Environmental Assessment

Issuance of a Bald and Golden Eagle Protection Act Permit to Take Golden Eagles by the Hopi Tribe for Native American Religious Purposes

U.S. Fish & Wildlife Service April 9, 2013

Summary

- For centuries, the Hopi Tribe of northeastern Arizona has been collecting nestling golden eagles for religious purposes from their lands and parts of nearby Navajo Nation lands.
- The U.S. Fish and Wildlife Service has annually issued a permit to the Hopi Tribe for this activity during 1986-2012; take of up to 40 nestling golden eagles annually was authorized from 1997 to 2012.
- This Environmental Assessment examines potential impacts to the human environment that could result from issuing this permit to the Hopi Tribe in 2013.
- To support this Environmental Assessment, the Southwest Region of the U.S. Fish and Wildlife Service, in partnership with the Hopi Tribe and Navajo Nation, conducted a technical assessment in 2012 of the Hopi Tribe's collection of nestling golden eagles.
- Results of the technical assessment suggested the Hopi Tribe's collection of nestling golden eagles is sustainable at three large geographic scales but not at two small scales (< 30,000 square miles).
- This Environmental Assessment considers eight alternatives, five of which are not carried forward for complete analysis.
- Any alternative that reduces authorized take may negatively affect the Hopi Tribe's culture and religion.
- Any alternative that results in take at current (1997-2012) levels on the part of Navajo Nation lands where the Hopi Tribe collects nestling golden eagles may negatively affect Navajo culture and religion and add to factors limiting the health of the golden eagle population on Navajo Nation lands.
- The Preferred Alternative calls for take of nestling golden eagles that is sustainable on the Hopi Tribe's lands at a large geographic scale and on part of the Navajo Nation lands at a smaller area scale, embracing both Tribes' views on managing golden eagles on their respective lands. This alternative would result in a psermit authorizing take of 40 nestling golden eagles in 2013, but would limit take from Navajo Nation lands to five golden eagles.

Table of Contents

Chapter 1: Purpose and Need for the Action 1
Introduction 1
Background 1
Purpose for the Action 2
Need for the Action 2
Decision to be Made 2
Consultation and Coordination 2
Chapter 2: Description of Proposed Alternatives 3
Alternatives Considered But Dismissed From Further Consideration 3
Alternatives Considered in This EA 4
Alternative A – No Action Alternative: Authorize Take of 40 Nestling Golden Eagles in 2013 . 4
Alternative B – Authorize Take of 40 Nestling Golden Eagles in 2013, Based on the Service's Two Standard Spatial Scales for Analyzing Population-level Effects of Eagle Take Permits..... 4
Alternative C – Authorize Take of 40 Nestling Golden Eagles in 2013, but limit the take on Navajo Lands to Five 5
Chapter 3. Affected Environment 5
Physical and Biological Environment 6
Status and Management of GE Populations in the Western United States 7
Cultural and Socioeconomic Issues 9
Chapter 4. Environmental Consequences 12
Consequences of Alternative A – No Action Alternative: Authorize Take of 40 Nestling Golden Eagles in 2013 13
Consequences of Alternative B: Authorize Take of 40 Nestling Golden Eagles in 2013 13
Potential Effects to GEs 13
Potential Effects on Cultures of the Hopi and Navajo 14
Consequences of Alternative C – Authorize Take of 40 Nestling GEs in 2013, but limit the take on Navajo Lands to Five 15
Potential Effects on GEs 15
Potential Effects on Cultures of the Hopi and Navajo 15
Cumulative Effects 17
Chapter 5. Conclusion 18
Chapter 6. List of Preparers 18
Chapter 7. List of Agencies and Individuals Contacted 19
References 20
Appendix A. ASSESSMENT OF THE HARVEST OF GOLDEN EAGLES ON LANDS OF THE HOPI TRIBE AND NAVAJO NATION, Final Report 11 February 2013 22

Appendix B. Supplement to "ASSESSMENT OF THE HARVEST OF GOLDEN EAGLES ON LANDS OF THE HOPI TRIBE AND NAVAJO NATION, Final Report 11 February 2013" by the Assessment Technical Team. 23

Appendix C. Technical background for Alternative C, "Authorize Take of 40 Nestling Golden Eagles in 2013, but limit the take on Navajo Lands to Five" 29

Appendix C continued: Code from R statistical software for update of the analysis used to assess golden eagle harvest by the Hopi Tribe (Appendix A, "ASSESSMENT OF THE HARVEST OF GOLDEN EAGLES ON LANDS OF THE HOPI TRIBE AND NAVAJO NATION, Final Report 11 February 2013"), following minor revisions to input values described in Appendix B. 31

Appendix D. Projected average annual take of nestling golden eagles from the collection area by the Hopi if take of golden eagle nestlings on the Navajo portion of collection area is reduced to five. Actual take data are from unpublished files of the U.S. Fish and Wildlife Service's Southwest Region; data were not available for 1998, 2000, 2001, and 2003. 44

Appendix E. Definitions of Terms and Acronyms Used in this Document 45

Tables

Table 1. Summary of Environmental Consequences by Alternative 16

Figures

Figure 1 Geographical areas at which effects of the Hopi's collection (take) of nestling golden eagles were evaluated in the Technical Assessment. 11

Chapter 1: Purpose and Need for the Action

Introduction

This Environmental Assessment (EA) has been created by the U.S. Fish and Wildlife Service (USFWS) to assess issuing a permit to the Hopi Tribe (Hopi) to collect (i.e., harvest, or "take") golden eagle (GE) nestlings for religious purposes. The collection will occur at traditional sacred sites in northeastern Arizona on Hopi lands and a portion of adjoining lands of the Navajo Nation (Navajo). This permit is allowed under the Bald and Golden Eagle Protection Act (16 U.S.C. 668 *et seq.* - Eagle Act) and the USFWS's eagle permit regulations (50 C.F.R. 22.22).

This EA will help the USFWS comply with the National Environmental Policy Act of 1969 (NEPA; 42 U.S.C. 4321 *et seq.*) and identify potential "significant" impacts that could result from any of the alternatives considered. The NEPA requires the USFWS to consider short- and long-term direct and indirect effects and their intensity, to determine whether those effects are positive or negative, and to consider any potential cumulative effects.

This EA considers all reasonable alternatives, including a No Action alternative defined in this context of issuing an annual permit as following the same path used previously (in other words, nothing new). Any EA results in either a "Finding of No Significant Impact" (FONSI) or concludes that the action will have a significant impact on the human environmental impacts are of such significance in which case an Environmental Impact Statement (EIS) must be completed.

Background

For Native Americans, permits to take eagles from the wild are limited to tribes that can show a traditional religious need that the USFWS's National Eagle Repository cannot meet. The primary example of this is the Hopi, who have collected nestling GEs from specific nest sites for their religious ceremonies for centuries. Historically authorized take of GEs, including the Hopi's, was examined in the USFWS's 2009 Final Environmental Assessment (FEA) of a proposal to permit take as provided under the Eagle Protection Act (hereafter referred to as 2009 FEA; USFWS 2009b). The USFWS considered this take part of a the biological baseline in the 20009 FEA, above which regional take "thresholds" for GEs are established to ensure USFWS does not authorize take that is not compatible with the preservation of eagles, as the Eagle Act requires.

Annually since 1986, the USFWS's Southwest Region (Southwest Region) has issued a permit to the Hopi for take of nestling GEs. The allowed level of take has ranged from a low of 12 to an unlimited number. Since 1997 the permit has authorized the Hopi to take 40 nestling GEs, although annual reports from the Hopi indicate annual take during 1997-2012 averaged 23 nestlings.

In 2012, the Southwest Region evaluated the population biology and "harvest management" of GEs on lands of the Hopi and Navajo. By 2012, enough data had been collected by the tribes and the USFWS to support a more specific analysis of the Hopi's take of nestling GEs on

sustainability of the GE population at multiple spatial (geographic) scales than had been done previously. A team that included eagle experts from the USFWS and both tribes completed the work as a comprehensive technical assessment (TA; Appendix A). Information from the TA and related supplements in appendices of this document supported this EA.

Relying on the TA, the Southwest Region developed three alternatives for issuing a permit to the Hopi in 2013. Alternatives B and C each considered multiple scales. Scales include: (1) Bird Conservation Region 16 (BCR 16), the Southern Rockies – Colorado Plateau Region; (2) the Hopi and Navajo lands "local area population" (LAP), which includes GEs on and within 140 miles of this area; 3) the area where the Hopi have collected nestling GEs in recent years (collection area, or CA) and a subset of this, the portion of the CA that is on Navajo lands (Navajo CA).

Purpose for the Action

The action is issuance of a permit authorizing the Hopi to take a certain number of nestling GEs for use in the tribe's religious ceremonies in 2013. The Southwest Region's Division of Migratory Birds has received an application for such a permit from the Hopi on November 7, 2012.

Need for the Action

The Hopi require this permit to legally take nestling GEs for religious purposes under federal law. Before issuing a permit of this kind, the USFWS must evaluate to ensure that any authorized take will be compatible with the preservation of the GE as required by the Eagle Act. The USFWS has further refined this standard to require that any authorized take will not impair the maintenance of stable or increasing breeding populations of GEs. Analysis of GE populations in the 2009 FEA focused on regional populations, but the agency may consider other factors that could warrant protection of smaller and/or isolated populations within a region. Cultural and religious needs and practices of Native Americans are an example of such factors.

Decision to be Made

The Southwest Region's Regional Director (RD) has the authority to issue permits for take of eagles resulting in mortality in the USFWS's Southwest Region. The RD must decide whether issuing a permit to the Hopi for take of nestling GEs at whatever level specified is compatible with the species' preservation. If the take is deemed compatible, the Southwest Region will issue a permit authorizing the take.

Consultation and Coordination

During at least the past eight years, staff of the USFWS have met with representatives of several tribes (Hopi, Navajo, Pueblo of Jemez, and Jicarilla Apache Tribe), the National Park Service, and the Arizona Game and Fish Department to discuss take of nestling GEs by the Hopi. In 2006, a technical team composed of GE experts from the Hopi, Navajo, and USFWS formed to make recommendations and design a study of GEs as part of an "Intergovernmental Compact" between the Hopi and Navajo (Compact; The Navajo Nation and the Hopi Tribe 2006). Since

then, a team of similar makeup has convened on several occasions to discuss information needed for management of GEs on and around Hopi-Navajo lands and to further develop eagle research proposals. In 2012, a team composed of experts from the USFWS, Hopi, and Navajo completed a TA on sustainability of the Hopi's take of nestling GEs. The Description of Proposed Alternatives in this EA (Chapter 2) includes or considers many of the technical team's conclusions and recommendations.

In February 2013, the Southwest Region provided preliminary draft alternatives on a permit for take of nestling GEs by the Hopi to the Hopi, Navajo, Pueblo of Jemez, Jicarilla Apache Tribe, and 25 other tribes to solicit their input for further development and refinement of the proposed alternatives. The Southwest Region then met to consult on the preliminary alternatives with the Navajo (March 21), Hopi (March 28), and Jemez (March 29).

Chapter 2: Description of Proposed Alternatives

Alternatives Considered But Dismissed From Further Consideration

Listed below are alternatives considered but dismissed from further consideration. They either do not meet the Hopi's needs, conflict with the USFWS Native American Policy, or are otherwise unreasonable.

(1) Do not issue a permit – Under this alternative no permit would be issued to the Hopi because any harvest is unsustainable. However, results of the TA indicate some level of harvest is compatible with maintenance of a stable population of GEs. A complete halt to the Hopi's collection is not warranted and would be unacceptable to the Hopi for religious and cultural reasons.

(2) Reduce take to some level, but allow the Hopi to implement alternate harvest strategies. These strategies would offset decreased productivity attributed to collection. One goal of the TA was to identify other methods that would increase productivity and at least partially compensate for nestlings removed. Methods proposed included: (a) removing only one nestling from nests with more than one nestling; (b) replacing collected nestlings with nestlings of similar age produced in captivity; and (c) removing first clutches of eggs shortly after laying, so they could be artificially hatched and used to produce nestlings in captivity; in addition this would promote breeding pairs to lay second clutches of eggs that ultimately produced nestlings for use by the Hopi; and (d) do not collect some nestlings during years of high productivity, which also is when survival of fledglings is likely greater. Although some of these methods were considered technically feasible, none were culturally acceptable to the Hopi.

(3) Issue a permit with no restriction on the numbers s of GEs that the Hopi are authorized to collect. The Final Rule (Federal Register Part II. Friday, September 11, 2009) states that the ". . . permit authorizes the take of bald eagles and golden eagles where the take is compatible with the preservation of the bald eagle and the golden eagle." Issuance of a permit without an upper limit on numbers of GEs to be taken would prevent the USFWS from determining whether ". . . the take is compatible with the preservation of the . . . golden eagle."

(4) Issue a permit with reduced take, but allow the Hopi the chance to conduct offsetting mitigation for any take that exceeds what has been determined to be sustainable. Under this alternative, the Hopi could undertake mitigation to offset losses of eagles. This alternative is similar to the permit process that currently required for wind energy companies. Examples of offsetting mitigation include power pole retrofits to prevent electrocution or replacing lead ammunition for hunting with non-toxic ammunition to reduce lead poisoning of eagles. Although this might be a feasible alternative in the future, the USFWS has not yet developed policy and procedures to implement compensatory mitigation in this manner. Therefore, this alternative is not carried forward for further analysis at this time.

(5) Offset take by the Hopi by increasing the USFWS's efforts to reduce deaths of GEs from other sources like shooting, poisoning, collision with wind turbines, or electrocution by power lines. Under this alternative, the USFWS could also increase its efforts to improve productivity of GEs by reducing disturbance near nest sites. The USFWS also would work to improve and preserve nesting habitat. However, opportunities for these actions are relatively limited. Most responsibility for actions to reduce mortality would fall upon the USFWS Office of Law Enforcement, requiring additional personnel conducting investigations and other enforcement activities. This alternative was deemed not feasible because the USFWS already is engaged in these initiatives to its fullest capacity and is not likely to get additional personnel and funding. In addition, because actions of this sort are national in scale, it is beyond the scope of this EA to analyze them.

Alternatives Considered in This EA

Alternative A – No Action Alternative: Authorize Take of 40 Nestling Golden Eagles in 2013

Under the No Action Alternative the USFWS would issue the Hopi a permit in 2013 to take 40 nestling GEs as has been done since 1997. In its 2009 FEA (USFWS 2009), the USFWS evaluated likely effects of the Hopi's collections (based on an average of 23 collected annually, 2002-2007) on GEs at the scale of BCR 16. The USFWS concluded the Hopi's collections were sustainable at that scale. An annual late summer survey of GE numbers in BCR 16 (Nielson et al. 2012) continues to show no statistically significant population decline when GEs of all ages are combined in the analysis. Thus, there has been no substantial change in the status of GEs in BCR 16 since collection by the Hopi was analyzed in USFWS's 2009 FEA (USFWS 2009b).

NOTE: The following two alternatives draw on results from the TA and the Appendix C addendum to the TA.

Alternative B – Authorize Take of 40 Nestling Golden Eagles in 2013, Based on the Service's Two Standard Spatial Scales for Analyzing Population-level Effects of Eagle Take Permits

The 2009 FEA indicated that population-level effects of permits for take of eagles are to be evaluated at two scales. The first is the BCR scale. In the 2009 FEA, USFWS evaluated likely effects of the Hopi's collections (based on an average of 23 collected annually, 2002-2007) on GEs at the scale of BCR 16, an area totaling 199,417 square miles. USFWS concluded the

Hopi's collections were sustainable at that scale. An annual late-summer survey of GE numbers in BCR 16 (Nielson et al. 2012) continues to convey no statistically significant population decline when GEs of all ages are combined in the analysis. This suggests there has been no substantial change in the status of GEs in BCR 16 since collection by the Hopi was analyzed in the 2009 FEA. Additionally, results of modeling in the TA suggested GEs currently can maintain a stable population at the BCR 16 scale despite annual collection of nestling GEs by the Hopi.

The USFWS's second scale for evaluating effects of permits for take of eagles is the LAP scale. The Hopi-Navajo LAP, covering 218,933 square miles, encompasses the most likely source area of GEs that may immigrate to the CA to offset take of GEs attributed to the collection. Analysis at this scale is particularly sensitive to the estimated median natal dispersal distance, which, in 2009, was 140 miles for GEs (USFWS 2009b). Based on productivity data gathered on the CA during 1996-2012, results of the TA suggested GEs can maintain a stable population at the Hopi-Navajo LAP scale despite annual collection of nestling GEs by the Hopi

Alternative C – Authorize Take of 40 Nestling Golden Eagles in 2013, but limit the take on Navajo Lands to Five

Alternative C is the preferred Alternative.

In 2006, the Hopi and Navajo co-signed an Intergovernmental Compact that called for "…maintaining the stability of the golden eagle population on Navajo and Hopi lands as a whole" (Compact section 5.5). The Navajo interpret this as management for a population that is healthy enough to be self-sustaining, that productivity and survival of GEs, on Navajo lands at least, should be high enough that immigration from surrounding landscapes is not needed to keep the population on Navajo lands stable. The Hopi, in contrast, believe the Compact's intended management goal for GEs is to maintain stability of the species' population on Hopi-Navajo lands with whatever level of immigration from surrounding landscapes may be needed and can be sustained. Immigration may be needed to offset some mortality, which includes the tribe's take of GE nestlings for religious purposes. Under Alternative C of this EA, perspectives of both the Hopi and Navajo are embraced; GEs would be managed on the tribes' respective portions of the CA according to the management scheme that best represents their particular cultural and religious beliefs and interpretations of the Compact's intent.

The technical underpinnings of this alternative are found in Appendix C.

Chapter 3. Affected Environment

The action area for this permit to take nestling GEs for religious purposes is the area where the Hopi collect nestling GEs. Throughout this document the area is referred to as the CA. This includes tribal lands of the Hopi and roughly the western one-third to one-half of tribal lands of the Navajo. Collections have also occurred on State of Arizona land and one National Monument and one National park. All of these are in northeastern Arizona. The CA is in the southwestern part of BCR 16, the Southern Rockies/Colorado Plateau. BCRs, developed by the

North American Bird Conservation Initiative (2012), are ecologically distinct regions in North America, each with its own general types of landforms, plant and animal communities, and natural resource management issues. BCRs are used by the USFWS as primary units for managing GE populations.

This EA is focused only on issuing a permit to the Hopi for take of nestling GEs. This action has no effects to land use, visual resources, air quality, noise, geology and soils, water resources, human health and safety, socioeconomics, and infrastructure, so the USFWS is neither describing those parts of the affected environment nor analyzing effects to them.

Physical and Biological Environment

The CA and other lands of the Hopi and Navajo chiefly are semi-arid to arid, level to rolling high plains (elevation roughly 6,000 feet) interspersed with extensive sandstone mesas, plateaus, ridges, canyons, and outcrops; clay buttes; mountains rising to 3000 feet above surrounding plains; and intermittent drainages. Plant cover on the plains generally is sparse, consisting chiefly of perennial grasses and forbs (e.g., Indian ricegrass [*Oryzopsis hymenoides*], blue grama [*Bouteloua gracilis*], broom snakeweed [*Gutierrezia sarothrae*); and 1- to 3-foot tall shrubs (saltbush [*Atriplex* spp.], greasewood [*Sarcobatus vermiculatus*], rabbitbrush [*Ericameria nauseosa*]). Slopes at bases of cliffs and lower mountain slopes often have sparse to relatively dense juniper (*Juniperus* spp.) and pinyon pine (*Pinus edulis*) tree cover. Intermittent drainages, known locally either as washes (broad, flat) or arroyos (narrow, steep-walled), are widely scattered, some including cottonwood trees (*Populus* spp.) or salt cedar (*Tamarix ramosissima*). Average annual precipitation across Hopi-Navajo lands is about 10 inches but varies considerably among years. Evaporation rates can be extremely high during summer.

Breeding pairs of GEs in northeastern Arizona construct bulky stick nests mainly on ledges of upper faces of 80- to 500-foot tall cliffs of mesas and sandstone outcrops. Pairs often have more than one nest within their breeding areas and may alternate among nests during multiple breeding seasons. Eggs are laid mainly during mid-February through mid-March (based on New Mexico data; Stahlecker et al. 2010). Most eggs hatch by mid-April and the young eagles fledge from their nests mainly during June. Based on recent satellite telemetry research, juvenile GEs in northeastern Arizona and northwestern New Mexico generally remain within 1-12 miles of their nests for 2-7 months after fledging (R. Murphy, USFWS-Southwest Region, unpublished data).

