K				
	90J08	M	629-32660	1/M				
76	90J09	M	629-32661	1/N				
Orme	90J10	F	629-32662	1/P				
Redmond	90J11	M	629-32663	1/R				

[1] AGFD bird number.
[2] VID color bands: 1989=purple, 1990=blue.

Bald eagle nestlings banded from 1991 to 1992 in Arizona by Mesta et al. (1992).

Natal Area	Bird Number[1]	Sex	USFWS Band	VID Symbol (Blue Color)	Breeding Area	First Year Breeding	Age of Death	Comments
1991								
Horse Mesa	91J01	F	629-32751	2/A				
	91J02	F	629-32752	2/B				
	91J03	M[2]	629-32753	--	Sheep	1994	3	Replaced.
Ive's Wash	91J04	M	629-32754	2/C			0	
	91J05	F	629-32755	2/D			0	
Fort McDowell	91J06	F	629-32756	2/E	Box Bar	1995	6	Replaced.
Alamo	91J07	F	629-36004	2/G				
	91J08	F	629-36005	2/H	Winkelman/ Pinto	1996		
Pinal	91J09	M[3]	629-36006	2/K	Box Bar	1998	10	Replaced
Coolidge	91J10	F	629-36007	2/M				
76	91J11	M	629-36008	2/N				
Blue Point	91J12	F	629-36009	2/P	Ive's Wash	1995		
	91J13	M	629-36010	2/R	Coolidge	1996	5	
Ladders	91J14	M	629-36011	2/S	Sheep	1995	5	Replaced.
Redmond	91J15	F	629-36012	2/T				
	91J16	M	629-36013	2/U			0	
Cibecue	91J17	M	629-36014	2/V				
	91J18	M	629-36015	2/W				
Table Mountain	91J19	M	629-36016	2/X				
Lone Pine	91J20	M	629-36017	2/Y				
Orme	91J21	M	629-36018	2/Z				
1992								
Alamo	92J01	F	629-36019	3/A				
	92J02	M	629-36020	3/B	Alamo	1996		
Ive's Wash	92J03	M	629-36021	3/C				
	92J04	M	629-36022	3/D				
Orme	92J05	F	629-36025	3/E			0	
	92J06	M	629-36026	3/G	Sycamore	1997		
Coolidge	92J07	M	629-36027	3/H	Winkelman/ Coldwater	1996		
Blue Point	92J08	F	629-36028	3/K				
	92J09	M	629-36029	3/M				

[1] AGFD bird number.
[2] Single banded three year old male breeding at the Sheep BA in 1994, assumed to be this Horse Mesa nestling.
[3] Reported as female when banded. Breeding as a male in the Box Bar pair.

Appendix C. Continued.

Natal Area	Bird Number[1]	Sex	USFWS Band	VID Symbol (Blue Color)	Breeding Area	First Year Breeding	Age of Death	Comments
1992 continued								
Ladders	92J10	M	629-36030	3/N				
	92J11	F	629-36033	3/P				
76	92J12	F	629-36031	3/R				
East Verde	92J13	F	629-36032	3/S	Suicide	1999		
Bartlett	92J14	F	629-36034	3/T				

[1] AGFD bird number.

Bald eagle nestlings banded from 1993 to 2002 in Arizona.

Natal Area	Bird Number	Sex	USFWS Band	VID Symbol (Blue Color)	Breeding Area	First Year Breeding	Age of Death	Comments
1993								
Alamo	93J01	F	629-36037	4/A				Fostered to Ive's Wash.
Ive's Wash	93J02	F	629-36038	4/B				
Pleasant	93J03	M	629-36039	4/C				Died 1993?
Bartlett	93J04	M	629-36040	4/D	Coolidge	1998	7	Replaced.
East Verde	93J05	F	629-36041	4/E	Bartlett	2000	7	Replaced.
Pinal	93J06	M	629-36042	4/G				
Fort McDowell	93J07	M	629-36043	4/H			0	
	93J08	M	629-36044	4/K				
Blue Point	93J09	M	629-36045	4/M	Suicide	2000		
	93J10	M	629-36046	4/N	Fort McDowell	1997		
Tonto	93J11	M	629-36047	4/P				
	93J12	M	629-36048	4/R				
Pinto	93J13	M	629-36049	4/S				
Orme	93J14	F	629-36050	4/T			0	
	93J15	F	629-36051	4/U				
Horse Mesa	93J16	F	629-36052	4/V				
Coolidge	93J17	M	629-36053	4/W				
	93J18	F	629-36054	4/X				
Tower	93J19	M	629-36055	4/Y				
Alamo	93J20	M	629-36056	4/Z				
Table Mountain	93J21	F	629-36057	1/Z				
	93J22	M	629-36058	1/Y				
1994								
Ive's Wash	94J01	M	629-36071	5/A			0	
Tonto	94J02	M	629-36072	5/B			0	
	94J03	M	629-36073	5/C				
Blue Point	94J04	M	629-36074	5/D	Pinto	1998		
	94J05	M	629-36075	5/E	Doka	1998		
Pleasant	94J06	M	629-36076	5/G	Box Bar/Box Bar	1997		Replaced and reentered.
	94J07	F	629-36077	5/H	Box Bar	1998		
Alamo	94J08	F	629-36078	5/K				
Bartlett	94J09	F	629-36079	5/M				
Orme	94J10	M	629-36080	5/N			0	
	94J11	M	629-36081	5/P				
76	94J12	M	629-36082	5/R	Sheep	1999		
	94J13	F	629-36083	5/S	Perkinsville	2000		
Table Mountain	94J14	M	629-36084	5/T				
Ladders	94J15	M	629-36085	5/U				
	94J16	F	629-36086	5/V				
Cibecue	94J17	M	629-36087	5/W				
Luna	94J18	F	629-36088	5/X				
Pinal	94J19	M	629-36089	5/Y				
1995								
Alamo	95J01	M	629-15768	6/A				
	95J02	M	629-15769	6/B				
Pleasant	95J03	F	629-15766	6/C				
	95J04	M	629-15767	6/D	Blue Point	1999		
Blue Point	95J05	F	629-15770	6/E				
	95J06	F	629-15771	6/G				

Appendix C. Continued.