Black-tailed jackrabbits (*Lepus californicus*) and cottontail rabbits (*Sylvilagus* spp.) appear to be primary prey of GEs in northeastern Arizona and northwestern New Mexico (Stahlecker et al. 2009). The annual population level of both prey species, especially that of the hare, fluctuates dramatically in the region as is typical elsewhere in the western United States (Kochert et al. 2002). These fluctuations in abundance may or may not have clear, direct ties to patterns of precipitation and plant production (Lightfoot et al. 2011). In the western states, breeding pairs of GEs generally continue to occupy their territories in years when hares and rabbits are scarce, but under such conditions some or most pairs may not lay eggs and relatively few produce fledged young (Kochert et al. 2002). Gunnison's prairie dogs (*Cynomys gunnisoni*) or common ravens (*Corvus corax*; typically juveniles), the next most frequently observed prey at GE nests in the region (Stahlecker et al. 2009), can be important alternate prey locally when hares and rabbits are scarce.

Fundamental aspects of the demography of GEs breeding on Hopi-Navajo lands are well documented and are summarized in the TA (Appendix A). Compared to GEs breeding elsewhere in western North America (Kochert et al. 2002), overall breeding density is relatively moderate (roughly 1 breeding area per 200 square miles). Overall productivity on Hopi-Navajo lands (annual average, 0.34 young fledged per occupied breeding area (OBA; Appendix B) is less than average and below the estimated level needed to sustain the local population if no GEs were to immigrate to the Hopi-Navajo lands from surrounding areas (0.55 young fledged per OBA; Appendix A). An estimated 78% of non-adult GEs originating from northeastern Arizona, northwestern New Mexico, and southwestern Colorado survive annually, which is a moderate level; adult survival is undocumented in the southwestern United States but is assumed to be about 90% (Appendix A).

Status and Management of GE Populations in the Western United States

Before 2003, size of the GE population in any major region of North America was unmeasured as was the change in size of any of the populations over time (also known as "trend). In 2003, the USFWS contracted with Western EcoSystems Technology, Inc. to design and conduct an aerial survey for GEs across four major BCRs in the western United States. This "Westwide Survey" has been conducted with a consistent approach in late summer annually during 2006-2012. Primary goals of the survey are to estimate total population size and determine population trends of GEs within the entire four-BCR area and within each BCR (Good et al. 2007). About 11,000 miles of transects are flown annually in the four-BCR area, which is thought to encompass roughly 80% of the GE breeding population in the western United States (2009 FEA [USFWS 2009b]): BCR 9 (Great Basin), BCR 10 (Northern Rockies), BCR 16, and BCR 17 (Badlands and Prairies). The Westwide Survey was designed to detect as little as a 3% change in population size during periods of 20 or more years.

The GE population size in the four-BCR area during late summer is estimated to be about 22,000-25,000 total individuals (based on averages from 2006-2012; Nielson et al. 2012). The estimated population density of GEs (average number per square mile) ranges from 0.002 to 0.003 in BCRs 9 and 16 to 0.008 in BCR 17 (calculated from Table 4 in Nielson et al. 2012). To date, there has been no statistically significant evidence of change in population size of GEs in any of the four BCRs or in the entire four-BCR area. There has, however, been a statistically significant decline in the number of GEs classified as juveniles (young-of-the-year) in BCRs 10 and 16 (Nielson et al. 2012). Reasons for the decline in numbers of juveniles in BCR 10 are unclear, but the decline in BCR 16 likely is related, at least in part, to prolonged, severe drought in the region. Region-wide change in production of juvenile GEs during multi-year periods appears to be typical of the species in much of the western United States (Kochert et al. 2002).

Other assessments of GE population size and trend have been conducted locally in several areas of the western United States (Kochert et al. 2002), but none of these have occurred within or adjacent to BCR 16. Counts of GEs at migration points or at Christmas Bird Counts may provide some long-term trend information (Farmer et al. 2008), but geographic origin of individual eagles tallied in these surveys generally is unknown. Population trends of resident GEs may be suggested by the North American Breeding Bird Survey (Sauer et al. 2012), but to

date there have been too few observations of GEs on this survey to reliably indicate patterns in trend (Farmer et al. 2008).

Management of eagles by the USFWS differs somewhat from that of other species of birds designated by the agency as "migratory birds" (USFWS 2010) in that eagles have additional protections and are subject to special authorizations under the Bald and Golden Eagle Protection Act. "Take" (see definitions) of eagles can be authorized by the USFWS, so long as the take is compatible with the preservation standard for the species, which the USFWS has further defined as to "…maintain stable or increasing breeding populations." The USFWS uses BCRs as management units for GEs (2009 FEA [USFWS 2009b]). Based on results of the Westwide Survey, total additional annual take that currently could be authorized by permit for GEs in any BCR is zero. This conservative level is based on initial analyses at the time of the 2009 FEA, which suggested negative population growth rates for the species (USFWS 2009b). If an updated analysis indicates increased population growth in a given BCR, the information may support a decision to permit take of a number of GEs in the BCR equal to 1% of the estimated annual production of juveniles. Meanwhile, take of GEs authorized under a permit issued by the USFWS may be possible if such take is entirely offset by some action that precludes the loss of an equal or greater number of eagles elsewhere, or that somehow increases the carrying capacity of the species' habitat and the production of eagles (USFWS 2009a,b).

Although uncompensated take of GEs currently cannot be authorized, the USFWS made clear in the preamble summary of its 2009 FEA (USFWS 2009b) that it "…will continue to issue historically authorized take permits under existing permit types at the level of take carried out under those permits (average over 2002-2007)." The USFWS continues to maintain historically-authorized take under existing permit types at the level of take carried out under the historical permits (average over 2002-2007) and within eagle management units in which the given historical take occurred. Together with unauthorized (illegal) historical take, the historically-authorized take would be considered part of a "baseline" level. Thus, the baseline of authorized and unauthorized historical take could include each form of take of eagles by Native Americans for religious purposes. The USFWS indicated that authorized take would continue unless substantial declines in GE populations indicated such authorizations should be reevaluated and possibly reduced. Reductions in the number of GEs available for take by permit from the USFWS to Native Americans for religious purposes should only be considered after much effort has been made to reduce other forms of take.

Major forms of take that could contribute to declines in GE populations in the western United States are reviewed in the 2009 FEA (USFWS 2009b). In the southwestern United States, most, if not all, of these factors likely decrease GE productivity and survival or limit the species' local distribution. These forms of take include mainly:

- electrocution on electrical distribution lines
- direct persecution or permanent removal of key prey species such as prairie dogs (*Cynomys spp.*).
- lead poisoning, mainly due to ingesting fragments of lead ammunition from carcasses
- lethal and sub-lethal effects of other environmental contaminants

- impacts associated with increasing energy development, such as collision with wind turbines
- intentional and unintentional poisoning
- collisions with vehicles and aircraft
- shooting
- disturbance to nests and breeding adults, by recreational rock climbers or off-road vehicles, for example (can interrupt feedings or trigger abandonment of nests by adults)
- removal or destruction of nests or eggs

A major form of indirect take of GEs in the western United States is decreased quantity and quality of habitat, resulting in decreased availability of prey. Examples include fragmentation due to energy development such as oil and gas extraction, conversion to agriculture or urban land use, and replacement of native grass-shrub habitat by cheatgrass (*Bromus tectorum*; Kochert et al. 2002). In the long term, climate change may be the most important factor negatively affecting GE populations (USFWS 2009b).

Cultural and Socioeconomic Issues

(Following are descriptions of the importance of GEs to the religion and culture of the Hopi and the Navajo. Most information stems from many personal communications with individuals from the respective tribes or with non-tribal persons who work for the tribes. Other information is from references cited, as indicated)

The GE is central to the Hopi's religion. Importance of eagles in the Hopi's religious ceremonial history is better known and documented than for any other Native American tribe. Records of eagle keeping by the Hopi date to the mid-1500s (Palmer 1988, p. 223) but the practice reaches back to time immemorial. Collection, or "gathering," of young GEs from sacred nest sites is the most important ceremonial obligation of certain clans and religious societies of the Hopi; each has its own traditional gathering area. Eagles symbolize spirits of the Hopi's ancestors. Clan ancestors used gathering areas at or near settlement sites and migration routes. The ceremonial practice of eagle gathering is a complex and privileged undertaking. Hopi religious practitioners pray and make offerings before their pilgrimage to the sacred nest sites. Once reaching the eagle gathering area, offerings are made at an eagle shrine. If a nestling or nearly fledged eagle is found in a nest, it is taken back to the Hopi villages. The eagle is then treated like a newborn infant in a Hopi family; it is washed, given a Hopi name, and tethered on a practitioner's rooftop. There, it is regularly fed fresh rabbits and other animals and presented with gifts.

After the eagle has fully matured, it is sent to its spiritual home during the homecoming immediately after the Katsina [Kachina] Home dance. The feathers are distributed among clan members and subsequently are used in Hopi religious ceremonies and rituals. For the Hopi, the eagle connects the spiritual and physical worlds. The annual gathering is considered a way of sustaining this connection.

The eagle is of great significance to the Navajo people, as part of their religious history and as medicine in Navajo religious ceremonies. Among these ceremonies is the Bead Way Chant, in which the Navajo express disagreement with take of GEs by the Hopi and seek to stop such take.

The Navajo believe the eagle was a child of a winged monster that lived on Shiprock Peak, presumably the 1,500-foot tall volcano core in what today is in far northwestern New Mexico, on Navajo lands (Linford 2000). One of the monster's ancestors is believed to be a Navajo woman, representing a direct link between the Navajo and eagle. The eagle's feathers were to be used by the Navajo to protect themselves from harm and as sacred adornments in ceremonies. There is oral history of limited take of eagles in the past by Navajo medicine people, as part of the Eagle Way ceremony. To obtain feathers for religious ceremony, Navajo medicine people would sing (chant) an adult eagle down and capture it. They would then take the feathers they needed and release the bird back into the wild. Today, the Navajo use eagle feathers for religious and medicinal purposes. The tribe is developing a facility to house permanently injured, non-releasable eagles from which shed feathers will be gathered for distribution to the tribe.

Navajo families with personal religious offering places and areas of religious ceremonial gatherings have expressed concern that eagles have disappeared in many traditional nesting places in western parts of Navajo Nation. To the Navajo, the sacred eagle embodies the religious character of the landscape and is a focus of religious life of the Navajo people who live in these areas.

Both the Hopi and the Navajo manage habitat and restrict human activities on their respective lands to improve the productivity and survival of GEs. The Hopi carefully manage livestock grazing on a broad scale to improve and maintain habitat conditions for populations of the eagle's prey. The Navajo monitor power lines for electrocutions (or potential for electrocutions) of eagles and other birds of prey and actively seek to resolve such mortality by changing equipment on power poles to safer designs. The Navajo also restrict construction activities near GE nest sites and sometimes reintroduce Gunnison's prairie dogs to areas where they disappeared. In addition, restrictions on construction activities and placement of structures near eagle nest sites are part of the Compact's focus (The Navajo Nation and the Hopi Tribe 2006).

The USFWS restricts permits to take eagles from the wild to tribes that can demonstrate a traditional religious need to take live, wild eagles for which the USFWS's National Eagle Repository does not provide an adequate substitute. The Hopi's take of nestling GEs is considered by the USFWS to be a clear example of this (although the USFWS has not yet formally developed criteria for authorizing take of eagles from the wild by Native Americans). Each year since 1986, the USFWS has issued a permit to the Hopi authorizing their take of nestling GEs for religious purposes. The maximum number of nestling GEs allowed to be taken annually under the permit has been either 18 (1986-1989), 12 (1990-1993), "unlimited" (1994-1996), or 40 (1997-2012). Annual take of GEs reported by the Hopi under this permit has ranged from two to 38 nestlings and averaged 23 during 2002-2007 (U.S. Fish and Wildlife Service 2009b). The number of GEs taken in a given year ultimately is determined by production of nestlings at the sacred nest sites. A subset of these nests is on Hopi ancestral lands that today are part of the Navajo Nation. Collection of nestling GEs by the Hopi from this area of Navajo lands has been a point of contention between the two tribes, mainly due to the Navajo's concerns and uncertainties regarding impacts on the GE population.

In 2006, the Hopi and the Navajo signed an Intergovernmental Compact that detailed conditions for the Hopi's collection of GEs on Navajo lands and outlined sideboards for related dealings

among the Hopi, the Navajo, and the USFWS (The Navajo Nation and the Hopi Tribe 2006). The United States Department of the Interior acknowledged the Compact via signature but did not sign the document as a contractual party. The Compact called for collection to be done in a way consistent with maintaining "the stability of the golden eagle population on Navajo and Hopi lands as a whole" (Intergovernmental Compact, Article 5, Section 5.5). Exhibit E of the Compact is a detailed plan of a study designed to gauge "…the management goal of maintaining a viable population of golden eagles. In the Compact, the tribes requested that the USFWS regulate take of GEs in the collection area at sustainable levels (The Navajo Nation and the Hopi Tribe 2006). However, the Compact's intended meaning of (population) stability or viability is unclear. One interpretation of the Compact's intent might be that the GE population occupying

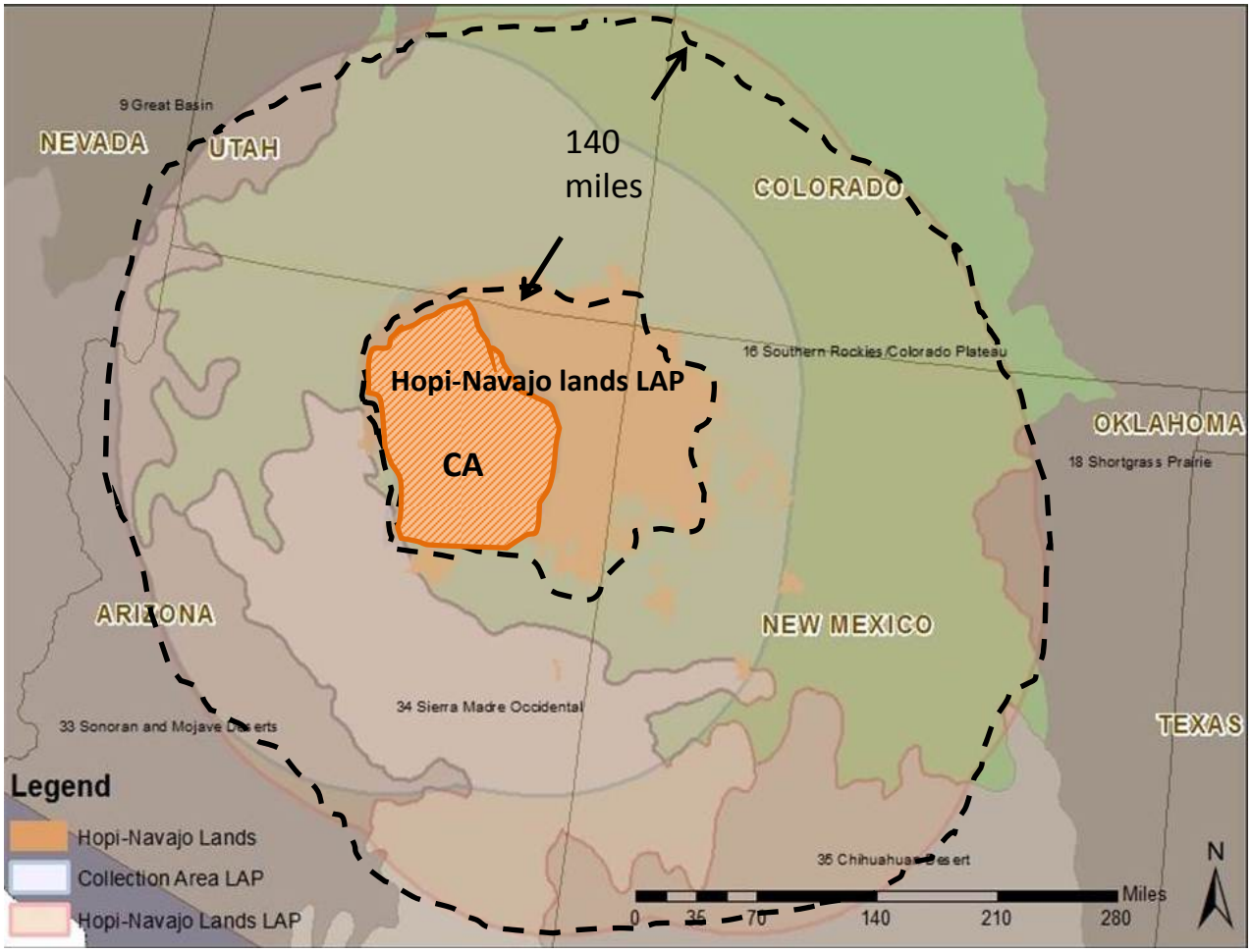

Figure 1 Geographical areas at which effects of the Hopi's collection (take) of nestling golden eagles were evaluated in the Technical Assessment (modified from Figure 1 in Appendix A). This Environmental Assessment (EA) considers three of these spatial scales plus a modification of one of the scales: (1) Bird Conservation Region 16, the Southern Rockies/Colorado Plateau (green area; extends north beyond figure), which is the U.S. Fish and Wildlife Service's golden eagle management unit that includes lands of the Hopi Tribe and Navajo Nation; (2) the area on and within 140 miles of the Hopi-Navajo lands, collectively called the Hopi-Navajo lands local area population ("Hopi-Navajo Lands LAP," bounded by outermost dashed line)); (3) the collection area, somewhere within the western one-half of the Hopi-Navajo lands (orange gridded area within Hopi-Navajo lands LAP). The boundary or boundaries of the latter is sensitive information not disclosed by the tribes and thus is crudely approximated here. The boundary or boundaries of the part of the collection area that is on Navajo lands, another area of focus in this EA, also is not disclosed by the tribes.

Hopi-Navajo lands must be self-sustaining. In other words, the Hopi-Navajo population should produce enough juvenile GEs annually, on average, to offset natural mortality and thus provide for a stable population without need for immigration by GEs from surrounding areas (a narrower interpretation might consider eagles occurring in the collection area as the intended reference population). This interpretation is biologically flawed because the GE is a highly mobile species that, in western North America, typically breeds more than 100 miles from where it was raised (USFWS 2009b); there is no evidence or scientific basis as to why GEs on Hopi-Navajo lands would be an exception. However, the Navajo's general interpretation of the Compact's intent is that the GE population on Hopi-Navajo lands should be healthy enough that it does not have to rely on immigration from surrounding areas. Putting this in terms used by population biologists, the Hopi-Navajo lands should not act as a "sink" (Pulliam 1988) and draw from surrounding populations of GEs to maintain its population of the species. Although the Navajo acknowledge that the population of GEs on either the CA or the Hopi-Navajo lands is unlikely closed to exchange of individuals with surrounding areas, they assert that the GE population, at least that occupying Navajo lands, should be healthy enough that it can sustain itself without immigration, as if it were a closed population. This interpretation is consistent with the Navajo's cultural and religious beliefs outlined above. A contrasting interpretation might be that mechanisms for maintaining stability or viability of the GE population occupying Hopi-Navajo lands (or, again, the GE population occupying the Hopi's CA) could include immigration of eagles from surrounding areas. The Hopi generally assert this biologically valid notion as the Compact's intended use of the term stability, although extent of the area from which GEs would immigrate to Hopi-Navajo lands is neither indicated nor implied in the Compact. The two widely divergent interpretations of the Compact's wording have considerable implications for the USFWS's decision on permit issuance, although either could potentially lead to reduced take of nestling GEs for the Hopi. Regardless, the Tribes also requested through the Compact that the USFWS determine what sources of take have the greatest impact on the affected GE population, and to consider this when making management decisions with regard to the Compact.

Finally, under the *Eagle Permits; Take Necessary To Protect Interests in Particular Localities; Final Rules* (Final Rule, USFWS 2009a), there are two critical and potentially diverging federal interests: 1) a trust responsibility to provide for the religious needs of federally recognized tribes, per the American Indian Religious Freedom Act, and 2) the preservation standard for eagles. Take of nestling GEs by the Hopi is, in part, regulated under the Final Rule, but also is informed by the Compact, which carries its own obligations on the Hopi and Navajo. , and the cultural and religious interests of both Tribes.

Chapter 4. Environmental Consequences

This chapter describes the likely effects of the alternatives presented in Chapter 2. Each is discussed with respect to two factors: (1) specific impacts to GEs, and (2) impacts on the Hopi and Navajo. The chapter also describes the range or types of effects the alternatives might have. Effects can be positive or negative; major or minor; and short- or long-term. This FEA evaluates direct, indirect and cumulative effects.

Direct effects are those caused by the action at the same time and place. Indirect effects are caused by the action but are later in time or farther removed in distance, and are reasonably

likely to happen. Cumulative effects are those that result from this action added to the effects of other past, present, and likely future actions. They include actions by other agencies (Federal or non-Federal) or other people. Cumulative impacts can result from individually minor but collectively significant actions taking place over time. Cumulative effects are discussed in a separate section at the end of this chapter.

Consequences of Alternative A – No Action Alternative: Authorize Take of 40 Nestling Golden Eagles in 2013

Under the No Action Alternative, the permit would be issued in 2013 the same as it was in 2012. Effect of the permit on the GE population would not differ from 2012. Effects to the Hopi and Navajo would also remain the same.

Consequences of Alternative B: Authorize Take of 40 Nestling Golden Eagles in 2013

Potential Effects to GEs

Direct Effects

Under Alternative B, direct and indirect, minor short- and long-term negative effects could occur at the population scale, the most applicable to the preservation standard for the GE. Direct effects include the loss of individual nestlings and effects to adults.

Issuance of this permit will result in minor short-and long-term negative effects to the local population since as many as 40 GE nestlings could be removed. This would result in lowered productivity which likely contributes to a current, significant decline in the number of GEs identified as juveniles in an aerial survey of BCR 16 conducted annually in late summer (Nielson et al. 2012). The decline may also be associated with decreased availability of prey due to an ongoing, severe drought in much of BCR 16. Cycles in availability of prey also effect productivity of GEs.

Collection, or attempts at collection, of nestling GEs by the Hopi could happen too early or too late and lead to the death of individual young birds accidentally. If collected too early, nestlings may die because they cannot regulate their body temperature or they may die from being handled. Nestlings could also be accidentally knocked from a nest during a collection attempt. Some young that can barely fly may leave their nest ledges and fall while trying to avoid capture and could be badly injured or killed by the fall. Rocks dislodged from above nests could strike and injure or kill nestlings. These are among possible impacts of concern when researchers visit nests of eagles and other birds of prey (Grier and Fyfe 1987) and may be relevant here.

Indirect Effects

Minor short- and long-term negative indirect effects could occur to individual eagles, breeding pairs, or breeding areas from issuing this permit.

Human-caused disturbance to breeding pairs of raptors, including GEs, may result in short- to long-term abandonment of breeding areas by individual birds (although such individuals ultimately may breed elsewhere), and in some cases could lead to permanent abandonment of a breeding area (Newton 1979, Watson 1997:232, Harmata 2002). For most species of raptors, this is unlikely when disturbance occurs late in the breeding effort, as it apparently does when the Hopi collect nestling GEs; in general, breeding raptors are most sensitive to human-caused disturbance during early phases of nesting (Newton 1979:140).

Potential disturbances from human activities, such as building of structures, within 0.5 to 1 mile of active GE nests in the CA are prohibited by the Compact unless agreed to by both Tribes in writing (the Navajo Nation and the Hopi Tribe 2006).

Other potential indirect impacts of the Hopi's collection activities on GEs may include disruption of feeding when nests are accessed too early in the nestling stage and the visits are prolonged; nests could be physically damaged when the Hopi access them although GE nests are, by and large, sturdy structures.

Potential Effects on Cultures of the Hopi and Navajo

Direct Effects

Issuance of this permit will have major short- and long-term positive effects to the Hopi. This permit will allow the Hopi to continue a tradition central and essential to their religion and culture. As with most Native Americans, the Hopi view the world in holistic terms in which health and spirituality are intimately linked. To them, spirituality is an important component of life and defines their core values.

Issuance of this permit may have moderate short- and long-term negative effects to the Navajo; some members of this tribe consider the collection as a wrongdoing and an affront to their ancestors and religion. Some Navajo members may be disturbed by the loss of opportunity to see juvenile GEs that fledge from nests locally.

Indirect Effects

Issuance of this permit may have minor-to-moderate short- and long-term negative effects to the Hopi and Navajo. To the Navajo, for example, declining numbers of eagles and the loss of the sacred eagle from traditional eagle territories has an adverse effect on the religious character of the landscape and on the religious life of Navajo people who live in these areas. To the Hopi, many sacred sites on Navajo lands are the Hopi's aboriginal lands, often close to Hopi traditional meeting places of the Hopi that dating back for centuries. Although the Compact provides for access by the Hopi to the Navajo portion of the CA, serious local conflicts can arise between members of the two Tribes over alleged trespass. There is potential for disagreement in recognizing certain eagle nests as sacred sites; these may not always be clearly defined, as GEs often use alternate nests and distances among alternate nest sites varies (Kochert et al. 2002). Ceremonies and rituals of the Hopi that are tied to the collection may be disrupted by these conflicts, inflicting hardship on some Hopi clans. These conflicts over sacred nest sites and

young eagles may perpetuate decades-old disputes between the two Tribes, particularly over land ownership and access (Brugge 1999).

Consequences of Alternative C – Authorize Take of 40 Nestling GEs in 2013, but limit the take on Navajo Lands to Five

Potential Effects on GEs

Direct Effects

Under Alternative C there will be minor long-term positive direct effects to the GE. Under this alternative, fewer GEs will be taken over time, assuming other factors influencing the GE population remain relatively unchanged. Based on total numbers of nestling GEs taken by the Hopi from the CA and the Navajo CA during 12 years between 1997 and 2012 (Appendix D), the Hopi's projected total take on the CA would decrease from an annual average of 22.4 nestlings to 18.6 nestlings, a 17% reduction (Appendix D). More importantly perhaps is that take of nestling GEs on the Navajo CA would decrease by 45%, from an annual average of 8.5 nestlings to 4.7 nestlings. On average, three to four more nestling GEs would fledge annually from the Navajo CA under this alternative.

Indirect Effects

Under Alternative C, there would be minor long-term positive indirect effects to the GE. Increased production of GE fledglings on the Navajo CA would slightly increase the likelihood that GEs produced on Navajo lands ultimately would be "recruited" into the breeding population of GEs on Navajo lands. The magnitude of these effects on the Hopi - Navajo LAP scale or larger scales probably would be inconsequential, however. Additional management would have to be widely implemented on Navajo lands to elevate GE productivity to the stability level of 0.55 fledglings per OBA (and/or to increase survival of GEs).

Disturbance to breeding pairs of GEs and their young in the Navajo CA may be reduced slightly, although the extent and importance of these effects are uncertain (see under Alternative A, above).

Potential Effects on Cultures of the Hopi and Navajo

Direct Effects

Under Alternative C, there would be moderate short- and long-term negative effects to Hopi culture. If the Hopi's average annual take of nestling GEs from the Navajo CA decreased by about four individuals (8.5 to 4.7), about four fewer clans of Hopi would be able to collect GEs at sacred nest sites in the Navajo CA in 2013 (assuming that one GE nestling would have been collected at each of the four nests and productivity is average). This could deny these practitioners a centuries-old religious practice fundamental to their culture and identity for the 2013 collection season. Their renowned Katsina [Kachina] Home dance would be diminished. In general, each clan has a sacred nest site to collect from. Although under this alternative, total take under permit from the USFWS would be 40 nestling GEs, clans denied opportunity to collect at their respective sacred nests may not be able to simply go elsewhere to collect nestling

GEs. Other nests on the CA likely are sacred nests where other clans traditionally collect. Outside the CA there apparently are few other nests from which nestling GEs can be collected (based on the Hopi's reports of ownership of lands where GEs were collected during 12 collection seasons between 1997 and 2012; Southwest Region files), due perhaps to land ownership or religious and cultural legitimacy of the nests. Unless access to collect from sacred nests on the Navajo CA was annually rotated somehow, certain clans of the Hopi could be unduly deprived of an opportunity to collect nestling GEs.

Under Alternative C there would be minor short- and long-term positive and negative effects to the Navajo. The Navajo believe that protection of eagles is a religious calling and may feel reduced take from the Navajo CA honors their ancestral heritage. Reduced take of GEs on the Navajo CA could contribute to an overall management plan to increase productivity and survival of GEs on Navajo lands, working towards the goal of a self-sustaining population.

Any take of GEs on Navajo lands will negatively impact their culture in the short- and long-term. To the Navajo, the sacred eagle embodies the religious character of the landscape and is a focus of religious life of the Navajo people.

Indirect Effects

Same as Alternative B, except that the spectrum of affected clans of Hopi is narrower, limited to those who collect from sacred sites in the Navajo portion of the CA.

Table 1. Summary of Environmental Consequences by Alternative

Alternative	Authorized level of take	Effects on GEs	Effects on Hopi Culture	Effects on Navajo Culture
Alternative A: No Action	40	No effect	No effect	Minor negative effect
Alternative B: two USFWS spatial scales used	40	No effect	No effect	Minor negative effect
Alternative C: scales used to determine take based on respective tribes' perspectives	40; five from Navajo lands	Minor beneficial effect as the GE population has less pressure and may increase slightly	Moderate negative effect	Minor positive and minor negative effect

Cumulative Effects

Cumulative effects are impacts on the environment that result from the incremental impact of the action when added to other past, present, and reasonably-foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions (40 CFR 1508.7). This brief evaluation of cumulative effects focuses primarily on the potential for impacts that will require modification of permit thresholds or conditions. Impacts could either be to eagle populations or societal resources. Cumulative effects on GEs associated with permits issued by the USFWS for take of the eagle were reviewed extensively in the 2009 FEA.

Direct mortality impacts to GEs on and within 140 miles of the Hopi-Navajo lands include mainly electrocution on power lines, collision with wind-turbine blades, lead poisoning, shooting, and vehicle collisions. These and other threats are reviewed briefly in Chapter 2 of this document. The USFWS estimates that more than 800 GEs are killed annually by electrocution on power lines in the western United States. Several hundred miles of old electrical distribution lines posing moderate to high electrocution risk to eagles likely occur on and within 140 miles of Hopi-Navajo lands. At least 21 wind-energy projects, with a collective capacity of more than 2000 megawatts, either occur or are planned for construction in roughly the next 5 years within 140 miles south to west of Hopi-Navajo lands, a trend likely to continue. GEs seem unusually vulnerable to collisions with wind turbines (Pagel et al. 2013). Wind-energy developers can take, under permit from the USFWS, limited numbers of GEs in association with project operations as long as such take is offset by precluding mortality of an equal number of eagles elsewhere. Examples of other forms of energy development with potential negative impacts to GEs include solar photovoltaic projects (loss of foraging habitat) and establishment of 500- to 600-kilovolt transmission lines (habitat fragmentation impact), although GEs may nest on transmission line towers in some areas where lack of nest sites was previously a limiting factor.

Incidence of lead poisoning in eagles is reviewed briefly in the 2009 FEA; population-level impacts of lead poisoning are not well understood. GEs lethally poisoned by lead or having high blood lead levels are sometimes found in the Hopi-Navajo lands area; the lead likely is from bullet fragments in carcasses and viscera of hunter-killed animals especially big game and prairie dogs. Lead poisoning of GEs likely will continue unless aggressive programs to replace lead ammunition with non-toxic ammunition become widespread and effective. GEs in the area also have been killed or debilitated by other poisons such as rodenticides; some such poisonings may be intentional.

The most important negative impact to GEs on and within 140 miles of Hopi-Navajo lands likely is decreasing quantity and quality of habitat, especially when it leads to decreased availability of prey. Underlying causes mainly are (1) long-term, heavy grazing by livestock, causing plant communities dominated by native forbs, grasses, and shrubs to be replaced by those dominated by annual weeds and bare ground, which provide poor habitat for eagle prey species; (2) long-term drought that reduces plant productivity; and (3) interaction between these two factors. Negative impacts of climate change could be more pronounced in the Southwest than in any other region of the contiguous United States (Darmenova et al. 2013). Abundance of prey for GEs in much of the Southwest, including the Hopi-Navajo lands area, likely will decline in

coming decades as temperatures and precipitation levels generally increase and decrease, respectively, reducing forage and cover.

Collective impacts of the above factors may cause the productivity and, ultimately, the abundance of GEs in the Hopi-Navajo lands area to decline. This could directly reduce opportunities for the Hopi to collect nestling GEs from the sacred sites. Although take of GEs from outside the Hopi-Navajo lands but within the LAP area can be permitted by the USFWS, permit applications for such take can only be considered after the need for eagles by Native Americans for religious purposes has been addressed. The number of GEs that may be taken annually under permit from the USFWS typically cannot comprise more than an estimated 5% of the total number of GEs in the LAP encompassing a given action area (for example, for wind-energy facilities). Take of GEs for religious purposes by the Hopi, and perhaps other Native American tribes, will reduce opportunities for permitted take for other purposes within the Hopi-Navajo lands LAP.

Chapter 5. Conclusion

Concerning the application for a permit by the Hopi Tribe to collect nestling golden eagles for use in religious ceremonies in 2013, the Southwest Region of the U.S. Fish and Wildlife Service has selected Alternative C, because it is the best balance of the interests expressed to us through consultation. Under this alternative, the permit will be issued for a take of 40 nestling golden eagles, no more than five of which may come from Navajo Nation lands. The 2012 Technical Assessment and supplements (Appendix B, Appendix C) in the Final Environmental Assessment indicate this level of take is sustainable at the geographic scales specified and is compatible with the U.S. Fish and Wildlife Service's preservation standard for the golden eagle.

Chapter 6. List of Preparers

This Environmental Assessment was prepared by the U.S. Fish and Wildlife Service, Division of Migratory Birds, Southwest Region Headquarters in Albuquerque, New Mexico. Jerry E Thompson (Chief of Permits Division) was the Project Management Technical Editor and author of Chapter 1. Robert K. Murphy, Wildlife Biologist, was primary author of Chapters 3 and 4 plus appendices B through E. Murphy and Thompson were primary authors of Chapter 2. C. Greg Esslinger (Migratory Bird Joint Venture Coordinator), William H. Howe (Non-game Migratory Bird Coordinator), and Greg M. Hughes (Chief, Division of Migratory Birds, Southwest Region) assisted with all chapters and provided critical reviews of the document. Lynn Wellman (Water Quality Specialist, Ecological Services) wrote the first draft of the document.

Brian A. Millsap (National Raptor Coordinator, U.S. Fish and Wildlife Service) conducted the revised modeling analysis that supported Appendix C.

Chapter 7. List of Agencies and Individuals Contacted

Native American Tribes

Havasupai Tribe

Hualapai Indian Tribe

Jicarilla Apache Nation

Kaibab Band of Paiute Indians of the Kaibab Indian Reservation

Navajo Nation

Ohkay Owingeh

Paiute Indizan Tribe of Utah

Pueblo of Acoma

Pueblo of Isleta

Pueblo of Jemez

Pueblo of Laguna

Pueblo of Nambe

Pueblo of Picuris

Ute Mountain Ute Tribe

Tonto Apache Tribe of Arizona

White Mountain Apache Tribe

Yavapai-Apache Nation

Yavapai-Prescott Tribe

Pueblo of Pojoaque

Pueblo of San Ildefonso

Pueblo of Sandia

Pueblo of Santo Domingo

Pueblo of Taos

Pueblo of Tesuque

Pueblo of Zia

Pueblo of Zuni

San Juan Southern Paiute Tribe of Arizona

Southern Ute Indian Tribe

The Hopi Tribe

Federal Agencies

Bureau of Indian Affairs

Coconino National Forest

Petrified Forest National Park

Wupatki National Monument

US Fish and Wildlife Service Division of Migratory Bird Management

US Fish and Wildlife Service Office of Law Enforcement

State Agencies

Arizona Game and Fish Department

Individuals

William Gregory Kelly, Navajo Nation

James Scarboro, The Hopi Tribe

Karl Johnson, Pueblo of Jemez

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Appendix A. ASSESSMENT OF THE HARVEST OF GOLDEN EAGLES ON LANDS OF THE HOPI TRIBE AND NAVAJO NATION, Final Report 11 February 2013

ASSESSMENT OF THE HARVEST OF GOLDEN EAGLES ON LANDS OF THE HOPI TRIBE AND NAVAJO NATION

Final Report 11 February 2013

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Executive Summary

The Southwest Region of the U.S. Fish and Wildlife Service (Service) must decide on issuance of a permit in spring 2013 to the Hopi Tribe (hereafter, Hopi) to collect (i.e., harvest, or "take") nestling golden eagles for religious purposes from Hopi lands and a portion of adjoining lands of the Navajo Nation (Navajo). To this end, the Service planned in June 2012 to conduct a comprehensive technical assessment of the population biology and management of golden eagles on lands of the Hopi and/or Navajo, which collectively cover most of northeastern Arizona, far southeastern Utah, and northwestern New Mexico. Goals of the assessment were to: (1) develop and apply scientific tools to evaluate sustainability of the current annual collection of golden eagles by the Hopi, and (2) use models and other standard scientific methods to evaluate effects of various collection alternatives and other management actions on population sustainability. In July 2012, the Service convened a team of technical representatives including 4 from its Southwest Region, Washington Office, and Patuxent Wildlife Research Center, and 3-4 from each of the Hopi and Navajo. Information from the technical assessment was to help guide the Service's decision on issuance of the permit through a formal Environmental Assessment, to comply with the National Environmental Policy Act (NEPA). This report details methods and results of the technical assessment.

Effects of the Hopi's harvest practice on sustainability of the golden eagle population depend on how sustainable harvest is defined relative to spatial (geographic) scale. Smallest scales include: (1) the area where eagles have been collected (collection area, or CA) in recent years, and (2) all Hopi and Navajo lands combined (HN). Large scales include: (1) the CA local area population (CALAP), defined as the area on and within 140 miles of the CA; (2) the HN local area population (HNLAP), defined as the area on and within 140 miles of the HN; and (3) Bird Conservation Region (BCR) 16, the Southern Rockies/Colorado Plateau BCR. In this assessment, the golden eagle population at each small-area scale was considered closed to emigration and immigration, but at each large-area scale was considered open relative to the CA or HN, i.e., that there was exchange of golden eagles, through immigration and emigration, between the CA or HN and the surrounding area specified.

A Leslie matrix-based population model was applied in a stochastic format to estimate the number of fledglings needed per occupied breeding area (BA) per year to maintain a stable or increasing golden eagle population. Model simulations suggested that, at either the CA or HN scale, an annual mean of about 0.61 fledglings per occupied BA is needed to maintain a stable population. Based on comparison to this point estimate, annual production of fledgling golden eagles would support a stable population at either scale if there was no collection of nestlings by the Hopi. With the collection, however, models suggested golden eagle productivity at either the CA or HN scale was substantially less than that needed to maintain a stable population. The mean of 23 eagles collected annually during 2002-2007 probably would have to decrease by about 82% and 65% (point estimates) to support a stable population at these 2 scales, respectively. Again, analyses for these 2 small-area scales assumed no emigration or immigration.

At CALAP and HNLAP scales, size of the golden eagle breeding population was estimated by extrapolating the species' breeding density from HN to the area within 140 miles of the CA or HN, respectively. Productivity in surrounding lands within 140 miles at either scale was assumed to equal that on Navajo lands outside the CA; requisite productivity was the same (0.61 fledglings per occupied BA) as that used for analyses at CA and HN scales. Results from the Leslie matrix model suggested that the collection did not influence golden eagle productivity at the 2 LAP scales. Using a similar approach, analysis at the BCR 16 scale similarly disclosed no evidence of a collection influence on productivity. Available data on recent trends in golden eagle numbers at the scale of BCR 16 suggest no significant change in population size since 2009 when the Service concluded in its Final Environmental Assessment that the Hopi Tribe's collections were sustainable at that scale.

Introduction

The Southwest Region of the U.S. Fish and Wildlife Service (Service) must decide on issuance of a permit in spring 2013 to the Hopi Tribe (hereafter, Hopi) to take nestling golden eagles for religious purposes from Hopi lands and a portion of adjoining lands of the Navajo Nation (Navajo). To this end, the Service planned in June 2012 to conduct a comprehensive technical assessment of the population biology and management of golden eagles on lands of the Hopi and/or Navajo, which collectively cover most of northeastern Arizona, far southeastern Utah, and northwestern New Mexico. Goals of the assessment were to: (1) develop and apply scientific tools to evaluate sustainability of the current annual collection of golden eagles by the Hopi, and (2) use models and other standard scientific methods to evaluate effects of various collection alternatives and other management actions on population sustainability. In July 2012, the Service convened a team of technical representatives including 4 from its Southwest Region, Washington Office, and Patuxent Wildlife Research Center, and 3-4 from each of the Hopi and Navajo. Information from the technical assessment was to help guide the Service's decision on issuance of the permit through a formal Environmental Assessment, to comply with the National Environmental Policy Act (NEPA). This report details methods and results of the technical assessment.

Methods

We assessed effects of the Hopi's harvest on golden eagle populations at 5 spatial (geographic) scales. The first 2 scales encompassed relatively small areas (up to about 30,000 miles^2). These were: (1) the Hopi collection area (hereafter termed CA) and (2) the Hopi-Navajo lands (HN; Fig. 1). We considered the population of golden eagles at both of these scales to be closed, i.e., that neither immigration nor emigration occurred and productivity (*p*, the mean [average] annual number of fledglings per breeding pair of golden eagles or occupied breeding area [BA]) must balance survival to support a stable population. The premise of closed populations at these scales stemmed from lack of consensus by the technical team on the Compact's intent in its references to population stability or viability, e.g., the "…[management] objective of maintaining the stability of the Golden eagle population on Hopi and Navajo lands as a whole." This could mean that the CA population should be self-sustaining to contribute towards a stable population at the HN scale, or that the HN population should be self-sustaining, regardless of whether the CA component of the population adds to or detracts from overall stability.