Natal Area	Bird Number	Sex	USFWS Band	VID Symbol (Blue Color)	Breeding Area	First Year Breeding	Age of Death	Comments
1995 continued								
Tonto	95J07	M	629-15772	6/H	Bartlett	2001		Sighted 1995.
Pinto	95J08	F	629-15773	6/K				
	95J09	F	629-15774	6/M	Lynx	2002		
East Verde	95J10	M	629-15775	6/N				
Redmond	95J11	M	629-15776	6/P				Sighted 1998.
Orme	95J12	F	629-15777	6/R			0	
	95J13	F	629-15778	6/S			0	
Horse Mesa	95J14	M	629-15779	6/T				
Table Mountain	95J15	M	629-15780	6/U				
	95J16	M	629-15781	6/V				
Ive's Wash	95J17	M	629-15782	6/W				
Coolidge	95J18	M	629-15783	6/X				
	95J19	F	629-15784	6/Y				Sighted 1996
Luna	95J20	M	629-15785	6/Z				
1996								
Blue Point	96J01	M	629-23541	7/A			0	
	96J02	M	629-23542	7/B				
Pinto	96J03	M	629-23543	7/C				
	96J04	M	629-23544	7/D				
	96J05	F	629-23545	7/E				
Pleasant	96J06	F	629-23546	7/G			0	
	96J07	M	629-23547	7/H			0	
East Verde	96J08	M	629-23548	7/K				
Sheep	96J09	F	629-23549	7/M				
	96J10	M	629-23550	7/N				
Tonto	96J11	M	629-23551	7/P				
	96J12	M	629-23552	7/R				
Ladders	96J13	F	629-23553	7/S				
Tower	96J14	F	629-23554	7/T	Oak Creek	2003		
	96J15	M	629-23555	7/U	Perkinsville	2000		
Table Mountain	96J16	M	629-23556	7/V			0	
	96J17	M	629-23557	7/W				
Ive's Wash	96J18	M	629-23558	7/X			0	
Horseshoe	96J19	M	629-23559	7/Y				
76	96J20	F	629-23560	7/Z			0	
	96J21	F	629-23561	1/X				
Luna	96J22	F	629-23562	1/V			0	
	96J23	F	629-23563	1/U			0	
Box Bar	96J24	F	629-23564	1/T			0	
Bartlett	96J25	M	629-23565	3/Y				
	96J26	M	629-23566	3/W				
1997								
Tonto	97J01	F	629-23567	8/A				
	97J02	F	629-23568	8/B				
Fort McDowell	97J03	M	629-23569	8/C				Sighted 2002.
	97J04	M	629-23570	8/D				
Pleasant	97J05	M	629-23571	8/E				
	97J06	M	629-23572	8/G			3	
Blue Point	97J07	F	629-23573	8/H			0	
	97J08	M	629-23574	8/K				
	97J09	F	629-23575	8/M				
Orme	97J10	M	629-23576	8/N				
	97J11	F	629-23577	8/P				
Luna	97J12	M	629-23578	8/R				
	97J13	F	629-23579	8/S			0	
Coolidge	97J14	F	629-23580	8/T	Rodeo	2003		
	97J15	M	629-23581	8/U				
Towers	97J16	M	629-23582	8/V				
Horseshoe	97J17	M	629-23583	8/W				
	97J18	M	629-23584	8/X				
Box Bar	97J19	M	629-23585	8/Y				Fostered to San Carlos.
76	97J20	M	629-23586	8/Z				
	97J21	M	629-23587	3/U				

Appendix C. Continued.

Natal Area	Bird Number	Sex	USFWS Band	VID Symbol (Blue Color)	Breeding Area	First Year Breeding	Age of Death	Comments
1997 continued								
Table Mountain	97J22	F	629-23588	3/V				
San Carlos	97J23	M	629-23589	5/Z			0	
Luna	97J24	M	629-23590	0/Z				
1998								
Fort McDowell	98J01	M	629-42651	9/A			0	
Sycamore	98J02	F	629-42652	9/B				
Pleasant	98J03	M	629-42653	9/C				
Box Bar	98J04	M	629-42654	9/D				
	98J05	F	629-42655	9/E			1	
Tonto	98J06	M	629-42656	9/G	Needle Rock	2002	5	
San Carlos	98J07	M	629-42657	9/H				
	98J08	F	629-42658	9/K				
Towers	98J09	M	629-42659	9/M				
	98J10	M	629-42660	9/N				
Ladders	98J11	M	629-42661	9/P				
	98J12	M	629-42662	9/R				
	98J13	M	629-42663	9/S			5	
Orme	98J14	F	629-42664	9/T				
Luna	98J15	M	629-42665	9/U				
76	98J16	F	629-42666	9/V				
	98J17	M	629-42667	9/W	Ladders	2003		
Redmond	98J18	M	629-42668	9/X				
1999								
Fort McDowell	99J01	M	629-42669	0/A			0	
	99J02	F	629-42670	0/B				
Tonto	99J03	M	629-42671	0/C				
	99J04	F	629-42672	0/D				
Sycamore	99J05	M	629-42673	0/E				
	99J06	F	629-42674	0/G				
Horseshoe	99J07	M	629-42675	0/H				
	99J08	F	629-42676	0/K				
Tower	99J09	M	629-42677	0/M				
	99J10	F	629-42678	0/N				
Pleasant	99J11	M	629-42680	0/R				
Blue Point	99J12	F	629-42679	0/P				
Pinto	99J13	F	629-42681	0/S				
	99J14	M	629-42682	0/T				
East Verde	99J15	M	629-42683	0/U				
	99J16	M	629-42684	0/V				
76	99J17	F	629-42685	0/W				
Sheep	99J18	F	629-42686	0/X				
Luna	99J19	M	629-42687	0/Y				
	99J20	M	629-42688	9/Y			0	
Ladders	99J21	M	629-42689	9/Z				
	99J22	F	629-42690	11/Z				
Orme	99J23	F	629-42691	11/Y				
Bartlett	99J24	M	629-42692	11/X				
Redmond	99J25	M	629-42693	11/W			0	
Cibecue	99J26	M	629-42694	11/V				
2000								
Fort McDowell	00J01	F	629-42695	11/A				
	00J02	M	629-42696	11/B				
Box Bar	00J03	F	629-42697	11/C				
	00J04	M	629-42698	11/D				
Doka	00J05	M	629-42699	11/E				
Pleasant	00J06	M	629-42700	11/G				
	00J07	M	629-23591	11/H				
76	00J08	F	629-23592	11/K				
	00J09	F	629-23593	11/M				
Suicide	00J10	M	629-23594	11/N				
	00J11	M	629-23595	11/P				
	00J12	F	629-23596	11/R				

Appendix C. Continued.