Third through fifth scales encompassed relatively large areas (up to about 219,000 mi^2). These were: (1) the CA local area population (CALAP), defined as the area on and within 140 miles of the CA; (2) the HN local area population (HNLAP), defined as the area on and within 140 miles of the HN; and (3) Bird Conservation Region (BCR) 16, the Southern Rockies/Colorado Plateau BCR (Fig. 1). We considered golden eagle populations at each of the 3 large-area scales to be open relative to the CA or HN, i.e., that there was exchange of golden eagles, through immigration and emigration, between the CA or HN and the surrounding area

specified. The 140-mile criterion for a local area population (LAP) was based on the median natal dispersal distance for golden eagles, derived from band recovery data (U.S. Fish and Wildlife Service 2009). The Service uses this standard to delineate the affected area in any situation where a permit to take golden eagles is being considered (U.S. Fish and Wildlife Service 2009, 2012). The BCR scale is the management unit area used by the Service to establish the threshold (maximum) number of individual golden eagles that may be taken under permit without offsetting the losses through compensatory mitigation, and is the scale at which golden eagle population size and trends typically are assessed by the Service.

At each spatial scale, our goal was to compare estimates of actual *p* with an estimate of the level of *p* needed to maintain a stable golden eagle population. At the BCR scale, we also referenced recent data to assess trend of the golden eagle population given continued collections by the Hopi. This was done because the Service, in its 2009 Final Environmental Assessment for the Eagle Permit Rule (U.S. Fish and Wildlife Service 2009), evaluated likely effects of the Hopi's collections at the scale of BCR 16 (based on mean of 23 collected annually, 2002-2007). The Service concluded the Hopi's collections were sustainable at that scale. Evidence of a significant population decline since 2009 could refute the Service's conclusion, even though cause(s) of such a decline may not be clear.

Summary data on golden eagle BA occupancy and *p* for spatial scales 1 and 2 were provided by the Hopi and Navajo for most years between 1996 and 2012 (Table 1). To estimate the total number of occupied BAs in a given year on HN, we only used data from years when surveys of golden eagle BAs were relatively complete on the CA, the non-CA portion of HN, or both (Table 1). We next calculated the density of occupied BAs on HN and then directly extrapolated this to each of the 3 large-area scales. We recognize that golden eagle breeding density on the HN may not be representative of the CALAP, HNLAP, or BCR 16 and took this into account in conclusions from these analyses, e.g., density on HN may be greater than that in surrounding landscapes.

We used a Leslie matrix-based population model (Krebs 2001) in a stochastic format to estimate the level of *p* needed to maintain a rate of population change (i.e., lambda, symbolized as λ) equal to or greater than 1.0, i.e., a stable or increasing population. Our model included 2 stages, 1 for non-adults (age 0 through 4 year) and another for adults ($\geq$ 5 year). Our estimates of non-adult survival were calculated directly from a sample of 17 golden eagle nestlings that were tagged with satellite transmitters during 2010-2011 by the Service and cooperators within the local area of HN (U.S. Fish and Wildlife Service, Southwest Region, Division of Migratory Birds, unpublished data). Although the sample size was not robust, the data were geographically pertinent; unpublished survival data from golden eagles at a relatively small area of wind energy development in California (Hunt 2002) were the best potential alternative but were considered less valid due to geographic disparity and contrasting land use. We calculated survival estimates with Program MARK (Cooch and White 2007). Given the small sample size available for analysis, we pooled data from all years and estimated survival using a 1-parameter model. We assumed this estimated survival rate applied to 3- and 4-year old golden eagles even though only

2 tagged eagles lived through year 3 and none had yet had an opportunity to survive to age 4. For adult survival, we used a published estimate (Whitfield et al. 2004, Katzner et al. 2006).

We used the "popbio" package (Stubben et al. 2012) for Leslie matrix manipulations and analysis, the "rv" package (Kerman 2012) for simulations, and the "fitdistrplus" package (Delignette-Muller and Delignette-Muller 2012) for fitting distributions and estimating distribution parameters, all in R software (R Development Core Team 2008; Appendix A). Using 100,000 Leslie matrix iterations, we simulated the distribution of survival parameters and optimized p to obtain a λ of 1.0. We fit the distribution of p by using a gamma distribution with shape and rate parameters obtained from the raw data. In each iteration, survival was simulated by using random draws from beta distributions for each of non-adult and adult survival. Shape parameters for the survival beta distributions were derived from the mean and standard deviations (SDs) of annual survival rate estimates. At each spatial scale, we calculated differences between the distribution of p required for a stable population and the distribution of observed p. We also estimated potential p by adjusting pre-collection counts of nestlings in the CA for brood mortality, estimated by calculating the difference between counts of nestlings and fledglings at nests on HN outside the CA.

Our calculation of the size of LAPs and use of "benchmark" harvest rates of 1% (benign level) and 5% (level prompting concern) followed U.S. Fish and Wildlife Service (2009 [Appendix C], 2012 [Appendix F]). We added these benchmarks as a gauge because the Service is required to evaluate and consider effects of *programmatic* take permits on eagles at eagle management unit, local-area, and project-area population scales, including cumulative effects, as part of its permit application review process (50 CFR 22.26 (f)(1) and USFWS 2009). However, permits from the Service for take of golden eagles for religious purposes are not programmatic, i.e., they are not for take that is recurring, is not caused solely by indirect effects, and that occurs over the long term or in a location or locations that cannot be specifically identified (as defined in 50 CFR 22.3). Still, the benchmarks help place the Hopi's collection in context with other forms of take that are routinely assessed by the Service.

Results

Our analysis of survival data from satellite-tagged golden eagles indicated a non-adult annual survival rate of 0.78 (SD = 0.08). Given this and a published adult survival rate of 0.90 (SD = 0.02), our Leslie matrix simulations indicated a mean p of 0.61 (SD = 0.72) fledgling golden eagles per BA are needed to maintain a stable population ($\lambda = 1.0$). The relatively large SD surrounding the estimate of requisite productivity does not reflect variation in actual productivity, but is due, in simulations, to extremes in productivity required in years of extremely low or high golden eagle survival. In the only other study of golden eagle survival via telemetry in the contiguous western United States, Hunt (2002) reported survival rates of 0.84 for juveniles, 0.79 for subadults and "floaters," and 0.91 for breeding adults at the Altamont Wind Resource Area in California. However, Hunt indicated that the pattern of survival at the site was unusual in that juveniles seldom were killed by collision with wind turbines whereas older eagles

(except breeding adults) often were killed this way. In contrast, McIntyre et al. (2006) reported first-year survival rates of 0.19 and 0.34 for 2 cohorts of juvenile golden eagles marked by telemetry at their natal sites in Alaska.

Available data on the number of occupied golden eagle BAs and nestling and fledgling counts for HN are summarized in Table 1. Differences between nestling and fledgling counts in parts of the Navajo Nation where collections by the Hopi did not occur averaged 0.09 young. Subtracting this value from nestling counts at the HN scale, we predicted the value of *p* in the absence of collection would be 0.68 (SD = 0.61). The difference between the potential and required levels of *p* for the HN was negligible (Fig. 2), suggesting that without collections, annual production of fledged young by golden eagles breeding on HN would support a stable population. However, *p* with the Hopi collection at the scale of the CA and of the HN overall was substantially less than needed for a stable population (Fig. 2). The current rate of overharvest is about 82% at the scale of the CA and 65% at the scale of the HN, i.e., collections would have to be reduced by means of about 82% and 65% to support a stable population at these 2 scales, respectively (Table 2). These results represent only point estimates, however.

A survey of all golden eagle BAs on HN has never been done in any single year, but nearly 100% of historically documented BAs likely were surveyed in 2012; 139 of the BAs were occupied (Table 1). During years when surveys of either the CA or non-collection area were complete or nearly so, minimum and maximum number of occupied BAs were 66 (2010) and 79 (2012) in the former, and 60 (2003) and 84 (2005) in the latter. These data suggest that 126 to 163 BAs could be occupied simultaneously across 27,169 miles^2 (Table 3) covered by HN, representing densities of 1 occupied BA per 167-216 mi^2. The midpoint of this range (1 per 191 mi^2) corroborated the density in 2012 (1 per 192 mi^2), when there was a complete survey of BAs across HN. Thus, for analyses at LAP scales, we extrapolated 1 occupied BA per 192 mi^2 to the 134,596 mi^2 that supports the CALAP and to the 218,933 mi^2 that supports the HNLAP. Almost no geographically relevant references on breeding density of golden eagles were available from elsewhere within the LAP or BCR 16 scales. The Arizona Game and Fish Department inventoried golden eagle nests in much of northwestern to southwestern and southeastern Arizona during 2011 and 2012 (McCarty and Jacobsen 2012), but the survey was not designed to determine breeding density, e.g., occupancy determination was not an objective. Moreover, attempts to derive density estimates may be biased by the skewed selection of survey areas (certain federal lands and renewable energy areas were principal targets; McCarty and Jacobsen 2011). In the Mohave Desert ecotype of west central Arizona, overlapping the west-southwest edge of BCR 16, Millsap (1981) estimated 1 occupied BA per 355 mi^2 based on nest spacing data. This arid landscape likely is some of the poorest golden eagle breeding habitat in the state. Stahlecker et al. (2010) reported 1 "[breeding] territory" per 100 mi^2 in northwestern New Mexico. Presumably, this included much of the non-collection area of HN. Occupancy rate was not reported, however, and the mean annual density of occupied BAs may have been less than 1 per 100 mi^2. A systematic, late-summer survey of golden eagles in BCR 16 was conducted annually during 2006-2012 by Nielsen et al. (2012). Mean annual density of golden eagles of all

ages in the BCR, calculated from Table 5 in Nielson et al., was 1 per 67 mi^2 (SD = 1 per 22 mi^2). If: (1) adults comprise about one-half to two-thirds of the golden eagle population (based on a mean of 51.7-69.2% of individuals classified as adults or adults/subadults in annual late summer surveys across most of the western U.S. by Nielson et al.), and (2) roughly one-fourth of adult golden eagles are nonbreeding individuals (based on simulations describing saturated breeding populations at Moffat's equilibrium; Table 3 in Millsap and Allen [2006]), then there is about 1 BA per 345 mi^2 and 258 mi^2 in marginal and good habitats, respectively, in BCR 16. The low end of this range about equals the breeding density in the Mohave Desert from Millsap (1981). We suspect the CA is among the best golden eagle breeding habitats and may support one of the highest breeding densities in the region and density across the rest of HN ranges from good to marginal. If anything, overall breeding density of golden eagles on HN may be lower than the 1 occupied BA per 192 mi^2 we used to approximate breeding density in areas surrounding HN. Baseline density information from surrounding areas could be improved, e.g., by expanding the nest inventory by Arizona Game and Fish Department to determine breeding density across broad areas west to south of HN. Until then, our projection of 1 BA per 192 mi^2 is a reasonable approximation with appropriate cautions in interpreting results.

We estimated annual *p* for the CALAP and HNLAP scales by assuming that the mean number of fledglings produced per BA outside the CA approximated that on HN as a whole, with actual CA *p* used for BAs within the CA. This analysis suggested that *p* of golden eagles at CALAP and HNLAP scales was not significantly influenced by the collection (Fig. 3). A deficit in *p* at both LAP scales might be apparent if *p* or breeding density of golden eagles in the local area outside HN was substantially lower than within HN, but there currently is no unequivocal evidence of this. At both LAP scales, the mean annual collection of 23 golden eagles by the Hopi did not approach the 5% benchmark of take identified by the Service as a level of concern for golden eagles (Table 3). However, the collection exceeded both benchmarks at the CA scale and exceeded the 1% benchmark at the HN scale (Table 4).

Following the approach we used to extrapolate golden eagle breeding density and *p* from HN to the 2 LAP scales, our analysis at the BCR 16 scale suggested the Hopi's collection did not influence *p* (Fig. 3). Additionally, an annual late-summer survey of golden eagle numbers in BCR 16 (Nielson et al. 2012) continues to convey a stable population trend. Thus, there has been no substantial change in the status of golden eagles in BCR 16 since collection by the Hopi was analyzed in the Service's 2009 Final Environmental Assessment (U.S. Fish and Wildlife Service 2009).

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Table 1. Number of occupied breeding areas (BAs) monitored and productivity of golden eagles on Hopi-Navajo lands during 1996-2012, including: (1) the area from which eagles were collected, (2) the area where eagles were not collected, and (3) both areas combined. Italicized-boldfaced numbers of occupied BAs represent near-complete survey efforts. Means are not averages of yearly means, but instead are calculated from overall totals.

	Collection area			**Non-collection area**			**All Hopi-Navajo Lands**		
Year	**Occupied BAs monitored**	**Nestlings**	**Fledglings**	**Occupied BAs monitored**	**Nestlings**	**Fledglings**	**Occupied BAs monitored**	**Nestlings**	**Fledglings**
1996	11	16	6	26	20	14	37	36	20
1997	17	5	0	25	9	7	42	14	7
1998	33	19	8	63	56	52	96	75	60
1999	35	22	10	70	46	39	105	68	49
2000	61	54	22	***76***	60	55	137	114	77
2001	58	58	15	***75***	44	35	133	102	50
2002	48	37	7	***71***	27	20	119	64	27
2003	24	9	5	***60***	12	9	84	21	14
2004	33	31	21	***76***	49	43	109	80	64
2005	34	25	16	***84***	65	59	118	90	75
2006	28	21	2				28	21	2
2007	20	31	4				20	31	4
2008	22	22	6				22	22	6
2009	26	23	6				26	23	6
2010	***66***	17	4	29	7	6	95	24	10
2011	50	27	11				50	27	11
2012	***79***	46	23	***60***	30	23	***139***	76	46
Total	645	463	166	715	425	362	1360	888	528
Mean		0.72	0.26		0.59	0.51		0.65	0.39

Table 2. Calculation of sustainable level of collection of golden eagles by the Hopi Tribe and change from current level to achieve sustainable level. Calculations are at 2 spatial scales: (1) the area of collection of golden eagles by the Hopi Tribe and (2) the Hopi-Navajo lands, which includes the collection area (see Figure 1). The golden eagles population at both scales is assumed to be closed to immigration and emigration. Productivity is the mean number of fledglings per occupied breeding area. Potential productivity is actual productivity corrected for mortality occurring between counts of nestlings and fledglings at nests on Hopi-Navajo lands outside the collection area. Requisite productivity is the estimated level of productivity needed to achieve a stable breeding population.

Mean No. of Fledglings per Occupied Breeding Area	**Collection Area Scale**	**Hopi-Navajo Lands Scale**
Potential productivity (*pp*)	0.68	0.68
Requisite productivity (*r*)	0.61	0.61
Collection (*c*)	0.38	0.20
Actual productivity (*pp* – *c*)	0.30	0.48
Sustainable level of collection (*s*; *pp* – *r*)	0.07	0.07
Change in collection to achieve *s* (*cc*; *c* – *s*)	- 0.31	- 0.13
Percentage change in collection to achieve *s* (*cc/c* * 100)	- 82%	- 65%

Table 3. "Benchmark" harvest rates for the local-area population (LAP) of golden eagles associated with each of (1) the area of collection of golden eagles by the Hopi Tribe and (2) the Hopi-Navajo lands within relevant Bird Conservation Regions (see Figure 1). The LAP is that which occurs on and within 140 miles of the area specified. Benchmark harvest rates follow U.S. Fish and Wildlife Service guidelines for programmatic take of eagles (Appendix C, 2009; Appendix F, 2012).

Bird Conservation Regions that overlap area	**Area of overlap (mi^2)**	**Golden eagle density (*n* individuals/mi^2) in overlap area[a]**	***n* golden eagles in overlap area**	***n* golden eagles at 1% benchmark for take[b]**	***n* golden eagles at 5% benchmark for take[b]**
Collection Area LAP					
Great Basin	4,283	0.03	109	1	5
Southern Rockies/Colorado Plateau	88,994	0.02	1,682	17	84
Sonoran and Mojave Deserts	14,273	0.01	90	1	4
Sierra Madre Occidental	27,046	0.01	203	2	10
Total	**134,596**		2,084	**21**	**104**
Hopi-Navajo Lands LAP					
Great Basin	4,362	0.03	111	1	6
Shortgrass Prairie	2,423	0.01	18	0	1
Southern Rockies/Colorado Plateau	142,458	0.02	2,692	27	135
Sonoran and Mojave Deserts	15,787	0.01	99	1	5
Sierra Madre Occidental	39,207	0.01	294	3	15
Chihuahuan Desert	14,696	0.01	145	1	7
Total	**218,933**		3,360	**34**	**168**

[a] Density values derived from the Partners in Flight database of landbird population estimates (Rocky Mountain Observatory 2007).

Table 3. "Benchmark" harvest rates for golden eagle populations associated with each of (1) the area of collection of golden eagles by the Hopi Tribe and (2) the Hopi-Navajo lands. Both areas are within Bird Conservation Region 16, the Southern Rockies/Colorado Plateau (see Figure 1). Benchmark harvest rates follow U.S. Fish and Wildlife Service guidelines for programmatic take of eagles (Appendix C, 2009; Appendix F, 2012). The 1% level of take from the population is considered benign, while 5% is considered a level of take at which concern is warranted.

Scale	**Area (mi^2)**	**Golden eagle density (*n* individuals/mi^2) in overlap area[a]**	***n* golden eagles in overlap area**	***n* golden eagles at 1% benchmark for take**	***n* golden eagles at 5% benchmark for take**
Collection Area	11,500[b]	0.02	230	2	12
Hopi-Navajo Lands	29,960	0.02	599	6	30

[a] Density value for BCR 16 is derived from the Partners in Flight database of landbird population estimates (Rocky Mountain Observatory 2007).
[b] Extent of collection area is coarsely approximated because exact boundaries of the Navajo Nation portion of the collection area are unknown.

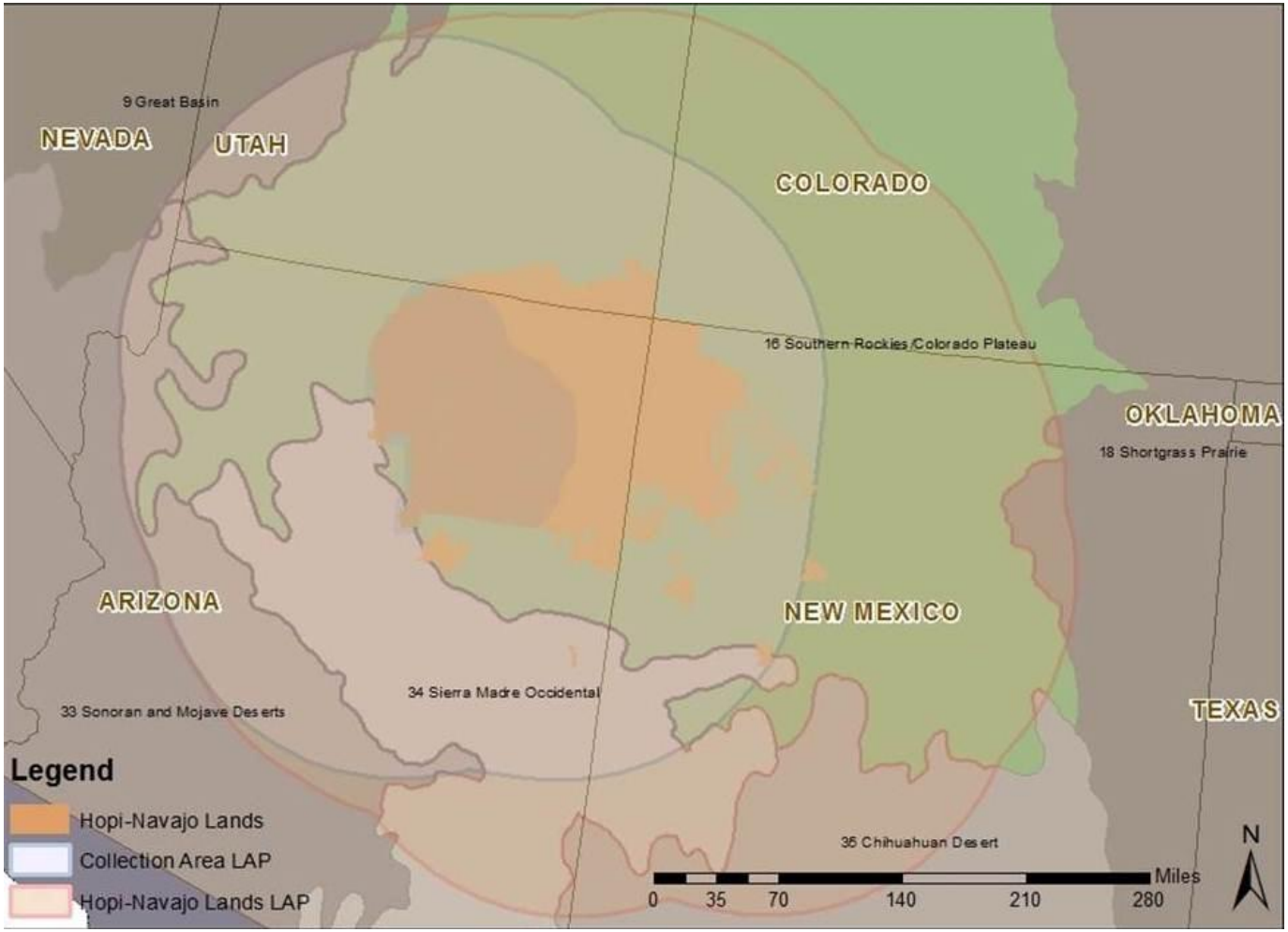


Figure 1. Several scales of the affected area associated with annual collections of golden eagles by the Hopi Tribe, as considered in this technical assessment: (1) the Hopi-Navajo (HN) lands, part of which is the area where collections occur (shaded section, exaggerated to protect sacred site locations); (2) the area encompassing the local area population (LAP) for the collection area, i.e., that on and within 140 miles; and (3) the area encompassing the LAP for HN lands, i.e., that on and within 140 miles of the collection area plus other HN lands. Bird Conservation Regions (BCRs) that overlap the various areas are indicated; BCR 16 Southern Rockies/Colorado Plateau is the U.S. Fish and Wildlife Service's golden eagle management unit that includes the HN lands.