Natal Area	Bird Number	Sex	USFWS Band	VID Symbol (Blue Color)	Breeding Area	First Year Breeding	Age of Death	Comments
2000 continued.								
Horseshoe	00J13	F	629-23597	11/S				
	00J14	F	629-23598	11/T				
Redmond	00J15	F	629-23599	11/U				
Luna	00J16	F	629-23600	12/Z			0	
	00J17	M	629-29451	12/Y			0	
	00J18	M	629-29452	12/X				
Tower	00J19	M	629-29453	12/W				
	00J20	M	629-29454	12/V				
Sheep	00J21	M	629-29455	12/U			0	
Alamo	00J22	F	629-29456	12/T			0	
Pinal	00J23	M	629-29457	12/S			0	
	00J24	M	629-29458	12/R			0	
2001								
Fort McDowell	01J01	M	629-29459	12/A				
	01J02	M	629-69460	12/B				
Box Bar	01J03	F	629-29136	12/C				
	01J04	F	629-29137	12/D				
Tonto	01J05	M	629-29138	12/E				
Pinto	01J06	M	629-29139	12/G				
	01J07	F	629-29140	12/H				
Pleasant	01J08	M	629-29141	12/K				
	01J09	M	629-29142	12/M				
Talkalai	01J10	F	629-29143	12/N				
Tower	01J11	M	629-29144	12/P			0	
Horseshoe	01J12	M	629-29145	13/A				
	01J13	F	629-29146	13/B				
Suicide	01J14	F	629-29147	13/C				
	01J15	M	629-29148	13/D				
Orme	01J16	M	629-29149	13/E				
76	01J17	M	629-29150	13/H				
	01J18	M	629-44001	13/K				
Ladders	01J19	M	629-44002	13/M				
	01J20	M	629-44003	13/N				
Redmond	01J21	M	629-44004	13/P				
Lone Pine	01J22	M	629-44005	13/R				
2002								
Sycamore	02J01	F	629-44006	13/S			0	
Fort McDowell	02J03	M	629-44007	13/U				
	02J04	M	629-44008	13/V				
Box Bar	02J05	F	629-44009	13/W				
Tonto	02J07	M	629-44010	13/X				
	02J08	M	629-45351	13/Y				
Alamo	02J09	F	629-45352	13/Z				
Pleasant	02J10	F	629-45353	14/A				
Orme	02J11	F	629-45354	14/B				
	02J12	F	629-45355	14/C			0	
Rodeo	02J13	F	629-45356	14/D				
Talkalai	02J14	M	629-45357	14/E				
	02J15	M	629-45358	14/H				
Sheep	02J16	M	629-45359	14/K				
	02J17	F	629-45360	14/M				
Tower	02J18	F	629-45361	14/N				
	02J19	M	629-45362	14/P				
Needle Rock	02J20	F	629-45363	14/R			0	
Luna	02J21	F	629-45364	14/S				
	02J22	F	629-45365	14/U				
Ladders	02J23	M	629-45366	14/V				
	02J24	M	629-45365	14/W				
Granite Reef	02J25	F	629-45368	14/X				
	02J26	F	629-45369	14/Y				
Horseshoe	02J27	F	629-45370	14/Z			0	
	02J28	F	629-45371	15/A				
Pinal	02J29	M	629-45301	15/B				

Appendix C. Continued.

Natal Area	Bird Number	Sex	USFWS Band	VID Symbol (Blue Color)	Breeding Area	First Year Breeding	Age of Death	Comments
2002 continued.								
Coolidge	02J30	M	629-45302	15/C			0	
	02J31	F	629-45303	15/D			0	
2003								
Sycamore	03J01	M	629-45305	15/E				
	03J02	F	629-45306	15/H				
Needle Rock	03J03	F	629-45307	15/K				
Box Bar	03J04	F	629-45308	15/M				
Suicide	03J05	M	629-45309	15/N				
	03J06	M	629-45310	15/P				
	03J07	M	629-45311	15/R				
Luna	03J08	M	629-45312	15/S				
Pleasant	03J09	F	629-45313	15/U				
Tower	03J10	M	629-45314	15/V				
	03J11	F	629-45315	15/W			0	
Orme	03J12	M	629-45316	15/X				
Bartlett	03J13	M	629-45317	15/Y				
Horseshoe	03J14	F	629-45318	15/Z				
Ladders	03J15	M	629-45319	17/A				
	03J16	M	629-45321	17/B				
Coolidge	03J17	M	629-45320	16/A			0	
	03J18	M	629-45322	16/B				

APPENDIX D: REVIEWERS COMMENTS AND RESPONSES

We solicited comments from a diverse group of reviewers. As appropriate, we connected comments from the same and different reviewers when we judged that the comments reflected the same theme. Consistent themes were related to understanding the difference between using breeder counts or population models to describe trends, and using the most recent assumptions of a closed population *versus* assuming the population is open.

Comments from: Wade Eakle, U.S. Army Corps of Engineers. **Referring to section**: Throughout. **Issues**: Our analysis uses data collected since 1987. However, the same protocol was used for productivity monitoring since 1983. Eakle would like us to include these earlier data and to attribute protocol development under Teryl Grubb. **Department Response**: We agree that earlier information should be included in our report, at least as background and for comparison. Our Tables 4, 5, and 16 now include these data, and when appropriate we note how the earlier work by Dr. Grubb, Dr. Robert Ohmart, and their colleagues were related to the current study. However, our individual identifications of birds date from VID banding that started in 1987. This is the period for which survivorship could be estimated, and we chose to use productivity data for the same period. The Discussion does compare our productivity and survivorship estimates with those from other regions and from other time periods in Arizona.

Comment from: Martin Taylor, Center for Biological Diversity, and Todd Katzner, Hawk Mountain Sanctuary Association. **Referring to section**: Throughout. **Issue**: Dr. Taylor asked us to include estimates for time to extinction and for extinction risk as part of a PVA. Dr. Katzner noted that we should address the distinction between ‘population viability analysis’ and ‘demographic analysis.’ **Department Response**: Our goals are to develop a model for population dynamics as a platform to discuss the current status, and to illustrate how different management options may affect this status. Population projections are notoriously unreliable, and due to sample size, projections for bald eagles in Arizona will be particularly uncertain. We are actively managing bald eagles in Arizona, and our data were collected over a period during which habitat quality and quantity, as well as human interaction with bald eagles, have changed dramatically. We therefore do not assume our data can or should be used to accurately project the future fate of bald eagles. On the other hand, replacement rate is certainly an indirect measure of status. The status is in question if replacement rates are below 1. We have clarified these goals in the Introduction, included a brief discussion of the possible uses and limitations of different analyses, removed reference to completing a PVA, and refer to this analysis instead as a demographic analysis.

Comment from: Martin Taylor, Center for Biological Diversity. **Referring to sections**: Table 2 and Appendix B. **Issues**: Some comments requested that symbols and notation be better explained. Dr. Taylor also requested more information to clarify whether we know a site was unoccupied or may have gone undetected. He also requested information on annual breeding information for each BA so that spatial patterns can be assessed. **Department Response**: We tightened up notation in both tables. We have tried to sort through the evidence for whether each BA was pioneered or newly detected when first located. However, these questions cannot be answered with certainty. Table 2 was modified considerably to include breeding status and productivity information; however, we did not attempt a spatial analysis at this time. The bald eagle in Arizona is an excellent candidate for this type of careful analysis, which can identify patterns occurring at scales larger than the individual BA.

Comment from: Marco Restani, St. Cloud University. **Referring to section**: Methods. **Issue**: Include more detail such as: When were monthly ORA flights initiated? How many BAs were checked each year? How and why were individual BAs selected? Did surveys occur away from typical bald eagle nesting habitat (rivers, lakes, ponds)? How were BAs for nest watches selected? How many nest watches per year? **Department Response**: We made considerable changes to address the specific questions that were raised. Our hope is that we made this technical report more readable for researchers familiar with bald eagle monitoring in other regions.

Comment from: Marco Restani, St. Cloud University. **Referring to section**: Methods. **Issue**: More detail on sexing of nestlings is warranted because of the nestling sex-bias reported. If there is emigration, it is expected to be female-biased; if errors in sexing are primarily in reporting females as males, the two issues could cover errors so that 1 in 44 error rate is misleading. **Department Response**: We added sections to Methods, Results, Discussion, and drafted Table 1 to discuss sex determination and sex ratios. We specifically address how tarsus measurements were applied to classify nestlings as males or females, how behavioral observations of banded adults were used to test the accuracy of nestling sex determination, the estimated sex ratios from counts of banded adults and nestlings, and the possible impact of sex ratio bias on dynamics.

Comments from: Marco Restani, St. Cloud University. **Referring to section**: Methods, Demographic modeling, Survivorship and resighting estimation, Results, Other elements describing reproductive biology, Breeding tenure and pair bonds, and Discussion, Additional inputs to model population dynamics, Sex ratios and age at first reproduction. **Related issues**: If a sex ratio bias exists, it is not necessarily true that males suffer higher mortality. Instead, there could be more male floaters, or [more] female dispersal. Our Discussion should cover how potential female-biased dispersal (known in bald eagles) might affect survivorship estimates, the closed assumption, and discussion of age at first breeding. What sex were the known immigrant and emigrant? Was there a female bias in the 83 unbanded breeders? If females are the limiting sex, we expect females to begin breeding earlier than males. Finally, biased nestling sex ratio does not necessarily present an “additional obstacle” to bald eagle recovery. **Department Response**: To address evidence for female-biased dispersal, we have added Figure 9 and tests of differences between the sexes in distance from natal to first breeding area. Although females travel farther than males, this difference is not qualitatively the same as that implied by complete dispersal from the breeding segment to a different one. The known immigrant is a male, while the known emigrant is a female. We have also added Figure 10 to illustrate the relative proportions of banded fledglings, males and females. As our results indicate, there is no evidence of lower survivorship or later breeding in males, and breeding tenure for males and females is equal. We have added material to the Discussion to summarize these points more clearly. At this time, we do not have a satisfactory understanding of how female-biased sex-ratio works through the dynamics in Arizona, and our studies are not targeted at this question. Instead, as information accrues, weak differences we see in sex-specific survivorship, age-at-first-reproduction, or dispersal may become more convincing.

Comment From: Henry Messing, U.S. Bureau of Reclamation, and Daniel Driscoll, American Eagle Research Institute. **Referring to Section**: Executive Summary; Methods, Demographic Modeling; Results, Estimates of λ and elasticity analysis; and Discussion, Understanding different population growth rate estimates. **Issue**: The population cannot be declining if it is known to be increasing. The text makes it sound as if the Arizona population is not increasing.

With the increasing number of pioneered and the reoccupancy of historical BAs, the population must be increasing in Arizona. Is something wrong with the model, the data, or the assumptions for the model? **Department Response**: To list a few possibilities, the discrepancy between the demographic λ and count-based estimates might reflect incorrect assumptions about newly discovered BAs (and resulting inaccuracy in counts), idiosyncrasies of our data, survivorship estimates that are low, emigration, shifting age at first reproduction as the population expands, and/or recruitment of breeders from unmarked populations.