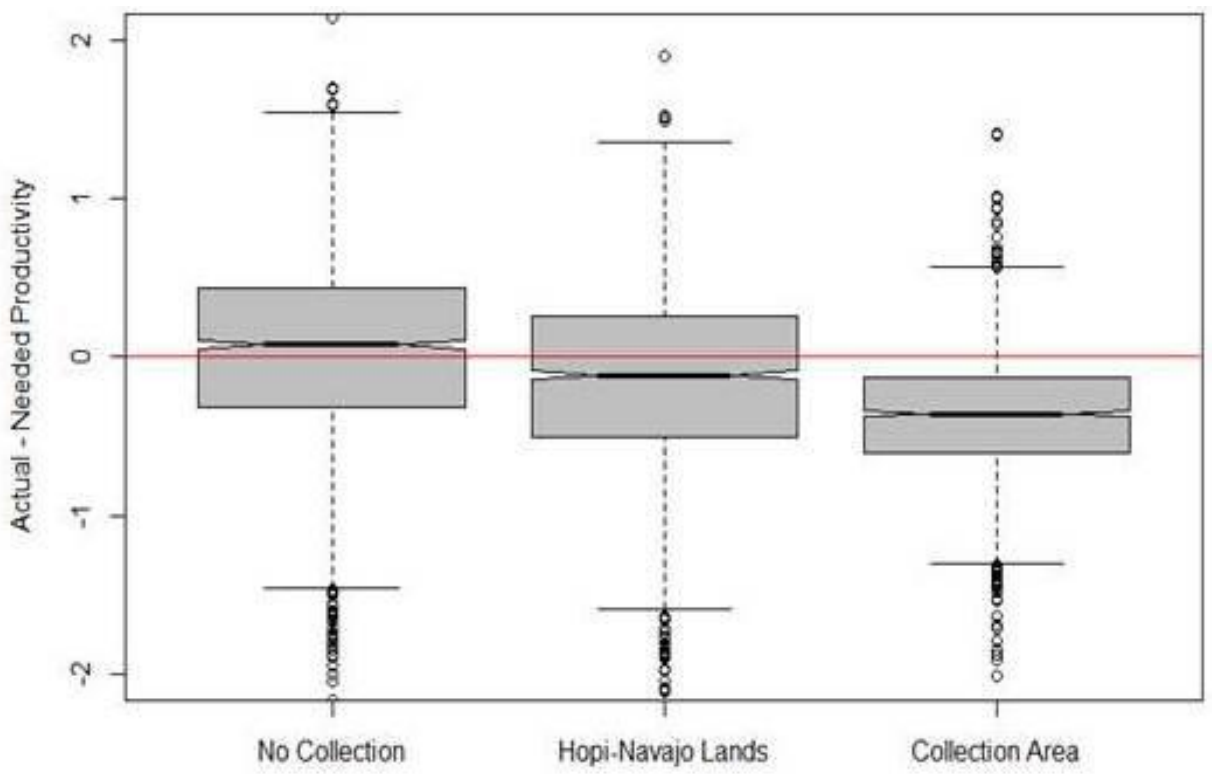


Figure 2. Differences between the estimated level of productivity needed to maintain a stable population and actual productivity of golden eagles at Hopi-Navajo lands (center) and collection area (right) scales. Productivity is the mean number of fledglings per occupied breeding area. The no collection scale reflects potential productivity estimated by adjusting pre-collection counts of nestlings in the collection area for brood mortality based on the difference between counts of nestlings and fledglings at nests on Hopi-Navajo lands outside the collection area. Shaded boxes represent median 50% interquantiles, whiskers represent minimum and maximum values, and values beyond are outliers. When comparing box plots, non-overlap of notches around median values suggests a significant difference ($P < 0.05$).

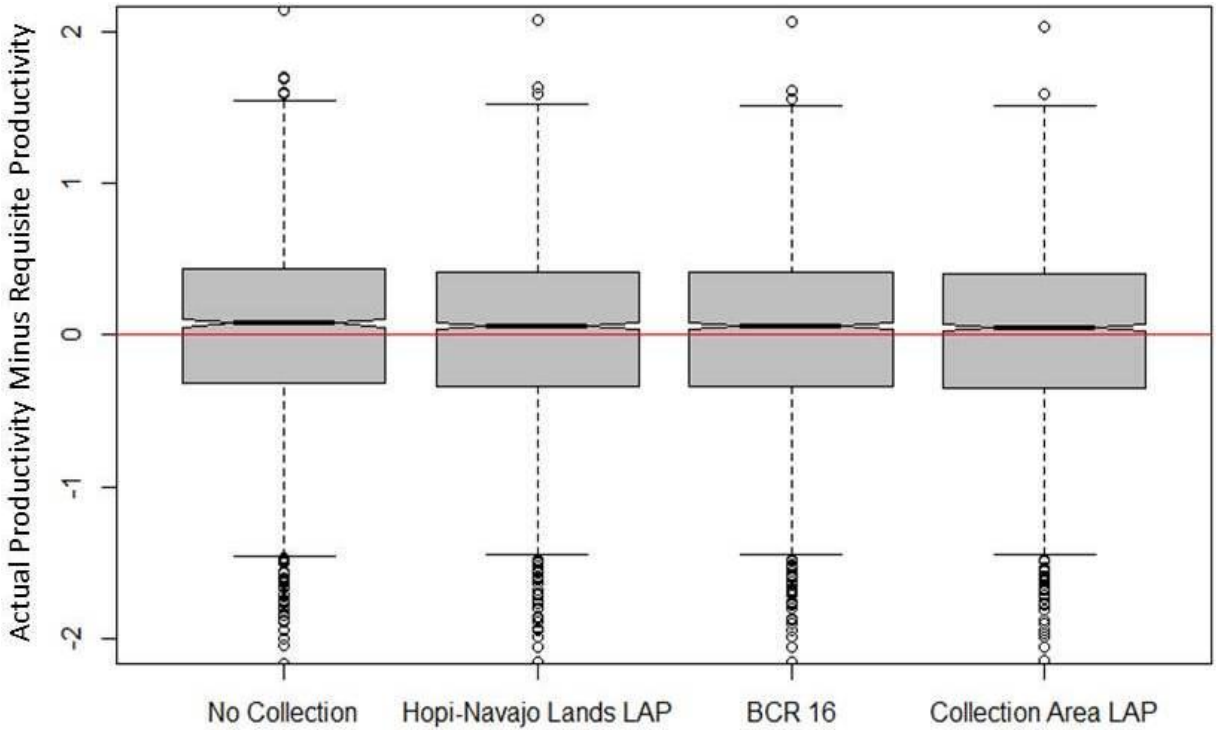


Figure 3. Differences between the estimated level of productivity needed to maintain a stable population and productivity of golden eagles at Hopi-Navajo lands local area population (LAP) and collection area LAP scales (second from left and far right). The LAP is the population on and within 140 miles of the area specified. Between the LAP scales is the BCR (Bird Conservation Region) 16 scale; BCR 16 is the U.S. Fish and Wildlife Service's golden eagle management unit that encompasses the Hopi-Navajo lands. Productivity is the mean number of fledglings per occupied breeding area. The no collection scale reflects potential productivity estimated by adjusting pre-collection counts of nestlings in the collection area for brood mortality based on the difference between counts of nestlings and fledglings at nests on Hopi-Navajo lands outside the collection area. Shaded boxes represent median 50% interquantiles, whiskers represent minimum and maximum values, and values beyond are outliers. When comparing box plots, non-overlap of notches around median values suggests a significant difference ($P < 0.05$); no such differences are apparent.

Appendix A. Code from R statistical software (R Development Core Team 2008) for analyses used in this assessment of golden eagle harvest by the Hopi Tribe.

```
######## Take Assessment for Hopi golden eagles
setwd("C:/Users/Brian/Desktop/Eagle Coordination/Tribal/Hopi take/R code")
######## Data set-up
require(popbio)
require(fitdistrplus)
require(rv)
load("C:/Users/Brian/Desktop/Eagle Coordination/Tribal/Hopi take/R code/R2PVAFcns.R")

A<-matrix(0,ncol=100,nrow=2)

Demo<-read.csv(textConnection(
  "Parm,Mean,SE,L95,U95
  NA,0.9795,NA,0.9576985,0.9902117
  A,0.9912,NA, 0.9712,0.999"),
 header=T,row.names="Parm")
Demo[,c(1,3,4)]<-Demo[,c(1,3,4)]^12;Demo

####Range of survival rates expolred; CIs not changed
#0.9922^12=91%
#0.9912^12=90%
#0.9855^12=84%
0.9795^12

# Convert mean and sd to beta parameters
N2Beta<-function(p,sd,conc=sd^2/p/(1-p)){
  conc<-ifelse(conc<=0|conc>=1,NA,conc)
  n<-1/conc-1  # number of events and non-events
  nu<-n*p      # number of events
  nup<-n*(1-p) # number of non-events
  return(cbind(nu=nu,nup=nup))
}
# Get the SEs from the means and CI[95%]s.
CI2SEBeta<-function(Mean,LCI,UCI,PctCI=95){
  Alpha<-(100-PctCI)/100
  CIProb<-c(Alpha/2,(1-Alpha/2))
  CIFcn<-function(Parm,Mean,CI,CIProb){
    SE<-Parm
    NuPNup<-N2Beta(Mean,SE)
    CIHat<-qbeta(CIProb,NuPNup[1],NuPNup[2])
    crossprod(CIHat-CI)
  }
  UConc<-sqrt(Mean*(1-Mean))
  Est<-optimize(f=CIFcn,interval=c(0.00001,0.999*UConc),
              Mean=Mean,CI=c(LCI,UCI),CIProb=CIProb
  )

  Est$minimum
}
Demo$SE<-with(Demo,mapply(CI2SEBeta,Mean=Mean,LCI=L95,UCI=U95,
                      MoreArgs=list(PctCI=95))
)
```

Demo

```
# Get beta alpha nd beta parameters for survival
muNa=Demo[1,1];muNa
varNa=Demo[1,2]^2;varNa
muA=Demo[2,1];muA
varA=Demo[2,2]^2;varA
alphaNa <- ((1 - muNa) / varNa - 1 / muNa) * muNa ^ 2;alphaNa
betaNa <- alphaNa * (1 / muNa - 1);betaNa
alphaA <- ((1 - muA) / varA - 1 / muA) * muA ^ 2;alphaA
betaA <- alphaA * (1 / muA - 1);betaA
xNa=rbeta(10000,alphaNa,betaNa)
hist(xNa)
xA=rbeta(10000,alphaA,betaA)
hist(xA)

##### Stochastic simulation to get p for lambda=1.0
nAge=5
rep=10000
sP=matrix(0,ncol=rep,nrow=1)
for (i in 1:rep){
  p=(2)/2
  Na=rbeta(1,alphaNa,betaNa)
  A=rbeta(1,alphaA,betaA)
  Lu=c(0,0,0,0,p,Na,0,0,0,0,0,Na,0,0,0,0,0,Na,0,0,0,0,0,Na,A)
  Lu=matrix(Lu,ncol=5,nrow=5);Lu
  Lu=t(Lu);Lu

# Function to find the Fc with no growth.
  LambdaFcn<-function(Fc,Lu=Lu){
    Lu[1,nAge]<-Fc
    abs(lambda(Lu)-1)
  }

  Est<-optimize(f=LambdaFcn,interval=c(0.00001,2.75),Lu=Lu)
  StableFc<-Est$minimum
  Lu[1,nAge]<-StableFc
  sP[1,i]=(2*(Lu[1,nAge])) #Double p to get p per nest from p per individual
}

#Gamma fits best
sp<-fitdist(as.vector(sP+1), distr="gamma")
plot(sp,col="red")
summary(sp)

# Gamma with error
sp<-with(sp,cbind(Mean=estimate,
                  Var=diag(sd)%*%cor%*%diag(sd))
)

sp
spSimN<-rvnorm(1,sp[,1],var=sp[,-1])
spSimN<-abs(spSimN);spSimN
spSimG<-rvgamma(1,spSimN[1],rate=spSimN[2])
spSimG
xlim<-3
```

```
spsimg<-sims(spSimG-1)
spDenG<-density(spsimg,n=2000)
sp<-rvhist(spSimG-1,xlim=c(0,xlim),ylim=c(0,max(spDenG$y+0.5)),col="dark gray")
lines(spDenG,col="blue")

######Needed productivity
Prod_needed=spSimG-1;Prod_needed
rvhist(Prod_needed,breaks=400,xlim=c(0,3),col="dark gray")
######Needed productivity

#########Evaluate actual productivity data

# Nestling data - pre-collection
aP <- read.table("C:/Users/Brian/Desktop/Eagle Coordination/Tribal/Hopi Take/nestlings.csv",
                 header=TRUE, sep=",", na.strings="NA", dec=".", strip.white=TRUE)
aP
#gamma
paGamma<-fitdist(aP$nestlings+1, distr="gamma")
plot(paGamma,col="red")
summary(paGamma)
# Gamma with error
paGammaEst<-with(paGamma,cbind(Mean=estimate,
                    Var=diag(sd)%*%cor%*%diag(sd))
)
paGammaEst
paSimN<-rvnorm(1,paGammaEst[,1],var=paGammaEst[,-1]);paSimN
paSimN<-abs(paSimN);paSimN
paSimG<-rvgamma(1,paSimN[1],rate=paSimN[2])
xlim<-3
pasimg<-sims(paSimG)
DenG<-density(pasimg-1,n=2000)
rvhist(paSimG-1,xlim=c(0,xlim),ylim=c(0,max(DenG$y+0.5)))
lines(DenG,col="blue")
summary(paSimG-1)

layout (matrix(1:1, ncol=1))
asPca<-paSimG-1
rvhist(asPca,xlim=c(0,3))
summary(asPca)

######Estimated pre-harvest productivity
Prod_base=asPca-0.09; Prod_base  #0.09 = nestling to fledgling per nest mortality estimated from data as point est.
rvhist(Prod_base,breaks=400,xlim=c(-2,3),col="dark gray")
######Estimated pre-harvest productivity


##################Difference between needed and actual productivity nestling period
DProd_base=Prod_base-Prod_needed;DProd_base
rvhist(DProd_base,breaks=400,xlim=c(-2,3),col="dark gray")
##################Difference between needed and actual productivity nestling period



#########################Hopi-Navajo Lands Scale##############################################
##### Fledgling data (post-collection)
aF <- read.table("C:/Users/Brian/Desktop/Eagle Coordination/Tribal/Hopi Take/fledglings.csv",
```

```
            header=TRUE, sep=",", na.strings="NA", dec=".", strip.white=TRUE)
aF

#gamma
pfaGamma<-fitdist(aF$fledglings+1,distr="gamma")
plot(pfaGamma,col="red")
summary(pfaGamma)
#Gamma with error
pfaGammaEst<-with(pfaGamma,cbind(Mean=estimate,
                        Var=diag(sd)%*%cor%*%diag(sd))
)

pfaSimN<-rvnorm(1,pfaGammaEst[,1],var=pfaGammaEst[,-1])
pfaSimN<-abs(pfaSimN);pfaSimN
pfaSimG<-rvgamma(1,pfaSimN[1],rate=pfaSimN[2])
xlim<-3
pfasimg<-sims(pfaSimG)
DenGf<-density(pfasimg-1,n=2000)
rvhist(pfaSimG-1,xlim=c(0,xlim),ylim=c(0,max(DenGf$y+0.5)))
lines(DenGf,col="blue")
summary(pfaSimG-1)

##################Actual productivity for HNL post-collection
Prod_aHNL=pfaSimG-1;Prod_aHNL
##################Actual productivity for HNL post-collection

##################Calculated reduction in harvest HNL scale
Prod_aHNL
Prod_needed
Prod_base

harvest_HNL=Prod_base-Prod_aHNL;harvest_HNL
sharvest_HNL=Prod_base-Prod_needed;sharvest_HNL
oharvest_HNL=harvest_HNL-sharvest_HNL;oharvest_HNL
poharvestHNL=0.14/0.2;poharvestHNL
##################Calculated reduction in harvest HNL scale


##################Difference for productivity for HNL post-collection
DProd_aHNL=Prod_aHNL-Prod_needed;DProd_aHNL
rvhist(DProd_HNL,breaks=400,xlim=c(-2,3),col="dark gray")
##################Difference for productivity for HNL post-collection


#########################collection Area Scale##############################################
##### Fledgling data (post-collection)
aFca <- read.table("C:/Users/Brian/Desktop/Eagle Coordination/Tribal/Hopi Take/fledglingsCA.csv",
            header=TRUE, sep=",", na.strings="NA", dec=".", strip.white=TRUE)
aFca
#gamma
pfcaGamma<-fitdist(aFca$fledglings+1,distr="gamma")
plot(pfcaGamma,col="red")
summary(pfcaGamma)
#Gamma with error
pfcaGammaEst<-with(pfcaGamma,cbind(Mean=estimate,
                        Var=diag(sd)%*%cor%*%diag(sd))
```

```
)

pfcaSimN<-rvnorm(1,pfcaGammaEst[,1],var=pfcaGammaEst[,-1])
pfcaSimN<-abs(pfcaSimN);pfcaSimN
pfcaSimG<-rvgamma(1,pfcaSimN[1],rate=pfcaSimN[2])
xlim<-3
pfcasimg<-sims(pfcaSimG)
DenGfca<-density(pfcasimg-1,n=2000)
rvhist(pfcaSimG-1,xlim=c(0,xlim),ylim=c(0,max(DenGfca$y+0.5)))
lines(DenGfca,col="blue")
summary(pfcaSimG-1)
postCollCA=(pfcaSimG-1)-(spSimG-1)

##################Actual productivity for CA post-collection
Prod_aCA=pfcaSimG-1;Prod_aCA
rvhist(Prod_aCA,breaks=400,xlim=c(-2,3),col="dark gray")
##################Actual productivity for CA post-collection

##################Difference for productivity for CA post-collection
DProd_aCA=Prod_aCA-Prod_base;DProd_aCA
rvhist(DProd_aCA,breaks=400,xlim=c(-2,3),col="dark gray")
##################Difference for productivity for CA post-collection

##################Calculated reduction in harvest CA scale
Prod_aCA
Prod_needed
Prod_base

harvest_CA=Prod_base-Prod_aCA;harvest_CA
sharvest_CA=Prod_base-Prod_needed;sharvest_CA
oharvest_CA=harvest_CA-sharvest_CA;oharvest_CA
poharvestCA=1-(rvmean(sharvest_CA)/rvmean(harvest_CA));poharvestCA
##################Calculated reduction in harvest CA scale

############Local Area Populatin Scale CA
caLAP_nests=715-73  #nests from density expansion to uncollected part of LAP
ca_nests=73    #nests from density expasion to collected part of LAP
caLAP_nestsT=caLAP_nests+ca_nests;caLAP_nestsT
caLAP_Fledged=(caLAP_nests*Prod_base)+(ca_nests*Prod_aCA);caLAP_Fledged
caLAP_needed=caLAP_nestsT*Prod_needed;caLAP_needed
DcaLAP_Fledged=caLAP_Fledged-caLAP_needed;DcaLAP_Fledged
DcaLap_Prod=DcaLAP_Fledged/caLAP_nestsT;DcaLap_Prod
############Local Area Populatin Scale CA

############CA Local Area Populatin Scale w/o collection
caLAP_base=caLAP_nestsT*Prod_base;caLAP_base
DcaLAP_base=caLAP_base-(caLAP_nestsT*Prod_needed);DcaLAP_base
############Local Area Populatin Scale w/o collection

############Local Area Populatin Scale HNL
hnlLAP_nests=1162-73  #nests from density expansion to uncollected part of LAP
ca_nests=73    #nests from density expasion to collected part of LAP
hnlLAP_nestsT=hnlLAP_nests+ca_nests;hnlLAP_nestsT
hnlLAP_Fledged=(hnlLAP_nests*Prod_base)+(ca_nests*Prod_aCA);hnlLAP_Fledged
hnlLAP_needed=hnlLAP_nestsT*Prod_needed;hnlLAP_needed
DhnlLAP_Fledged=hnlLAP_Fledged-hnlLAP_needed;DhnlLAP_Fledged
```

```
DhnlLap_Prod=DhnlLAP_Fledged/hnlLAP_nestsT;DhnlLap_Prod

############HNL Local Area Populatin Scale w/o collection
hnlLAP_base=hnlLAP_nestsT*Prod_base;hnlLAP_base
DhnlLAP_base=(hnlLAP_base-(hnlLAP_nestsT*Prod_needed))/hnlLAP_nestsT;DhnlLAP_base
############Local Area Populatin Scale w/o collection

############BCR 16 Populatin Scale
bcrLAP_nests=924-73  #nests from density expansion to uncollected part of BCR 16
ca_nests=73    #nests from density expasion to collected part of LAP
bcrLAP_nestsT=bcrLAP_nests+ca_nests;bcrLAP_nestsT
bcrLAP_Fledged=(bcrLAP_nests*Prod_base)+(ca_nests*Prod_aCA);bcrLAP_Fledged
bcrLAP_needed=bcrLAP_nestsT*Prod_needed;bcrLAP_needed
DbcrLAP_Fledged=bcrLAP_Fledged-bcrLAP_needed;DbcrLAP_Fledged
DbcrLap_Prod=DbcrLAP_Fledged/bcrLAP_nestsT;DbcrLap_Prod

############bcr Local Area Populatin Scale w/o collection
bcrLAP_base=bcrLAP_nestsT*Prod_base;bcrLAP_base
DbcrLAP_base=bcrLAP_base-(bcrLAP_nestsT*Prod_needed);DbcrLAP_base
############Local Area Populatin Scale w/o collection

#Boxplots
layout (matrix(1:1, ncol=1))
# daPsP=prod_needed-
# preColl=unlist(daPsP)
# summary(preColl) #unharvested difference between needed and observed
postCollHNL=unlist(pfaSimG-spSimG)
summary(postCollHNL)  #harvested diference between needed and observed HNL
postCollCA=unlist(postCollCA)
summary(postCollCA)
#prodLAP_CA=unlist(prodLAP_CA)

bplot=cbind(unlist(DProd_base),unlist(DProd_aHNL),unlist(DProd_aCA))
library(graphics)
names=c("No Collection","Hopi-Navajo Lands","Collection Area")
boxplot.matrix(bplot,ylim=c(-2,2),col="gray",notch=TRUE,names=names,ylab="Actual - Needed Productivity",
            main="Tribal Land Productivity With and Without Collection")
abline(h=0, col="red")

bplot=cbind(unlist(DhnlLAP_base),unlist(DhnlLap_Prod),unlist(DbcrLap_Prod),unlist(DcaLap_Prod))
library(graphics)
names=c("No Collection","HN Lands LAP","BCR 16","Collection Area LAP")
boxplot.matrix(bplot,ylim=c(-2,2),col="gray",notch=TRUE,names=names,ylab="Actual-Needed Productivity",
            main="Local Area Population and BCR Productivity With and Without Collection")
abline(h=0, col="red")
```

Appendix B. Supplement to "ASSESSMENT OF THE HARVEST OF GOLDEN EAGLES ON LANDS OF THE HOPI TRIBE AND NAVAJO NATION, Final Report 11 February 2013" by the Assessment Technical Team.

Revised Table 1 (beginning on following page): In the original Table 1 of the final "Technical Assessment" report, mean-numbers of nestlings and fledglings per occupied breeding area (OBA) were not averages of the respective columns, a standard approach, but instead were calculated from overall totals, as indicated in the heading of that table. In the revised table in this appendix, means are averages of columns, in this case yearly means of productivity. Some values are the same as in the original Table 1, while others differ slightly. The revised means were used as inputs to update the analysis of sustainable take (see Appendix C). In addition, estimates of standard deviations (SDs) associated with means are reported in the below table and were not in the original.

Compared to the original Table 1 in the Technical Assessment, the revised Table 1 in this appendix is expanded to include three columns with numbers of nestlings per OBA and three columns with numbers of fledglings per OBA, so is printed here in three parts: a, b, and c.

Table 1: Table 1a. Number of occupied breeding areas (OBAs) monitored and productivity of golden eagles on Hopi-Navajo lands during 1996-2012; Table 1a is the area from which eagles were collected, Table 1b is the area where eagles were not collected, and Table 1c is both areas combined. Italicized-boldfaced numbers of OBAs represent relatively complete survey efforts.

1a	**Collection area**				
Year	**OBAs monitored**	**Nestlings**	**Nestlings per OBA**	**Fledglings**	**Fledglings per OBA**
1996	11	16	1.45	6	0.55
1997	17	5	0.29	0	0.00
1998	33	19	0.58	8	0.24
1999	35	22	0.63	10	0.29
2000	61	54	0.89	22	0.36
2001	58	58	1.00	15	0.26
2002	48	37	0.77	7	0.15
2003	24	9	0.38	5	0.21
2004	33	31	0.94	21	0.64
2005	34	25	0.74	16	0.47
2006	28	21	0.75	2	0.07
2007	20	31	1.55	4	0.20
2008	22	22	1.00	6	0.27
2009	26	23	0.88	6	0.23
2010	***66***	17	0.26	4	0.06
2011	50	27	0.54	11	0.22
2012	***79***	46	0.58	23	0.29
Mean			**0.78**		**0.26**
SD			0.35		0.16

Table 1, continued: Table 1b. Number of occupied breeding areas (OBAs) monitored and productivity of golden eagles on Hopi-Navajo lands during 1996-2012; Table 1a is the area from which eagles were collected, Table 1b is the area where eagles were not collected, and Table 1c is both areas combined. Italicized-boldfaced numbers of OBAs represent relatively complete survey efforts.

1b	**Non-collection area**				
Year	**OBAs monitored**	**Nestlings**	**Nestlings per OBA**	**Fledglings**	**Fledglings per OBA**
1996	26	20	0.77	14	0.54
1997	25	9	0.36	7	0.28
1998	63	56	0.89	52	0.83
1999	70	46	0.66	39	0.56
2000	***76***	60	0.79	55	0.72
2001	***75***	44	0.59	35	0.47
2002	***71***	27	0.38	20	0.28
2003	***60***	12	0.20	9	0.15
2004	***76***	49	0.64	43	0.57
2005	***84***	65	0.77	59	0.70
2006					
2007					
2008					
2009					
2010	29	7	0.24	6	0.21
2011					
2012	***60***	30	0.50	23	0.38
Mean			**0.57[a]**		**0.47[a]**
SD			0.22		0.21

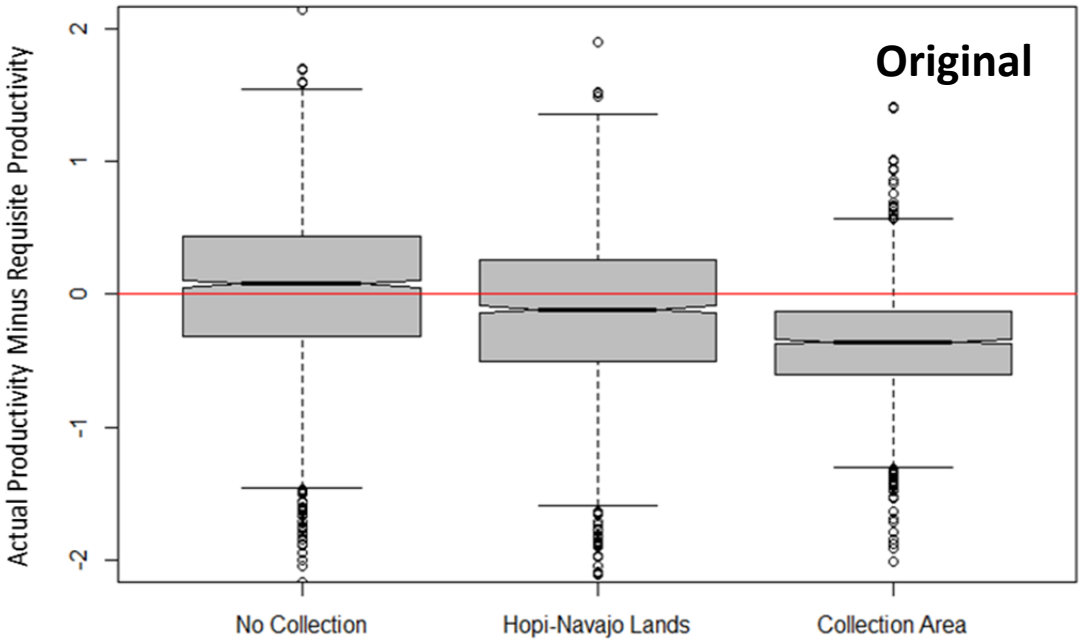
[a] The difference between the mean number of nestlings and fledglings per OBA in the non-collection area, representing mortality of young eagles between counts of nestlings and fledglings, is used in the Technical Assessment to estimate potential productivity of golden eagles in the collection area, where golden eagles are collected as nestlings. The difference based on above table 1b is 0.57 – 0.47 = 0.10, but when accounting for rounding area, it is 0.5659675 – 0.4734535 = 0.092514. Thus, 0.09 young per OBA represents mortality between nestling and fledgling counts in the updated Technical Assessment analysis Appendix C.

Table 1, continued: Table 1c. Number of occupied breeding areas (OBAs) monitored and productivity of golden eagles on Hopi-Navajo lands during 1996-2012; Table 1a is the area from which eagles were collected, Table 1b is the area where eagles were not collected, and Table 1c is both areas combined. Italicized-boldfaced numbers of OBAs represent relatively complete survey efforts.

1c	**All Hopi-Navajo Lands**				
Year	**OBAs monitored**	**Nestlings**	**Nestlings per OBA**	**Fledglings**	**Fledglings per OBA**
1996	37	36	0.97	20	0.54
1997	42	14	0.33	7	0.17
1998	96	75	0.78	60	0.63
1999	105	68	0.65	49	0.47
2000	137	114	0.83	77	0.56
2001	133	102	0.77	50	0.38
2002	119	64	0.54	27	0.23
2003	84	21	0.25	14	0.17
2004	109	80	0.73	64	0.59
2005	118	90	0.76	75	0.64
2006	28	21	0.75	2	0.07
2007	20	31	1.55	4	0.20
2008	22	22	1.00	6	0.27
2009	26	23	0.88	6	0.23
2010	95	24	0.25	10	0.11
2011	50	27	0.54	11	0.22
2012	***139***	76	0.55	46	0.33
Mean			**0.71**		**0.34**
SD			0.30		0.19

Revised Figure 2 (next page): Differences between the estimated level of productivity needed to maintain a stable population and actual productivity of golden eagles at collection area and Hopi-Navajo lands scales. Productivity is the mean number of fledglings per OBA. The no collection scale reflects potential productivity estimated by adjusting pre-collection counts of nestlings in the collection area for brood mortality based on the difference between counts of nestlings and fledglings at nests on Hopi-Navajo lands outside the collection area. Shaded boxes represent median 50% interquantiles, whiskers represent minimum and maximum values, and values beyond are outliers. When comparing box plots, non-overlap of notches around median values suggests a significant difference ($P < 0.05$).

The original figure from the 11 February 2013 final report is compared here to an 18 March 2013 revision stemming from recalculation of productivity values (see revised Table 1 in this appendix) followed by an updated analysis of requisite productivity (see Appendix C). In the revised figure, both the collection area and Hopi-Navajo lands are represented as no-collection reference points; no-collection in the original figure included only Hopi-Navajo lands. Otherwise, results conveyed in the revised figure are indistinguishable from those in the original.



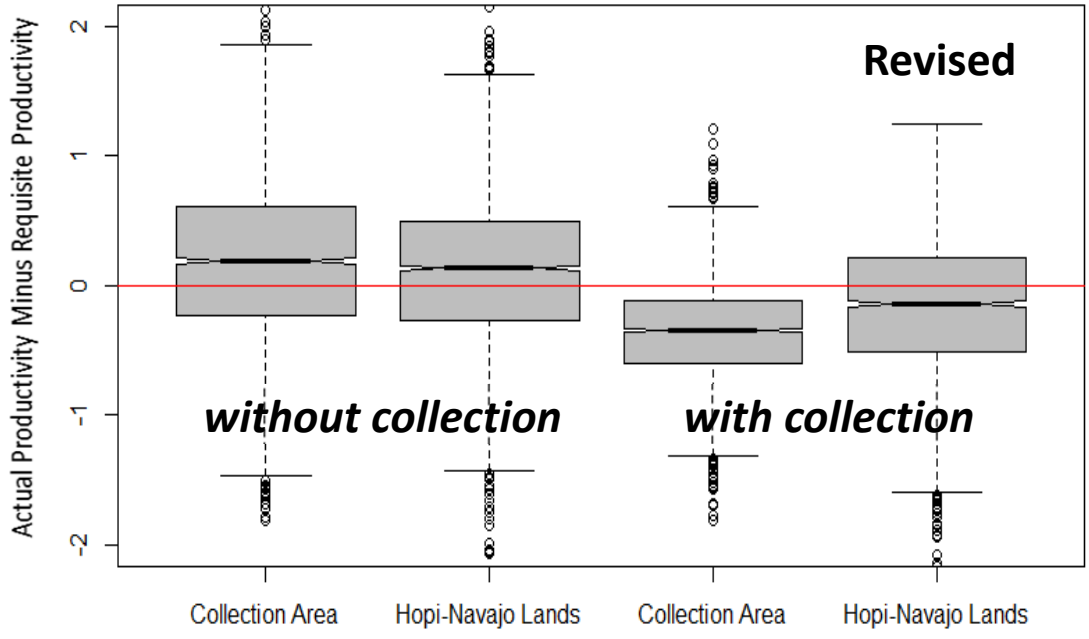


Figure 3 in the 11 February 2013 final report conveyed differences between the estimated level of productivity needed to maintain a stable population and actual productivity of golden eagles at the collection area local area population (LAP) scale, the Hopi-Navajo lands LAP scale, and the BCR 16 scale. There were no distinguishable changes to Figure 3 following the updated analysis (see Appendix C).

Appendix C. Technical background for Alternative C, "Authorize Take of 40 Nestling Golden Eagles in 2013, but limit the take on Navajo Lands to Five"

GE productivity on the Navajo non-CA is 0.47 fledglings per OBA (updated mean; see Appendix B). This is about 15% below an estimated level required for population stability at scales considered in the TA (Appendix A). In the original analysis presented in the TA, the estimated productivity level required for population stability was 0.61. Following slight revisions of inputs, described in Appendix B, the requisite productivity estimate changed to 0.55 (see R software output at end of this appendix). This estimate was the mean of a gamma distribution generated by Leslie matrix modeling as described in the TA and further discussed at the end of this appendix. The difference between the requisite productivity level and actual productivity on the Navajo non-CA suggests additional factors limit GEs in the Navajo non-CA. In the absence of collection, productivity on the Navajo CA could, conceivably, resemble the 0.47 level documented on the Navajo non-CA. If so, a reasonable expectation under this alternative is that the Hopi's take of GE nestlings on the Navajo CA should decrease only to a level that increases productivity to 0.47, not to the 0.55 "stability level." A productivity increase from 0.47 to 0.55 on the Navajo CA would require the Navajo to reduce other limiting factors, just as it would on the Navajo non-CA.

However, average production of GE nestlings on the CA is 0.78 per OBA, 40% more than 0.47 on the Navajo non-CA area (Table 1, Appendix B). Potential productivity on the CA is 0.68 fledglings per OBA, after accounting for the loss of 0.09 young eagles between counts of nestlings and counts of fledglings (Appendix B, revised Table 1 but regard the footnote in part B of this table). This 0.68 level of potential productivity is 24% greater than the estimated 0.55 needed for population stability; the difference between the two productivity levels, 0.13 fledglings per OBA, represents sustainable take of 0.15 nestlings per OBA (again, accounting for mortality between counts of nestlings and counts of fledglings). If the relatively high level (0.68) of potential productivity on the CA can be assumed to be roughly comparable between Hopi and Navajo portions of the CA, a reasonable expectation under this alternative is that some nestling GEs can be taken from the Navajo CA without undermining the 0.55 stability level for that area. A second assumption is that GE breeding density (number of square miles per OBA) is uniform across the CA. A third assumption is that Navajo lands comprise one-half of the CA. Per the latter two assumptions, Navajo lands encompass roughly one-half of the OBAs from which the Hopi take GEs. According to the TA (Appendix A), 66-79 breeding areas may be occupied by GEs in the CA in a given year. Using the mid-point of this range (72.5), one-half of 72.5 OBAs equals about 36 breeding areas on the Navajo collection area from which nestling GEs can be taken. Given 0.15 nestlings per OBA as a sustainable level of take (above), the Hopi could take an average of 5.4 (5) nestling GEs from the Navajo CA without undercutting the 0.55 stability level of productivity.

Above assumptions are weakly founded, however. Notions of comparable productivity and uniform breeding density stem only from knowledge that Hopi lands and the Navajo CA are in close proximity. The third assumption about extent of the Navajo CA is based on knowledge of the Hopi's land area and that the entire CA comprises roughly the western one-half of Hopi-Navajo lands (Figure 1 in the TA, Appendix A), but this is a very crude approximation. These

assumptions were made because both tribes consider their respective breeding and productivity data for the CA to be highly sensitive and do not publicly disclose any such data.

A somewhat different approach to the same end is, briefly: (1) estimate potential fledgling production on the CA (0.68 * 73 = 49.6 fledglings) and assume one-half of the fledglings (24.8) are on the Navajo CA; (2) estimate fledgling production needed to maintain a stable population (0.55 * 73 = 40.2) and assume one-half of these fledglings (20.1) are on the Navajo CA; (3) estimate sustainable take on the Navajo CA by subtracting the stability level of production from the potential level of production (24.8 – 20.1 = 4.7 fledglings); and (4) accounting for natural mortality among young GEs between counts of nestlings and counts of fledglings (0.09 per OBA). Sustainable take would be 5.4 (5) nestling GEs.

The above approaches to estimating sustainable take on the Navajo CA are coarse. Conclusions stem simply from arithmetic means from normal distributions. In contrast, the TA's approach of using Leslie matrix models in a stochastic framework (Appendix A) is a robust means of estimating the sustainable level of collection. Simulations included 10,000 iterations, with results based on probability density under a gamma distribution. After minor revisions of summary data in the TA's original Table 1 (Appendix B), Leslie matrix simulations were conducted once again using R software with the updated input values (Appendix A; updated output at end of this appendix).

The updated value for estimated potential productivity of GEs on the CA, based on a gamma distribution, is 0.71 (SD = 1.2), versus 0.68 (SD = 0.61) originally in the TA. The maximum density value of 0.71 is slightly greater than the arithmetic mean of 0.68 used above, mainly because the gamma distribution is slightly skewed to the right. As stated early in this appendix, the estimated requisite productivity value derived from a gamma distribution of probable values is 0.55 fledglings per OBA (SD = 0.70); this translates into 0.64 nestlings per OBA (0.55 + 0.09 = 0.64). Sustainable rate of take at the CA scale under the updated analysis is 0.14 nestlings per OBA (0.78 – 0.64 = 0.14; the 0.78 level of potential productivity is from the revised Table 1 in Appendix B). This is the equivalent of 10.2 nestlings that can be sustainably collected from the CA at that respective scale. If, under the assumption above that Navajo lands comprise roughly one-half of the CA, 5.1 nestlings would be the sustainable take at the Navajo CA scale. This closely approximates the above estimate of 5.4 based means in revised Table 1 plus the requisite productivity level of 0.55 fledglings per OBA derived from the modeling.

An updated analysis at the Hopi/Navajo Lands Local Area Population (HNLAP) scale produced the same results (output at end of this appendix) as the original analysis (Appendix A), which is unsurprising given the large spatial scale and very minor changes in input data. Again, productivity of GEs at the HNLAP scale was not significantly influenced by the collection of an annual mean of 23 nestling GEs under a yearly permit for 40 during 2002-2007 (see Figure 3 in the TA).