Comment from: Martin Taylor, Center for Biological Diversity. **Referring to section**: Results, Inputs for simulation models, Survivorship estimates from Program MARK and literature. **Issues**: Dr. Taylor requested that we state clearly how many observations were used for the mark-resight analysis, and whether environmental stochasticity is included in the error estimates. The reported standard errors seem quite small. **Department Response**: As reported in the current Table 3, there were 314 banded fledglings in this study. Of these, 49 survived to breed in Arizona. Thus, our estimate of the proportion surviving to breed in Arizona is based on 314 eagles and is pretty precise. Survivorship to older ages is based on a smaller number of birds (49 or fewer as death reduces this sample each year) until 8 years of age and older, when we used an additional 30 birds in our sample. These were banded birds that were unidentified and/or carried only a USFWS band from the period before 1987. This explains our relatively small standard errors, which include demographic error only.

Comment from: Marco Restani, St. Cloud University. **Referring to section**: Results, Estimates of λ and elasticity analysis, and Discussion, Understanding different population growth rate estimates, Is the Arizona population closed? **Issue**: There are only weak data supporting the idea that the population is closed, so how do we justify use of closed population models? How can a closed population be decreasing given the information on increasing counts of breeders in Table 4? If we hold that this is a closed population, the model is performing pretty poorly. This may be related to the apparent lack of fit of the model for estimating survivorship. **Department Response**: See response to H. Messing above.

Comment From: Marco Restani, St. Cloud University. **Referring to Section**: Discussion, Gaps in our understanding of Arizona bald eagles. **Issue**: Work on this species in Arizona has occurred for decades. Why can’t this technical report “assess the availability of breeding habitat?” **Department Response**: In short, the assessment of available breeding habitat is not the subject of this report. Such an assessment would have to consider, especially in Arizona: 1) the health of the riparian forest, 2) perennial and intermittent waters, and stream flow, 3) the abundance, distribution, and diversity of prey species, 4) an assessment of human activity, and 5) the abundance and distribution of available nesting substrate. This is in addition to the vital growth rates of the species reported in this document. It has been our experience over time, and as stated in this report, that much of this information has not been collected and these factors are constantly changing. Past experts believed that the abundance of bald eagles were at carrying capacity in the early 1990s, and that most of the suitable habitat had been surveyed. However, the abundance of bald eagles in Arizona continues to grow and we have documented 19 more BAs since that time. It is therefore clear that we do not have a current understanding of all of the factors that make one habitat suitable over another, and especially in areas where these factors change over time.

Comment From: Gary White, Colorado State University, and Daniel Driscoll, American Eagle Research Institute. **Referring to Sections**: Discussion, Gaps in our understanding of Arizona bald eagles. **Issue**: Our report underestimates the 0-4 survival rate. Our estimate of apparent survivorship to age 4 assumes that birds that did not return also did not emigrate. Dr. White wonders if a few emigrants and/or few immigrants might reconcile population dynamics models with the counts of adult breeders. "In the northern spotted owl work, we used radio telemetry data to estimate the emigration rate, and correct the estimates." **Department Response**: We have added language in the report to refer to survivorship to age 4 as "apparent." Also, we continue to mention the previously unexpected possibility of emigration and/or immigration. The Leslie matrix models do account for possible juvenile emigration (included in apparent survivorship) but not for possible adult immigration. Thus, the replacement rate will be biased down. According to our calculations, the number of immigrants would have to increase each year in order to have λ greater than one. A constant number of immigrants (whether 2 or 10 females) would lead to a replacement rate of approximately 1. We do not pursue specific calculations in our analysis, because it is not clear what the exact scenario of increasing immigration would be. We note that our closed models can be interpreted as a measure (without bias) of the extent to which processes currently operating allow the bald eagle in Arizona to maintain itself. We also call for telemetry work on fledglings.

Comment From: Gary White, Colorado State University. **Referring to Sections**: **Issue**: "Immigration of adults is not incorporated into the Leslie matrix, whereas emigration of juveniles is incorporated into the Leslie matrix. …in my mind, the Pradel models have replaced the Leslie matrix approach as a way to estimate lambda for a population… The drawback is that you must band unmarked birds as soon as you detect them…" **Department Response**: It is not even remotely possible for us to band all detected adult bald eagles. We do not band adults unless they are injured or otherwise captured for other purposes. Instead, we comment on the possibility that adult immigration could affect our estimates of lambda. We note that our closed models can be interpreted as a measure of the extent to which processes currently operating allow the bald eagle in Arizona to maintain itself.

Comment from: Henry Messing, U.S. Bureau of Reclamation, and Daniel Driscoll, American Eagle Research Institute. **Referring to section**: Executive Summary; Discussion, Comparisons of life history parameters to other studies, Reproductive rates; and Recommendations. **Issue**: Discuss the impacts of density dependence on productivity. When a population increases towards carrying capacity, breeder interference is expected to reduce productivity. Also, could it be that productivity is reduced by new pairs breeding in marginal habitat? **Department Response**: Several authors have developed the concept that recovering species may initially be governed by density-independent growth, but if they are territorial, habitat availability will eventually become limiting. In species for which reproduction can be deferred, the consequence might be that in an area with a fixed number of BAs, there could nonetheless be more and more adult eagles competing for food and perhaps engaged in more frequent and intense competition for BAs. Some pairs may be using sub-optimal habitat. This more competitive situation might decrease productivity and adult survivorship. Decreasing productivity and survivorship can be predicted under scenarios that have very different conservation implications. On the one hand, declines in productivity and/or survivorship may signal increased or additional threats. On the other hand, the same signals may represent a thriving population that has increased to the point where density-dependence is affecting regulation. As a management agency, we need to distinguish been the two alternatives. It would be irresponsible to observe decreasing productivity and/or survivorship and unquestioningly attribute these to a population experiencing the consequences of reaching carrying capacity. We have added text to our report noting these issues.

Comment from: Henry Messing, U.S. Bureau of Reclamation, Daniel Driscoll, American Eagle Research Institute, and Robert Steidl, University of Arizona. **Referring to section**: Introduction. **Issue**: Since there is essentially no information on numbers or even presence of bald eagles before dam building was initiated, no trend could be documented for Arizona bald eagles, and speculating on possible causes of a decline is not possible. Effects of introduction of non-native fishes on bald eagles have not been documented, while Hunt et al. (1992) report that reservoirs are good foraging habitat for eagles. **Department Response**: We agree that there are no quantitative data to begin to describe any trends prior to the 1970s. We reworded the Introduction to reflect this.

Comment from: Henry Messing, U.S. Bureau of Reclamation, Robert Steidl, University of Arizona, and Marco Restani, Saint Cloud State University. **Referring to section**: Introduction; and Discussion, Gaps in our understanding of bald eagles in Arizona. **Issue**: This section discusses relative effectiveness of management at the nest or to reduce adult mortality, so it is relevant to list the sources of bald eagle nest failure and post-fledging mortality. What is the evidence that nest success and survivorship are declining due to harassment and killing? **Department Response**: We did not quantify specific mortality factors due to a small number of recoveries (mortalities) during the study period. We mention causes of mortality that should be addressed to help increase λ in the elasticities analysis (Table 15), but we do not weigh the effect each mortality factor has on λ in the age classes. The reference to nest success and survivorship declining due to harassment and killing simply cites threats mentioned in other reports such as Hunt et al. (1992). We assume the threats have remained the same, although no specific analysis has been conducted since Hunt et al. (1992). The importance of these factors on growth should be examined in future analyses.

Comment from: Martin Taylor, Center for Biological Diversity. **Referring to section**: Introduction. **Issue**: "[AGFD] … refuses to do any extinction time analysis..." **Department Response**: Although risk assessment is appropriate for management of any species, especially endangered or threatened ones, we are not alone in thinking that mean time to predicted extinction is poor form of risk assessment (Ludwig 1996a, Beissinger and Westphal 1998, Morris and Doak 2002). Dr. Taylor cites Brook et al. (2002) as arguing in favor of predicting extinction risk, but the use of PVA they described is more sophisticated than a single number from a demographic projection. At this stage of development, our goal was to publish demographic information as a framework before proceeding with other elements of a population viability analysis. Our report includes the first capture-recapture survivorship and deferred-breeding estimates, and brings up the issue of assessing the level of possible genetic exchange. We consider this an ambitious but not final assessment of the bald eagle in Arizona. We provide a basic demographic analysis as a way to compare count- and population-dynamics-based models of growth. We do not conceal any information, nor do we provide a final and hasty risk assessment. We do call for appropriate follow-ups to this report, and these should include description of spatial and temporal variability, plus assessment of density-dependent effects.

Comment From: Martin Taylor, Center for Biological Diversity. **Referring to Section**: Introduction. **Issue**: "Only deterministic lambdas are calculated and these estimates are buried away on page 30 and not even cited in the executive summary. Why is [AGFD] trying to hide the basic message that comes out of the data presented in the draft that [desert-nesting bald eagles] face extinction in the near term unless the life history threats currently allowed to continue are alleviated?…Your reliance on deterministic lambda values is dishonest as it fails to present an informative picture of the life history data including uncertainty and stochasticity." **Department Response**: Stochastic factors are known to have important effects on population dynamics, so that even populations with lambdas averaging greater than 1 can go extinct. However, deterministic lambdas are not dishonest, and certainly reflect underlying, *deterministic* factors that affect population growth year-to-year ('threats'). In this report, where we focus on sensitivities and on comparing the effects of various unknowns, such as sex ratio bias and age at first reproduction, deterministic lambdas and relative changes in lambda *are* appropriate. Environmental variability must also be examined and we propose that this more complex task be addressed as soon as possible. The Executive Summary does report discrepancies between count-based and population dynamics-based estimates of lambda, and reports the range of population gain/loss projected for different models. In addition, we have added language to highlight the fact that environmental variability added to persistent factors will only reduce projected population growth.

Comment from: Robert Steidl, University of Arizona. **Referring to section**: Methods, Data collection, Banding and resighting. **Issue**: Our rules for using incomplete information to assign identities to some banded birds resulted in resighting histories of "111" instead of "101," for instance. Is this interpretation correct and was it necessary? **Department Response**: Bald eagles are often incompletely identified when using spotting scopes compared to trapping and handling. However, this has become the most efficient method to assign identities. Therefore, this section lays out our rules for circumstances under which we felt comfortable assigning identities. We had two sets of rules. The first set of rules makes use of the known biology of bald eagles (they tend to defend the same BA each year) and only uses information from the identity of birds seen the previous and subsequent year at the BA. The second set of rules applies to bald eagles that were on a BA but for which we had no banding information. In this case, if an identified bird had been seen in the previous and subsequent year, but there was a failed breeding attempt in the intervening year and the banding status of the bald eagle could not be ascertained, we would nonetheless convert the "101" history to "111." This allowed us to remove most of the *detection* error from our estimates of resighting rates. This means that age-specific resighting probability reflects the probability that these birds have begun breeding, and should approach 1 in older birds.

Comment From: Henry Messing, U.S. Bureau of Reclamation, and Daniel Driscoll, American Eagle Research Institute. **Referring to Section**: Methods, Demographic modeling, Survivorship and resighting estimation. **Issue**: How do you account for the Pinto female and Pinal male relationship when you refer to bald eagles as a monogamous species? **Department Response**: The Pinal male defended the Pinal BA but also mated with the Pinto female during the late 1980s, and more recently the Orme male also mated with the Rodeo female in the early 2000s. Note that genetic analysis might reveal more instances of extra-pair mating. In the last few decades, it has become clear that the majority of avian species do not have a single mating tactic (monogamy or polygyny, for instance), but many species can be characterized by a more complex mating strategy that explains how specific situations may lead individual birds to employ less typical mating tactics. Our only point in mentioning the mating strategy at all was to explain our assumptions for counting breeding adults and for attributing incomplete band identifications. The mating strategy of bald eagles means that we assume no more than two adults per occupied breeding area, but a BA can also be defended by a single adult (male or female), so we only counted two adults if presence of both could be confirmed.