Appendix C continued: Code from R statistical software for update of the analysis used to assess golden eagle harvest by the Hopi Tribe (Appendix A, "ASSESSMENT OF THE HARVEST OF GOLDEN EAGLES ON LANDS OF THE HOPI TRIBE AND NAVAJO NATION, Final Report 11 February 2013"), following minor revisions to input values described in Appendix B.

```
> ######## PBR for Hopi golden eagles
> ######## Data set-up
> require(popbio)
> require(fitdistrplus)
> require(rv)
> #load("R2PVAFcns.R")
> CI2SEBeta<-function(Mean,LCI,UCI,PctCI=95){
+   Alpha<-(100-PctCI)/100
+   CIProb<-c(Alpha/2,(1-Alpha/2))
+   CIFcn<-function(Parm,Mean,CI,CIProb){
+     SE<-Parm
+     NuPNup<-N2Beta(Mean,SE)
+     CIHat<-qbeta(CIProb,NuPNup[1],NuPNup[2])
+     crossprod(CIHat-CI)
+   }
+   UConc<-sqrt(Mean*(1-Mean))
+   Est<-optimize(f=CIFcn,interval=c(0.00001,0.999*UConc),
+                 Mean=Mean,CI=c(LCI,UCI),CIProb=CIProb
+   )
+   #  if(Est$convergence!=0)
+   #   warning(paste("Convergence error",Est$convergence))
+   Est$minimum
+ }
>
> A<-matrix(0,ncol=100,nrow=2)
>
> Demo<-read.csv(textConnection(
+   "Parm,Mean,SE,L95,U95
+   NA,0.9795322,NA,0.9576985,0.9902117
+   A,0.9922,NA, 0.9712,0.999"),
+  header=T,row.names="Parm")
> Demo[,c(1,3,4)]<-Demo[,c(1,3,4)]^12;Demo
          Mean SE       L95       U95
  NA 0.7802335 NA 0.5953134 0.8886621
  A  0.9103128 NA 0.7042131 0.9880658
> #0.9922^12=91%
> #0.9912^12=90%
> # Convert mean and sd to beta parameters
> N2Beta<-function(p,sd,conc=sd^2/p/(1-p)){
+   conc<-ifelse(conc<=0|conc>=1,NA,conc)
+   n<-1/conc-1  # number of events and non-events
+   nu<-n*p      # number of events
+   nup<-n*(1-p) # number of non-events
+   return(cbind(nu=nu,nup=nup))
+ }
> # Get the SEs from the means and CI[95%]s.
> CI2SEBeta<-function(Mean,LCI,UCI,PctCI=95){
+   Alpha<-(100-PctCI)/100
+   CIProb<-c(Alpha/2,(1-Alpha/2))
+   CIFcn<-function(Parm,Mean,CI,CIProb){
+     SE<-Parm
+     NuPNup<-N2Beta(Mean,SE)
+     CIHat<-qbeta(CIProb,NuPNup[1],NuPNup[2])
+     crossprod(CIHat-CI)
+   }
+   UConc<-sqrt(Mean*(1-Mean))
+   Est<-optimize(f=CIFcn,interval=c(0.00001,0.999*UConc),
```

```
+                  Mean=Mean,CI=c(LCI,UCI),CIProb=CIProb
+   )
+   #  if(Est$convergence!=0)
+   #   warning(paste("Convergence error",Est$convergence))
+   Est$minimum
+ }
> Demo$SE<-with(Demo,mapply(CI2SEBeta,Mean=Mean,LCI=L95,UCI=U95,
+                           MoreArgs=list(PctCI=95))
+ )
> Demo
          Mean         SE       L95       U95
  NA 0.7802335 0.07853396 0.5953134 0.8886621
  A  0.9103128 0.07894859 0.7042131 0.9880658
> # Get beta alpha nd beta parameters for survival
> muNa=Demo[1,1];muNa
[1] 0.7802335
> varNa=Demo[1,2]^2;varNa
[1] 0.006167583
> muA=Demo[2,1];muA
[1] 0.9103128
> varA=Demo[2,2]^2;varA
[1] 0.00623288
> alphaNa <- ((1 - muNa) / varNa - 1 / muNa) * muNa ^ 2;alphaNa
[1] 20.91157
> betaNa <- alphaNa * (1 / muNa - 1);betaNa
[1] 5.890111
> alphaA <- ((1 - muA) / varA - 1 / muA) * muA ^ 2;alphaA
[1] 11.01371
> betaA <- alphaA * (1 / muA - 1);betaA
[1] 1.085109
> xNa=rbeta(10000,alphaNa,betaNa)
> hist(xNa)
> xA=rbeta(10000,alphaA,betaA)
> hist(xA)
>
> ##### Stochastic simulation to get p for lambda=1.0
> nAge=5
> rep=10000
> sP=matrix(0,ncol=rep,nrow=1)
> for (i in 1:rep){
+   p=(2)/2
+   Na=rbeta(1,alphaNa,betaNa)
+   A=rbeta(1,alphaA,betaA)
+   Lu=c(0,0,0,0,p,Na,0,0,0,0,0,Na,0,0,0,0,0,Na,0,0,0,0,0,Na,A)
+   Lu=matrix(Lu,ncol=5,nrow=5);Lu
+   Lu=t(Lu);Lu
+
+   # Function to find the Fc with no growth.
+   LambdaFcn<-function(Fc,Lu=Lu){
+     Lu[1,nAge]<-Fc
+     abs(lambda(Lu)-1)
+   }
+
+   Est<-optimize(f=LambdaFcn,interval=c(0.00001,2.75),Lu=Lu)
+   StableFc<-Est$minimum
+   Lu[1,nAge]<-StableFc
+   sP[1,i]=(2*(Lu[1,nAge])) #Double p to get p per nest from p per
individual
+ }
>
> #Gamma fits best
> sp<-fitdist(as.vector(sP+1), distr="gamma")
> plot(sp,col="red")
> summary(sp)
```

```
Fitting of the distribution ' gamma ' by maximum likelihood
Parameters :
      estimate Std. Error
shape 9.846299 0.13695342
rate  6.388670 0.09116341
Loglikelihood:  -6732.103   AIC:  13468.21   BIC:  13482.63
Correlation matrix:
          shape      rate
shape 1.0000000 0.9747422
rate  0.9747422 1.0000000

>
> # Gamma with error
> sp<-with(sp,cbind(Mean=estimate,
+                   Var=diag(sd)%*%cor%*%diag(sd))
+ )
>
> sp
          Mean
shape 9.846299 0.01875624 0.012169793
rate  6.388670 0.01216979 0.008310767
> spSimN<-rvnorm(1,sp[,1],var=sp[,-1])
> spSimN<-abs(spSimN);spSimN
     name mean   sd  1% 2.5% 25% 50% 75% 97.5%  99% sims
[1] shape  9.8 0.37 9.5  9.6 9.8 9.8 9.9  10.1 10.2 2500
[2]  rate  6.4 0.30 6.2  6.2 6.3 6.4 6.4   6.6  6.6 2500
> spSimG<-rvgamma(1,spSimN[1],rate=spSimN[2])
> spSimG
    mean  sd   1% 2.5% 25% 50% 75% 97.5% 99% sims
[1]  1.6 0.7 0.65 0.77 1.2 1.5 1.8   2.7   3 2500
> xlim<-3
> spsimg<-sims(spSimG-1)
> #simg<-simg[simg<110];simg
> spDenG<-density(spsimg,n=2000)
> sp<-rvhist(spSimG-1,xlim=c(0,xlim),ylim=c(0,max(spDenG$y+0.5)),col="dark
gray")
> lines(spDenG,col="blue")
> summary(spSimG-1)
        mean        sd         1%       2.5%      25%       50%       75%
97.5%      99% sims
[1] 0.552827 0.7032354 -0.3458241 -0.2271644 0.201058 0.5012073 0.8355856
1.659623 1.968584 2500
>
> ######Needed productivity
> Prod_needed=spSimG-1;Prod_needed
    mean  sd    1%  2.5% 25% 50%  75% 97.5% 99% sims
[1] 0.55 0.7 -0.35 -0.23 0.2 0.5 0.84   1.7   2 2500
> rvhist(Prod_needed,breaks=400,xlim=c(0,3),col="dark gray")
> ######Needed productivity
>
> #########Evaluate actual productivity data
>
> # Nestling data - pre-collection
> aP <- read.table("C:/Users/Brian/Desktop/Eagle Coordination/Tribal/Hopi
Take/nestlings2.csv",
+                          header=TRUE, sep=",", na.strings="NA", dec=".",
strip.white=TRUE)
> aP
   nestlings
1  0.9729730
2  0.3333333
3  0.7812500
4  0.6476190
5  0.8321168
```

```
6  0.7669173
7  0.5378151
8  0.2500000
9  0.7339450
10 0.7627119
11 0.7500000
12 1.5500000
13 1.0000000
14 0.8846154
15 0.2526316
16 0.5400000
17 0.5467626
> colMeans(aP)
nestlings
0.7142759
> #gamma
> paGamma<-fitdist(aP$nestlings+1, distr="gamma")
> plot(paGamma,col="red")
> summary(paGamma)
Fitting of the distribution ' gamma ' by maximum likelihood
Parameters :
      estimate Std. Error
shape 33.14449  11.311736
rate  19.33422   6.648573
Loglikelihood:  -3.354783   AIC:  10.70957   BIC:  12.37599
Correlation matrix:
          shape      rate
shape 1.0000000 0.9924674
rate  0.9924674 1.0000000

>
> # Gamma with error
> paGammaEst<-with(paGamma,cbind(Mean=estimate,
+                                Var=diag(sd)%*%cor%*%diag(sd))
+ )
> paGammaEst
          Mean
shape 33.14449 127.9554 74.64040
rate  19.33422  74.6404 44.20353
> paSimN<-rvnorm(1,paGammaEst[,1],var=paGammaEst[,-1]);paSimN
     name mean  sd  1% 2.5% 25% 50% 75% 97.5% 99% sims
[1] shape   33 3.4 6.5   10  26  33  41    55  59 2500
[2]  rate   19 2.6 3.2    6  15  19  24    32  35 2500
> paSimN<-abs(paSimN);paSimN
     name mean  sd  1% 2.5% 25% 50% 75% 97.5% 99% sims
[1] shape   33 3.4 6.5   10  26  33  41    55  59 2500
[2]  rate   19 2.6 3.2    6  15  19  24    32  35 2500
> paSimG<-rvgamma(1,paSimN[1],rate=paSimN[2])
> xlim<-3
> pasimg<-sims(paSimG)
> DenG<-density(pasimg-1,n=2000)
> rvhist(paSimG-1,xlim=c(0,xlim),ylim=c(0,max(DenG$y+0.5)))
> lines(DenG,col="blue")
> summary(paSimG-1)
         mean       sd           1%      2.5%       25%       50%       75%
97.5%      99% sims
[1] 0.7677857 1.462182 0.002824471 0.1246604 0.4975783 0.6927876 0.9277025
1.463212 1.686659 2500
>
> layout (matrix(1:1, ncol=1))
> asPca<-paSimG-1
> rvhist(asPca,xlim=c(0,3))
> summary(asPca)
```

```
          mean        sd           1%       2.5%        25%        50%        75%
97.5%      99% sims
[1] 0.7677857 1.462182 0.002824471 0.1246604 0.4975783 0.6927876 0.9277025
1.463212 1.686659 2500
>
> ######Estimated pre-harvest productivity
> Prod_base=asPca-0.09; Prod_base  #0.09 = nestling to fledgling per nest
mortality estimated from data as point est.
    mean  sd     1%  2.5%  25% 50%  75% 97.5% 99% sims
[1] 0.68 1.5 -0.087 0.035 0.41 0.6 0.84   1.4 1.6 2500
> rvhist(Prod_base,breaks=400,xlim=c(-2,3),col="dark gray")
> ######Estimated pre-harvest productivity
>
>
> ##################Difference between needed and actual productivity
nestling period
> DProd_base=Prod_base-Prod_needed;DProd_base
    mean  sd   1% 2.5%   25%  50%  75% 97.5% 99% sims
[1] 0.12 1.5 -1.5 -1.2 -0.29 0.12 0.49   1.2 1.4 2500
> rvhist(DProd_base,breaks=400,xlim=c(-2,3),col="dark gray")
> ##################Difference between needed and actual productivity
nestling period
>
>
>
> #########################Hopi-Navajo Lands
Scale##############################################
> ##### Fledgling data (post-collection)
> aF <- read.table("C:/Users/Brian/Desktop/Eagle Coordination/Tribal/Hopi
Take/fledglings2.csv",
+                  header=TRUE, sep=",", na.strings="NA", dec=".",
strip.white=TRUE)
> aF
   fledglings
1        0.54
2        0.17
3        0.63
4        0.47
5        0.56
6        0.38
7        0.23
8        0.17
9        0.59
10       0.64
11       0.07
12       0.20
13       0.27
14       0.23
15       0.11
16       0.22
17       0.33
>
> #gamma
> pfaGamma<-fitdist(aF$fledglings+1,distr="gamma")
> plot(pfaGamma,col="red")
> summary(pfaGamma)
Fitting of the distribution ' gamma ' by maximum likelihood
Parameters :
      estimate Std. Error
shape 52.79277   18.05086
rate  39.34560   13.51698
Loglikelihood:  4.702606   AIC:  -5.405211   BIC:  -3.738785
Correlation matrix:
          shape      rate
```

```
shape 1.0000000 0.9952684
rate  0.9952684 1.0000000

> #Gamma with error
> pfaGammaEst<-with(pfaGamma,cbind(Mean=estimate,
+                                  Var=diag(sd)%*%cor%*%diag(sd))
+ )
>
> pfaSimN<-rvnorm(1,pfaGammaEst[,1],var=pfaGammaEst[,-1])
> pfaSimN<-abs(pfaSimN);pfaSimN
     name mean  sd   1% 2.5% 25% 50% 75% 97.5% 99% sims
[1] shape   53 4.2 10.4   18  41  53  65    89  96 2500
[2]  rate   39 3.7  7.9   14  31  39  49    66  71 2500
> pfaSimG<-rvgamma(1,pfaSimN[1],rate=pfaSimN[2])
> xlim<-3
> pfasimg<-sims(pfaSimG)
> DenGf<-density(pfasimg-1,n=2000)
> rvhist(pfaSimG-1,xlim=c(0,xlim),ylim=c(0,max(DenGf$y+0.5)))
> lines(DenGf,col="blue")
> summary(pfaSimG-1)
         mean         sd          1%         2.5%      25%        50%        75%
97.5%       99% sims
[1] 0.3395323 0.4661354 -0.1205587 -0.04395384 0.202236 0.3307349 0.4639977
0.7825137 0.8880951 2500
>
> ##################Actual productivity for HNL post-collection
> Prod_aHNL=pfaSimG-1;Prod_aHNL
    mean   sd    1%   2.5% 25%  50%  75% 97.5%  99% sims
[1] 0.34 0.47 -0.12 -0.044 0.2 0.33 0.46  0.78 0.89 2500
> ##################Actual productivity for HNL post-collection
>
> ##################Calculated reduction in harvest HNL scale
> Prod_aHNL
    mean   sd    1%   2.5% 25%  50%  75% 97.5%  99% sims
[1] 0.34 0.47 -0.12 -0.044 0.2 0.33 0.46  0.78 0.89 2500
> Prod_needed
    mean  sd    1%  2.5% 25% 50%  75% 97.5% 99% sims
[1] 0.55 0.7 -0.35 -0.23 0.2 0.5 0.84   1.7   2 2500
> Prod_base
    mean  sd     1%  2.5%  25% 50%  75% 97.5% 99% sims
[1] 0.68 1.5 -0.087 0.035 0.41 0.6 0.84   1.4 1.6 2500
>
> harvest_HNL=Prod_base-Prod_aHNL;harvest_HNL
    mean  sd    1%  2.5%   25%  50%  75% 97.5% 99% sims
[1] 0.34 1.5 -0.59 -0.42 0.019 0.27 0.54   1.1 1.3 2500
> sharvest_HNL=Prod_base-Prod_needed;sharvest_HNL
    mean  sd   1% 2.5%   25%  50%  75% 97.5% 99% sims
[1] 0.12 1.5 -1.5 -1.2 -0.29 0.12 0.49   1.2 1.4 2500
> oharvest_HNL=harvest_HNL-sharvest_HNL;oharvest_HNL
    mean   sd    1%  2.5%   25%  50%  75% 97.5% 99% sims
[1] 0.21 0.73 -0.84 -0.71 -0.17 0.17 0.54   1.4 1.7 2500
> poharvestHNL=(rvmean(sharvest_HNL)/rvmean(harvest_HNL));poharvestHNL
[1] 0.3694234
>
> ##################Calculated reduction in harvest HNL scale
>
>
> ##################Difference for productivity for HNL post-collection
> DProd_aHNL=Prod_aHNL-Prod_needed;DProd_aHNL
     mean   sd   1% 2.5%   25%   50%  75% 97.5%  99% sims
[1] -0.21 0.73 -1.7 -1.4 -0.54 -0.17 0.17  0.71 0.84 2500
> rvhist(DProd_aHNL,breaks=400,xlim=c(-2,3),col="dark gray")
> ##################Difference for productivity for HNL post-collection
>
```

```
>
> #########################collection Area
Scale#################################################
> ##### Fledgling data (post-collection)
> aFca <- read.table("C:/Users/Brian/Desktop/Eagle Coordination/Tribal/Hopi
Take/fledglingsCA2.csv",
+                    header=TRUE, sep=",", na.strings="NA", dec=".",
strip.white=TRUE)
> aFca
   fledglings
1  0.54545455
2  0.00000000
3  0.24242424
4  0.28571429
5  0.36065574
6  0.25862069
7  0.14583333
8  0.20833333
9  0.63636364
10 0.47058824
11 0.07142857
12 0.20000000
13 0.27272727
14 0.23076923
15 0.06060606
16 0.22000000
17 0.29113924
> #gamma
> pfcaGamma<-fitdist(aFca$fledglings+1,distr="gamma")
> plot(pfcaGamma,col="red")
> summary(pfcaGamma)
Fitting of the distribution ' gamma ' by maximum likelihood
Parameters :
      estimate Std. Error
shape 63.47035   21.71323
rate  50.18492   17.23612
Loglikelihood:  7.255022   AIC:  -10.51004   BIC:  -8.843617
Correlation matrix:
          shape      rate
shape 1.0000000 0.9960638
rate  0.9960638 1.0000000

> #Gamma with error
> pfcaGammaEst<-with(pfcaGamma,cbind(Mean=estimate,
+                                    Var=diag(sd)%*%cor%*%diag(sd))
+ )
>
> pfcaSimN<-rvnorm(1,pfcaGammaEst[,1],var=pfcaGammaEst[,-1])
> pfcaSimN<-abs(pfcaSimN);pfcaSimN
     name mean  sd 1% 2.5% 25% 50% 75% 97.5% 99% sims
[1] shape   64 4.6 17   23  50  63  78   105 112 2500
[2]  rate   50 4.1 13   18  39  50  61    83  89 2500
> pfcaSimG<-rvgamma(1,pfcaSimN[1],rate=pfcaSimN[2])
> xlim<-3
> pfcasimg<-sims(pfcaSimG)
> DenGfca<-density(pfcasimg-1,n=2000)
> rvhist(pfcaSimG-1,xlim=c(0,xlim),ylim=c(0,max(DenGfca$y+0.5)))
> lines(DenGfca,col="blue")
> summary(pfcaSimG-1)
         mean        sd          1%        2.5%       25%       50%       75%
97.5%       99% sims
[1] 0.2656961 0.4168672 -0.1014117 -0.04639818 0.1496886 0.2533303 0.3738278
0.6401879 0.7383723 2500
> postCollCA=(pfcaSimG-1)-(spSimG-1)
```

```
>
> #############CA scale without collection
> aFcanh <- read.table("C:/Users/Brian/Desktop/Eagle Coordination/Tribal/Hopi
Take/fledglingsCAnh.csv",
+                    header=TRUE, sep=",", na.strings="NA", dec=".",
strip.white=TRUE);aFcanh
   fledglings
1        1.36
2        0.20
3        0.49
4        0.54
5        0.80
6        0.91
7        0.68
8        0.29
9        0.85
10       0.65
11       0.66
12       1.46
13       0.91
14       0.79
15       0.17
16       0.45
17       0.49
> pfcanhGamma<-fitdist(aFcanh$fledglings+1,distr="gamma")
> plot(pfcanhGamma,col="red")
> summary(pfcanhGamma)
Fitting of the distribution ' gamma ' by maximum likelihood
Parameters :
      estimate Std. Error
shape 24.93619   8.496461
rate  14.77048   5.083590
Loglikelihood:  -5.456476   AIC:  14.91295   BIC:  16.57938
Correlation matrix:
          shape      rate
shape 1.0000000 0.9899927
rate  0.9899927 1.0000000

> #Gamma with error
> pfcanhGammaEst<-with(pfcanhGamma,cbind(Mean=estimate,
+                                        Var=diag(sd)%*%cor%*%diag(sd))
+ )
>
> pfcanhSimN<-rvnorm(1,pfcanhGammaEst[,1],var=pfcanhGammaEst[,-1])
> pfcanhSimN<-abs(pfcanhSimN);pfcanhSimN
     name mean  sd  1% 2.5% 25% 50% 75% 97.5% 99% sims
[1] shape   25 2.9 4.6  8.4  19  25  31    42  45 2500
[2]  rate   15 2.3 2.8  4.7  11  15  18    25  27 2500
> pfcanhSimG<-rvgamma(1,pfcanhSimN[1],rate=pfcanhSimN[2])
> xlim<-3
> pfcanhsimg<-sims(pfcanhSimG)
> DenGfcanh<-density(pfcanhsimg-1,n=2000)
> rvhist(pfcanhSimG-1,xlim=c(0,xlim),ylim=c(0,max(DenGfcanh$y+0.5)))
> lines(DenGfcanh,col="blue")
> summary(pfcanhSimG-1)
         mean       sd          1%       2.5%       25%       50%       75%
97.5%      99% sims
[1] 0.7108504 1.202773 -0.1945948 -0.0061451 0.4242931 0.6615823 0.9052178
1.511939 1.832311 2500
> noCollCA=(pfcanhSimG-1)-(spSimG-1);noCollCA
    mean  sd   1% 2.5%   25%  50%  75% 97.5% 99% sims
[1] 0.16 1.2 -1.5 -1.1 -0.27 0.16 0.53   1.3 1.5 2500
> summary(noCollCA)
```

```
          mean        sd        1%      2.5%        25%       50%       75%
97.5%      99% sims
[1] 0.1580234 1.236354 -1.51447 -1.107696 -0.2698084 0.1605347 0.5315249
1.281531 1.494118 2500
> DProd_baseCA=pfcanhSimG-1-Prod_needed;DProd_baseCA
    mean  sd   1% 2.5%   25%  50%  75% 97.5% 99% sims
[1] 0.16 1.2 -1.5 -1.1 -0.27 0.16 0.53   1.3 1.5 2500
> rvhist(DProd_baseCA,breaks=400,xlim=c(-2,3),col="dark gray")
>
>
> ############Local Area Populatin Scale w/o collection
>
>
> ##################Actual productivity for CA post-collection
> Prod_aCA=pfcaSimG-1;Prod_aCA
    mean   sd   1%   2.5%  25%  50%  75% 97.5%  99% sims
[1] 0.27 0.42 -0.1 -0.046 0.15 0.25 0.37  0.64 0.74 2500
> rvhist(Prod_aCA,breaks=400,xlim=c(-2,3),col="dark gray")
> ##################Actual productivity for CA post-collection
>
> ##################Difference for productivity for CA post-collection
> DProd_aCA=Prod_aCA-Prod_base;DProd_aCA
     mean  sd   1% 2.5%   25%   50%   75% 97.5%  99% sims
[1] -0.41 1.5 -1.4 -1.2 -0.59 -0.35 -0.11  0.31 0.45 2500
> rvhist(DProd_aCA,breaks=400,xlim=c(-2,3),col="dark gray")
> ##################Difference for productivity for CA post-collection
>
> ##################Calculated reduction in harvest CA scale
> Prod_aCA
    mean   sd   1%   2.5%  25%  50%  75% 97.5%  99% sims
[1] 0.27 0.42 -0.1 -0.046 0.15 0.25 0.37  0.64 0.74 2500
> Prod_needed
    mean  sd    1%  2.5% 25% 50%  75% 97.5% 99% sims
[1] 0.55 0.7 -0.35 -0.23 0.2 0.5 0.84   1.7   2 2500
> Prod_base
    mean  sd     1%  2.5%  25% 50%  75% 97.5% 99% sims
[1] 0.68 1.5 -0.087 0.035 0.41 0.6 0.84   1.4 1.6 2500
>
> harvest_CA=Prod_base-Prod_aCA;harvest_CA
    mean  sd    1%  2.5%  25%  50%  75% 97.5% 99% sims
[1] 0.41 1.5 -0.45 -0.31 0.11 0.35 0.59   1.2 1.4 2500
> sharvest_CA=Prod_base-Prod_needed;sharvest_CA
    mean  sd   1% 2.5%   25%  50%  75% 97.5% 99% sims
[1] 0.12 1.5 -1.5 -1.2 -0.29 0.12 0.49   1.2 1.4 2500
> oharvest_CA=harvest_CA-sharvest_CA;oharvest_CA
    mean   sd    1%  2.5%   25%  50%  75% 97.5% 99% sims
[1] 0.29 0.72 -0.74 -0.58 -0.07 0.23 0.59   1.4 1.8 2500
> poharvestCA=1-(rvmean(sharvest_CA)/rvmean(harvest_CA));poharvestCA
[1] 0.6967681
> ##################Calculated reduction in harvest CA scale
>
>
> # #########Summary graphics Histgram form
> #
> # #Hopi-Navajo Lands scale
> # #Potential productivity
> # #Nestlings adjusted to account for observed brood loss 0.09 in
uncollected area
> # layout (matrix(1:3, ncol=1))
> # rvhist(spSimG,breaks=200,col="dark gray",xlim=c(0,3),
> #        main="Productivity Needed for Lambda = 1.0",xlab="Fledglings per
Nest + 1")
> # abline(v=c(rvmean(spSimG),
```

```
> #
rvquantile(spSimG,probs=c(0.05,0.5,0.95))),col=c("black","red","red","red"),l
wd=2)
> # summary(spSimG)
> # rvhist(paSimG-0.09,breaks=800,col="dark gray",xlim=c(0,3),
> #        main="Observed Productivity",xlab="Adjusted Nestlings per Nest +
1")
> # abline(v=c(rvmean(paSimG-0.09),
> #            rvquantile(paSimG-
0.09,probs=c(0.05,0.5,0.95))),col=c("black","red","red","red"),lwd=2)
> #
> # rvhist(paSimG-0.09-spSimG,breaks=450,col="dark gray",xlim=c(-2.5,2),
> #        main="Observed - Needed Productivity",xlab="Adjusted Nestlings per
Nest")
> # abline(v=c(rvmean(paSimG-0.09-spSimG),
> #            rvquantile(paSimG-0.09-
spSimG,probs=c(0.05,0.5,0.95))),col=c("black","red","red","red"),lwd=2)
> # text(-0.7,.6,"Mean Difference = -0.009")
> # summary(paSimG-0.09-spSimG)
> # spSimG-1
> # paSimG-1-0.09
> #
> # #Actual
> # layout (matrix(1:3, ncol=1))
> # rvhist(spSimG,breaks=200,col="dark gray",xlim=c(0,2),
> #        main="Productivity Needed for Lambda = 1.0",xlab="Fledglings per
Nest")
> # summary(spSimG)
> # abline(v=c(rvmean(spSimG-1),
> #            rvquantile(spSimG-
1,probs=c(0.05,0.5,0.95))),col=c("black","red","red","red"),lwd=2)
> #
> # rvhist(pfaSimG,breaks=1000,col="dark gray",xlim=c(0,2),
> #        main="Observed Productivity",xlab="Fledglings per Nest")
> # abline(v=c(rvmean(pfaSimG),
> #
rvquantile(pfaSimG,probs=c(0.05,0.5,0.95))),col=c("black","red","red","red"),
lwd=2)
> #
> # rvhist(pfaSimG-spSimG,breaks=800,col="dark gray",xlim=c(-2.5,2),
> #        main="Observed - Needed Productivity",xlab="Fledglings per Nest")
> # abline(v=c(rvmean(pfaSimG-spSimG),
> #            rvquantile(pfaSimG-
spSimG,probs=c(0.05,0.5,0.95))),col=c("black","red","red","red"),lwd=2)
> # summary(pfaSimG-spSimG)
> # text(-1,0.7,"Mean Difference = -0.29")
> # summary(pfaSimG-spSimG)
> # summary(pfaSimG-1)
>
> # #Collection Area scale
> # layout (matrix(1:3, ncol=1))
> # rvhist(spSimG,breaks=200,col="dark gray",xlim=c(0,2),
> #        main="Productivity Needed for Lambda = 1.0",xlab="Fledglings per
Nest")
> # summary(spSimG)
> # abline(v=c(rvmean(spSimG),
> #
rvquantile(spSimG,probs=c(0.05,0.5,0.95))),col=c("black","red","red","red"),l
wd=2)
> #
> # rvhist(pfcaSimG,breaks=4000,col="dark gray",xlim=c(0,2),
> #        main="Observed Productivity",xlab="Fledglings per Nest")
> # abline(v=c(rvmean(pfcaSimG),
```

```
> #
rvquantile(pfcaSimG,probs=c(0.05,0.5,0.95))),col=c("black","red","red","red")
,lwd=2)
> #
> # rvhist(pfcaSimG-spSimG,breaks=2000,col="dark gray",xlim=c(-2.5,2),
> #        main="Observed - Needed Productivity",xlab="Fledglings per Nest")
> # abline(v=c(rvmean(pfcaSimG-spSimG),
> #            rvquantile(pfcaSimG-
spSimG,probs=c(0.05,0.5,0.95))),col=c("black","red","red","red"),lwd=2)
> # summary(pfcaSimG-spSimG)
> # text(-1,0.7,"Mean Difference = -0.37")
> # summary(pfaSimG-spSimG)
> # summary(pfaSimG-1)
> # postColl=unlist(pfaSimG-spSimG)
>
> ############Local Area Populatin Scale CA
> caLAP_nests=715-73  #nests from density expansion to uncollected part of
LAP
> ca_nests=73    #nests from density expasion to collected part of LAP
> caLAP_nestsT=caLAP_nests+ca_nests;caLAP_nestsT
[1] 715
> caLAP_Fledged=(caLAP_nests*Prod_base)+(ca_nests*Prod_aCA);caLAP_Fledged
    mean sd  1% 2.5% 25% 50% 75% 97.5%  99% sims
[1]  455 37 -46   37 278 408 557   894 1044 2500
> caLAP_needed=caLAP_nestsT*Prod_needed;caLAP_needed
    mean sd   1% 2.5% 25% 50% 75% 97.5%  99% sims
[1]  395 19 -247 -162 144 358 597  1187 1408 2500
> DcaLAP_Fledged=caLAP_Fledged-caLAP_needed;DcaLAP_Fledged
    mean sd    1% 2.5%  25% 50% 75% 97.5% 99% sims
[1]   59 38 -1089 -858 -220  60 314   795 939 2500
> DcaLap_Prod=DcaLAP_Fledged/caLAP_nestsT;DcaLap_Prod
     mean  sd   1% 2.5%   25%   50%  75% 97.5% 99% sims
[1] 0.083 1.4 -1.5 -1.2 -0.31 0.083 0.44   1.1 1.3 2500
> ############Local Area Populatin Scale CA
>
> ############CA Local Area Populatin Scale w/o collection
> caLAP_base=caLAP_nestsT*Prod_base;caLAP_base
    mean sd  1% 2.5% 25% 50% 75% 97.5%  99% sims
[1]  485 39 -62   25 291 431 599   982 1142 2500
> DcaLAP_base=caLAP_base-(caLAP_nestsT*Prod_needed);DcaLAP_base
    mean sd    1% 2.5%  25% 50% 75% 97.5%  99% sims
[1]   89 40 -1096 -855 -205  82 348   859 1006 2500
> ############Local Area Populatin Scale w/o collection
>
> ############Local Area Populatin Scale HNL
> hnlLAP_nests=1162-73  #nests from density expansion to uncollected part of
LAP
> ca_nests=73    #nests from density expasion to collected part of LAP
> hnlLAP_nestsT=hnlLAP_nests+ca_nests;hnlLAP_nestsT
[1] 1162
> hnlLAP_Fledged=(hnlLAP_nests*Prod_base)+(ca_nests*Prod_aCA);hnlLAP_Fledged
    mean sd  1% 2.5% 25% 50% 75% 97.5%  99% sims
[1]  758 48 -86   50 459 677 930  1502 1758 2500
> hnlLAP_needed=hnlLAP_nestsT*Prod_needed;hnlLAP_needed
    mean sd   1% 2.5% 25% 50% 75% 97.5%  99% sims
[1]  642 24 -402 -264 234 582 971  1928 2287 2500
> DhnlLAP_Fledged=hnlLAP_Fledged-hnlLAP_needed;DhnlLAP_Fledged
    mean sd    1%  2.5%  25% 50% 75% 97.5%  99% sims
[1]  115 49 -1781 -1390 -347 114 533  1327 1567 2500
> DhnlLap_Prod=DhnlLAP_Fledged/hnlLAP_nestsT;DhnlLap_Prod
     mean  sd   1% 2.5%  25%   50%  75% 97.5% 99% sims
[1] 0.099 1.4 -1.5 -1.2 -0.3 0.098 0.46   1.1 1.3 2500
>
> ############HNL Local Area Populatin Scale w/o collection
```

```
> hnlLAP_base=hnlLAP_nestsT*Prod_base;hnlLAP_base
    mean sd   1% 2.5% 25% 50% 75% 97.5%  99% sims
[1]  788 50 -101   40 474 700 973  1596 1855 2500
> DhnlLAP_base=(hnlLAP_base-
(hnlLAP_nestsT*Prod_needed))/hnlLAP_nestsT;DhnlLAP_base
    mean  sd   1% 2.5%   25%  50%  75% 97.5% 99% sims
[1] 0.12 1.5 -1.5 -1.2 -0.29 0.12 0.49   1.2 1.4 2500
> ############Local Area Populatin Scale w/o collection
>
> ############BCR 16 Populatin Scale
> bcrLAP_nests=924-73  #nests from density expansion to uncollected part of
BCR 16
> ca_nests=73    #nests from density expasion to collected part of LAP
> bcrLAP_nestsT=bcrLAP_nests+ca_nests;bcrLAP_nestsT
[1] 924
> bcrLAP_Fledged=(bcrLAP_nests*Prod_base)+(ca_nests*Prod_aCA);bcrLAP_Fledged
    mean sd  1% 2.5% 25% 50% 75% 97.5%  99% sims
[1]  596 43 -66   45 362 534 731  1180 1378 2500
> bcrLAP_needed=bcrLAP_nestsT*Prod_needed;bcrLAP_needed
    mean sd   1% 2.5% 25% 50% 75% 97.5%  99% sims
[1]  511 21 -320 -210 186 463 772  1533 1819 2500
> DbcrLAP_Fledged=bcrLAP_Fledged-bcrLAP_needed;DbcrLAP_Fledged
    mean sd    1%  2.5%  25% 50% 75% 97.5%  99% sims
[1]   85 43 -1416 -1108 -280  84 416  1043 1234 2500
> DbcrLap_Prod=DbcrLAP_Fledged/bcrLAP_nestsT;DbcrLap_Prod
     mean  sd   1% 2.5%  25%   50%  75% 97.5% 99% sims
[1] 0.092 1.4 -1.5 -1.2 -0.3 0.091 0.45   1.1 1.3 2500
>
> ############bcr Local Area Populatin Scale w/o collection
> bcrLAP_base=bcrLAP_nestsT*Prod_base;bcrLAP_base
    mean sd  1% 2.5% 25% 50% 75% 97.5%  99% sims
[1]  626 44 -81   32 377 557 774  1269 1475 2500
> DbcrLAP_base=bcrLAP_base-(bcrLAP_nestsT*Prod_needed);DbcrLAP_base
    mean sd    1%  2.5%  25% 50% 75% 97.5%  99% sims
[1]  115 45 -1416 -1104 -265 107 450  1111 1301 2500
> ############Local Area Populatin Scale w/o collection
>
> #Boxplots
> layout (matrix(1:1, ncol=1))
> # daPsP=prod_needed-
> # preColl=unlist(daPsP)
> # summary(preColl) #unharvested difference between needed and observed
> postCollHNL=unlist(pfaSimG-spSimG)
> summary(postCollHNL)  #harvested diference between needed and observed HNL
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
-2.7100 -0.5389 -0.1695 -0.2133  0.1654  1.6410
> postCollCA=unlist(postCollCA)
> summary(postCollCA)
    Min.  1st Qu.   Median     Mean  3rd Qu.     Max.
-2.83800 -0.58860 -0.23070 -0.28710  0.07041  1.07700
> #prodLAP_CA=unlist(prodLAP_CA)
>
>
bplot=cbind(unlist(DProd_baseCA),unlist(DProd_base),unlist(DProd_aCA),unlist(
DProd_aHNL))
> library(graphics)
> names=c("Collection Area","HN Lands","Collection Area","HN Lands")
> boxplot.matrix(bplot,ylim=c(-
2,2),col="gray",notch=TRUE,names=names,ylab="Actual - Needed Productivity",
+                main="Tribal Land Productivity With and Without Collection")
> abline(h=0, col="red")
>
```

```
>
bplot=cbind(unlist(DhnlLAP_base),unlist(DhnlLap_Prod),unlist(DbcrLap_Prod),un
list(DcaLap_Prod))
> library(graphics)
> names=c("No Collection","HN Lands LAP","BCR 16","Collection Area LAP")
> boxplot.matrix(bplot,ylim=c(-
2,2),col="gray",notch=TRUE,names=names,ylab="Actual-Needed Productivity",
+                main="Local Area Population and BCR Productivity With and
Without Collection")
> abline(h=0, col="red")
> summary(spSimG-1)
```