Comment From: Henry Messing, U.S. Bureau of Reclamation, and Wade Eakle, U.S. Army Corps of Engineers. **Referring to Section**: Methods, Demographic modeling, Survivorship and resighting estimation; and Results, Comparison of life history parameters to other studies, Survivorship. **Issue**: On one hand you state that emigration is included and then state that the population is closed. Also, do environmental quality of our riparian areas and vital rates of the bird mesh to make this a regional population with potential for growth? **Department Response**: Both emigration and mortality cause losses, so when we measure losses, since we consider emigration equal to 0, we attribute all losses to mortality. Thus, emigration is not 'included,' but it is accounted for as if the bird had died. Naturally, if it is reasonable, we could attempt to attribute some of these losses to emigration. It is rare for biologists to have even a comfortable guess at the level of emigration and/or immigration characterizing a population of interest. If compelled to guess based on banding information, we could come up with rates close to zero. Instead, we considered the population 'closed,' which is equivalent to modeling an 'open' population with immigration rate = 0 and emigration rate = 0. Prior to and separate from our study, the bald eagle in Arizona had been described as a closed one, so we provide a simple review of information that led to that conclusion, and we note that modeling as closed gives us information about how well bald eagles would do at replacing themselves *if this were closed*. As managers, this question is of immediate interest to us. Obviously, environmental quality is reflected in the birth and death rates we estimate, and we recommend new focus on the environmental factors that influence these birth and death rates.

Comment from: Daniel Driscoll, American Eagle Research Institute. **Referring to section**: Methods, Demographic modeling, Survivorship and resighting estimation; and Results, Inputs for simulation models, Survivorship estimates from Program MARK and literature. **Issue**: While mentioning immigration and emigration from the Arizona population, you failed to mention the 1988 Cliff nestling found during the breeding season at El Novillo Reservoir, Sonora, Mexico, or the blue banded individual currently(?) breeding at Lake Hemet in California (near Temecula). **Department Response**: We do not count these birds as emigrants since 1) there was no evidence the 1988 Cliff nestling was breeding, although we are aware that there are breeding areas around the reservoir, and 2) the blue-banded individual breeding at Lake Hemet has not been identified, not even to state-of-origin.

Comment from: Daniel Driscoll, American Eagle Research Institute and Martin Taylor, Center for Biological Diversity. **Referring to section**: Methods, Demographic modeling, Estimating the number of non-breeders. **Issue**: There is bias in estimates of the non-breeding adult population size due to lack of resighting effort outside BAs. Mr. Driscoll asked how we accounted for fatalities of nonbreeders (without band recovery). **Department Response**: Jolly-Seber analysis of survivorship is based on resighting (not band recovery) and estimates the probability that a bird that has not been resighted is actually dead. Since there were so few recoveries (known fatalities) of breeders, we did not use recovery information in our estimates. Thus, even our mortality estimates for breeders are based on sightings, not on band recoveries. We assumed that non-breeders have the same mortality rate as same-aged breeders. We have no information on whether non-breeders might have higher or lower survivorship than breeders, so this is a reasonable assumption at this time. We suspect that the bias would be more severe if we used models that assumed there were no floaters.

Comment From: Martin Taylor, Center for Biological Diversity. **Referring to Section**: Methods, Tables 2. **Issue**: Dr. Taylor asks for clarification of symbols and blank spaces. **Department Response**: Symbol blank spaces are not defined in the legend for Table 2.

Comment from: Daniel Driscoll, American Eagle Research Institute. **Referring to section**: Results, Inputs for simulation models, Survivorship estimates from Program MARK and literature. **Issue**: Hunt et al. (1992) found survivorship of transmittered juveniles to be 50%, which was equal to Florida and similar to Alaska (61%). Our survivorship estimates may be low at 27.9%. **Department Response**: We estimated survivorship from the 49 of 314 nestling-banded bald eagles that returned to breed in Arizona during the study period. We explain that survivorship may be higher if bald eagles from Arizona are breeding undetected, since we modeled the population as closed. However, in the absence of telemetry data, we must rely on band resighting for our estimates. If survivorship to age 4 was actually 50% but we only observed 28% returning, then 44% of those surviving to age 4 must have emigrated or deferred breeding beyond age 5. Note that survivorship of 50-61% is quite high and not the norm in other studies to date (Table 10).

Comment From: Martin Taylor, Center for Biological Diversity. **Referring to Section**: Results, Table 8. **Issue**: Dr. Taylor points out that the table includes mixed types of survivorship estimates, some annual, some for a 4-year period. He requests annual estimates for the first 4 years, plus their standard errors. **Department Response**: Note that Table 8 reflects our set up for Program MARK. We explain in the text how we forced an estimate of 100% survivorship to age 4, the first year at which we expected eagles to return to breed. This is equivalent to setting the first three annual survivorship estimates equal to 1. The actual percentage that survives to age 4 and is resighted represents the compound survivorship over those four years, times the proportion that did not emigrate (which we assumed to be 100%). To clarify our presentation, we have added rows to Table 8 to accommodate annual survivorships only, but we cannot provide confidence intervals (or, equivalently, standard errors) because there is no annual estimation error when survivorship for the first three age classes is fixed at 100%. Tables 10 through 12 report annualized survivorship that we used in our models.

Comment from: Wade Eakle, U.S. Army Corps of Engineers. **Referring to section**: Results, Inputs for simulation models, Age at first reproduction; and Discussion, Comparisons of life history parameters to other studies, Reproductive rates. **Issue**: "I suspect there might be correlation between productivity and lead agency management activities in those years. It may be worthwhile to investigate what differences, if any, in management activities took place and still exist…One possible explanation might be the ORA flights themselves. With as many [as] 6 ORA flights taking place during the breeding season, this management activity itself, and the disturbance caused by helicopter overflights to breeding eagles, could partially explain the productivity decline." **Department Response**: We explain that our survey methods and management actions differ from normal and that our lower productivity may reflect the different protocols. We consider our breeding segment as not experiencing a decline in productivity, but that our lower estimates reflect more accurate measurements than the rest of the studies on bald eagles due to our monthly monitoring, the influence of the ABENWP, and our rescue attempts.

Comment from: Martin Taylor, Center for Biological Diversity. **Referring to section**: Results, Inputs for simulation models, Survivorship estimates from Program MARK and literature. **Issue**: "…you refer to a 'decreasing time trend' does this mean you found a negative time trend in survivorship? Why isn't this crucial information reported in the Executive summary? Please disclose the fitted parameters and standard errors for these models." **Department Response**: Our top two models for estimating survivorship did not include any time trend, so we chose to model survivorship as time-invariant. However, the increases in QAICs are very small (less than two units) for the next two models, which estimated a decreasing trend in survivorship since 1987. Combined with the parameter-specific weights given in Table 7, this means that models incorporating a time trend for survivorship were not the most favorable but were also reasonable, and should not be discounted. Because trends are necessarily easier to detect as time passes, we mentioned that addition of more years of data might strengthen those models that include time trends. On the other hand, if the trends reflected a true pattern, then time is a costly commodity. Evidence of decreasing survivorship (increasing mortality) can be obtained other ways and will be given more attention after this analysis. We note that the trend was most pronounced for the oldest age class of eagles, which may mean that it is an artifact of our inability due to sample size to estimate annual survivorship separately for older age classes. That is, as time goes on, banded eagles in the oldest age class (all those over age 7) were also aging, until the banded population was in stable age distribution. Because we started identifying cohorts in 1987, the first known-aged eagles joined the oldest age class in 1995. Each year since then, the oldest possible known-aged eagles in the class have been a year older. So if there is an age at which survivorship decreases instead of increasing linearly (which seems reasonable), then we would have expected average survivorship for that oldest age class to decrease before the stable age structure was achieved. This capture-resight analysis will not be able to distinguish a true trend from such an artifactual result. The effect of time trend on survivorship, averaged over all models and weighted as indicated in Table 7, would estimate that survivorship for 5 year olds decreased 0.5% between 1987 and 2002, while survivorship for the oldest age class dropped 2.6% (from 0.921 to 0.895) over the same interval.

Comment From: Daniel Driscoll, American Eagle Research Institute. **Referring to Section**: Results, Other elements describing reproductive biology, Dispersal distances from natal area to breeding area. **Issue**: The distance data is biased by the fact that you are only looking at BAs within Arizona. **Department Response**: For the 53 banded bald eagles where we could identify natal areas, our results are accurate. However, we do recognize that there may be Arizona birds breeding in other unmonitored regions that would increase dispersal distance. In the absence of additional information, we can only report on existing data.

Comment from: Martin Taylor, Center for Biological Diversity. **Referring to section**: Results, Estimates of λ and elasticity analysis. **Issue**: Dr. Taylor states that when he uses our data in a VORTEX analysis to include stochastic and demographic analysis, "proportion breeding had moderate leverage, and juvenile mortality had the greatest." He notes that this does not match our elasticity values showing survivorship of adults and then of pre-reproductives had the greatest elasticity. **Department Response**: Our elasticity analysis calculated elasticities for matrix elements only, and we now clarify this in the text. Although it is possible to calculate elasticities for specific vital rates, we did not do so. Our fertilities are linear functions of age-specific reproductive rates (proportion breeding) and of productivity rates. Further, from our correspondence with Dr. Taylor, we have not yet clarified what 'leverage' calculates or how he used VORTEX to do this.

Comment from: Daniel Driscoll, American Eagle Research Institute. **Referring to section**: Discussion, Comparison of life history parameters to other studies, Reproductive rates. **Issue**: How you define a breeding area is biased. **Department Response**: We have attempted to maintain strict use of the definitions set forth in Postupalsky, and Steenhof and Kochert. However, our methods for monitoring BAs and occupancy (helicopter flights) would limit our time in these areas. We therefore used and defined operational terms (Appendix A) that would explain how we reached a conclusion on the status of a BA. We simply did not have the time or funds to spend at each of the 47 breeding areas to determine: 1) if the pair was there although it was not observed on our ORA flights, or 2) if the bald eagles that were observed were actually mated and not wintering birds. Due to these limitations, we felt a conservative approach towards designating a breeding area was warranted by waiting until breeding activity was confirmed.

Comment from: Daniel Driscoll, American Eagle Research Institute. **Referring to section**: Discussion, Understanding different population growth rate estimates, Undetected population segments described in the analysis. **Issue**: At this point, most of the floaters should also be banded if they were Arizona nestlings. **Department Response**: We expect the level of banded floaters and breeders to level off at some point in time to the banding rate (80%) assuming a closed population and equal survivorship for banded and unbanded bald eagles. Figure 10 shows that those rates have not yet converged.

Comment from: Daniel Driscoll, American Eagle Research Institute. **Referring to section**: Discussion, Understanding different population growth rate estimates, Undetected population segments described in the analysis. **Issue**: The report mentions future plans to develop a model examining the effects on nest success of disturbance, nest substrate, and aquatic habitat. Grubb's reports cover in detail the disturbance data, and Hunt et al. (1992) contained comparisons of nest substrate, and aquatic habitat. **Department Response**: The earlier analyses were completed on data collected from the 1980s. Any analysis in the future would not be an original attempt, but an effort to use the most extensive and recent information available to incorporate into this analysis.

Comment from: Daniel Driscoll, American Eagle Research Institute. **Referring to section**: Recommendations. **Issue**: To focus your banding and resighting information on the Bill Williams River and on the BAs in the east-central mountains would be in error. The only case of immigration, with a possible second into Mexico, came from the Verde River. **Department Response**: We recognize that the effort to band and resight must continue in all BAs to capture the incidental cases of longer dispersal and to refine our estimates. We specifically mention these outlying BAs only because their proximity to other breeding segments mean they are most likely to either contribute to, or receive breeders from those segments.

Comment from: Daniel Driscoll, American Eagle Research Institute. **Referring to section**: Recommendations. **Issue**: The statement that the Arizona population is not increasing at the same rate as occupancy due in part to the occurrence of inbreeding activity may not be accurate. For example, Florida bald eagles are the most inbred population of bald eagles in North America growing from 15 nests in the late 1960s to over 1,500. **Department Response**: The Florida population is not strictly comparable to Arizona because unlike Florida, Arizona is geographically isolated from other breeding centers. Our resighting data from the last 16 years has only shown one case of emigration and one of immigration in over 70% of the population that was banded and identified. We therefore recommend that a detailed analysis examine whether genetic effects might limit reproduction and occupancy.