Appendix D. Projected average annual take of nestling golden eagles from the collection area by the Hopi if take of golden eagle nestlings on the Navajo portion of collection area is reduced to five. Actual take data are from unpublished files of the U.S. Fish and Wildlife Service's Southwest Region; data were not available for 1998, 2000, 2001, and 2003.

	Actual total take on Collection Area	Actual take on Navajo portion of Collection Area	Projected take on Navajo portion of Collection Area if 5 were permitted	Projected Total take on Collection Area if 5 were permitted on Navajo Portion of Collection Area
1997	7	3	3	7
1998				
1999	32	10	5	27
2000				
2001				
2002	14	6	5	13
2003				
2004	26	10	5	21
2005	25	9	5	21
2006	22	3	3	22
2007	36	11	5	30
2008	38	18	5	25
2009	23	8	5	20
2010	11	8	5	8
2011	18	11	5	12
2012	17	5	5	17
average	**22.4**	**8.5**	**4.7**	**18.6**

Appendix E. Definitions of Terms and Acronyms Used in this Document

2009 FEA – *2009 Final Environmental Assessment*. This document analyzed a proposal to permit take of eagles as provided under the Bald and Golden Eagle Protection Act (see USFWS 2009b in **References** in this document).

BCR – *Bird Conservation Region*. The North American Bird Conservation Initiative defines BCRs as "… ecologically distinct regions in North America with similar bird communities, habitats, and resource management issues… These ecoregions encompass areas that are similar in their biotic (e.g., plant and wildlife) and abiotic (e.g., soils, drainage patterns, temperature, and annual precipitation) characteristics." See map at http://www.nabci-us.org/map.html.

CA – *collection area.* Geographical area in northeastern Arizona from which the Hopi Tribe annually collects GEs for religious purposes. The area is composed of lands of the Hopi Tribe and some of the western part or parts of lands of the Navajo Nation (exact boundaries are not disclosed to the public by either tribe).

EA – *Environmental Assessment*. Decision-making document under the NEPA (defined below) for evaluating potential positive and negative effects of proposed actions involving federal agencies. A goal of the EA is to determine whether the action will have "significant" effects on the environment; if so, an EIS (defined below) is warranted and if not, a FONSI (defined below) is prepared.

EIS – *Environmental Impact Statement*. Decision-making document under the NEPA (defined below) for evaluating potential positive and negative effects of proposed actions involving federal agencies. Differs from EA (defined above) in that a proposed action evaluated in an EIS has been determined to be potentially "significant."

FONSI – *Finding of No Significant Impact*. Document issued when the action considered in an EA (defined above) is found to have no "significant" impacts on environmental quality.

GE – *golden eagle*

LAP – *local area population.* For GEs, those individuals occurring on and within 140 miles of a specified action area such as an energy development site. The 140-mile criterion for GEs is based on the species' median natal dispersal distance in North America. The LAP encompasses the most likely area of exchange of individual eagles through immigration and emigration.

Median natal dispersal distance – Midpoint in a tabulation of distances between locations where individual GEs in North America were banded as nestlings or fledglings and where they subsequently were documented, via their bands, as adults during the breeding season. Based on an analysis used in the USFWS's 2009 Final Environmental Assessment (USFWS 2009b), this distance is 140 miles for GEs.

Navajo CA – Portion of the CA (defined above) that is on lands of the Navajo Nation (defined above).

NEPA – *National Environmental Policy Act*. The NEPA is an environmental law established in the United States in 1969 to protect natural resources through comprehensive evaluation of effects of proposed actions involving federal agencies. Key documents of the NEPA process are the EA and EIS (defined above).

non-CA – *non-collection area*. Portion of Navajo Nation's lands where the Hopi Tribe is not allowed to collect GEs.

OBA – *occupied breeding area.* Term used in describing the breeding biology of raptors (birds of prey), an OBA is the space defended by a mated pair of raptors, containing one or more nest sites. Sometimes referred to as an occupied territory.

Productivity – Average number of fledglings produced per breeding pair, regardless of whether a given pair lays eggs or has eggs that hatch. A pair of adult eagles that occupies a nest or group of nests through at least the early part of normal breeding season is considered a breeding pair; in years or areas where prey are scarce, some pairs of eagles may fail to lay or hatch eggs and their presence at nests may diminish as the normal breeding season progresses.

USFWS – *United States Fish and Wildlife Service*

significant – In the NEPA (defined above) process, "significant" requires consideration of both context and intensity (40 CFR 1501.7): (1) context – significance of an action must be analyzed in its current and proposed short- and long-term effects on the whole of a given resource; (2) intensity – refers to the severity of the effect.

RD – *Regional Director*

take – "…pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, destroy, molest, or disturb." (see USFWS 2009a in **References** in this document)

TA – *Technical Assessment*. The 2013 "Assessment of the Harvest of Golden Eagles on Lands of the Hopi Tribe and Navajo Nation" (**Appendix A** in this document)