Arizona Golden Eagle Productivity Assessment 2016

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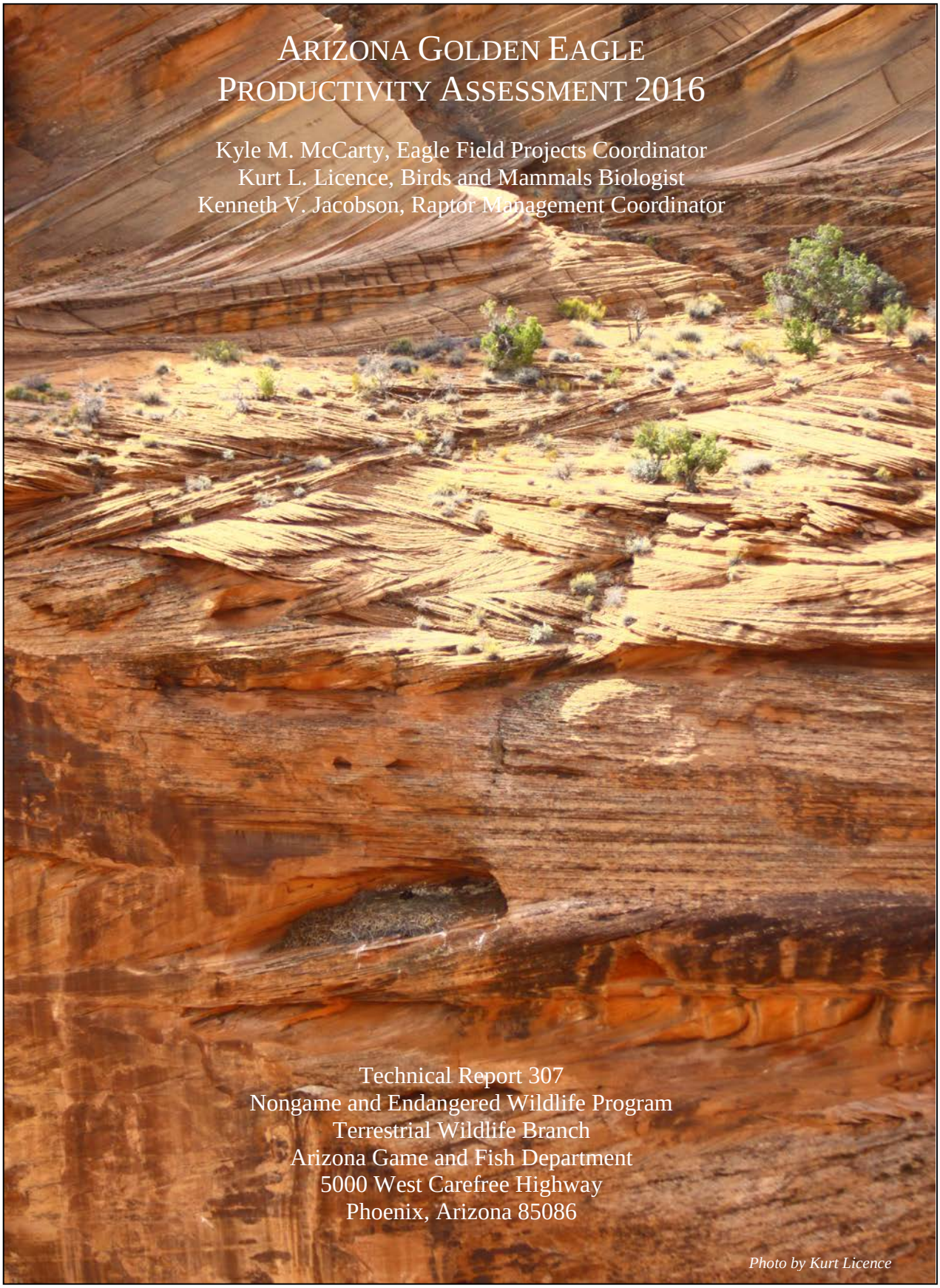

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Photo by Kurt Licence

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ARIZONA GOLDEN EAGLE PRODUCTIVITY ASSESSMENT 2016

Kyle M. McCarty, Kurt L. Licence, and Kenneth V. Jacobson

INTRODUCTION

In 1940, the U.S. Congress passed the Bald Eagle Protection Act to protect declining bald eagle populations (*Haliaeetus leucocephalus*). In 1962, this act was amended to include golden eagles (*Aquila chrysaetos*), becoming the Bald and Golden Eagle Protection Act (Eagle Act) (16 U.S.C. 668-668d, 54 Stat. 250). More recently, the U.S. Fish and Wildlife Service (USFWS) clarified the definition of disturb and finalized regulations providing a mechanism to authorize take (USFWS 2007a, b; USFWS 2009). For implementation of take permits to be compatible with the congressional intent of the Eagle Act (i.e., stable or increasing breeding populations), accurate population estimates and trends are needed (Millsap et al. 2013). In April 2012, the USFWS proposed revisions to eagle take permits which would have extended programmatic permits to a maximum of 30 years (USFWS 2012), a rule which was challenged in court and overturned. As a result, the USFWS developed a new proposal in May 2016 to reinstate the 30-year permit and to re-evaluate take permit implementation (USFWS 2016).

Prior to 2011, information on the status, distribution, and life history of breeding golden eagles in Arizona was limited (Millsap 1981, Eakle and Grubb 1986, Grubb and Eakle 1987, Corman and Wise-Gervais 2005). Observations collected by the Arizona Game and Fish Department (Department) were dated (i.e., 1970s), and no formalized study to document statewide population numbers had ever been implemented. In 2006, the Department conducted a ground survey effort limited to 85 previously known breeding areas (BAs) and found 14 were occupied by golden eagles (AGFD unpublished data). All of these past observations and other information from partners established a foundation for a more coordinated population assessment effort in Arizona. In 2010, the Southwestern Golden Eagle Management Committee (SWGEMC) was formed by land and wildlife management agencies to enhance coordination, increase communication, and provide oversight for Arizona golden eagle management. Some members of the SWGEMC provided funds to the Department to implement statewide nest inventory, occupancy, and productivity surveys.

From 2011 to 2014, the Department conducted statewide aerial occupancy and nest survey efforts for cliff-nesting golden eagles (McCarty and Jacobson 2011, 2012; McCarty et al. 2013, 2014). Building upon these initial survey results, the Department began assessing productivity at a subsample of known BAs in 2015 (McCarty et al. 2015). After the 2016 season, there were 255 current golden eagle BAs, 47 historic BAs, and 422 potential BAs outside of Native American lands in Arizona.

STUDY AREA

The USFWS manages golden eagles by Bird Conservation Regions (BCRs) (USFWS 2009), however in May 2016 the USFWS proposed changing eagle management units to correspond with national migratory flyways (USFWS 2016). Arizona includes BCR 16 (Southern Rockies/Colorado Plateau), 33 (Sonoran and Mohave Deserts), 34 (Sierra Madre Occidental), and a small portion of BCR 35 (Chihuahuan Desert) (NABCI 2000) (Figure 1).

In 2016, productivity assessments were conducted in all of Arizona's BCRs and included portions of every county except Yuma and Santa Cruz. Assessments occurred on BLM, U.S. Forest Service (USFS), State Trust, National Park Service (NPS), USFWS, and private lands.

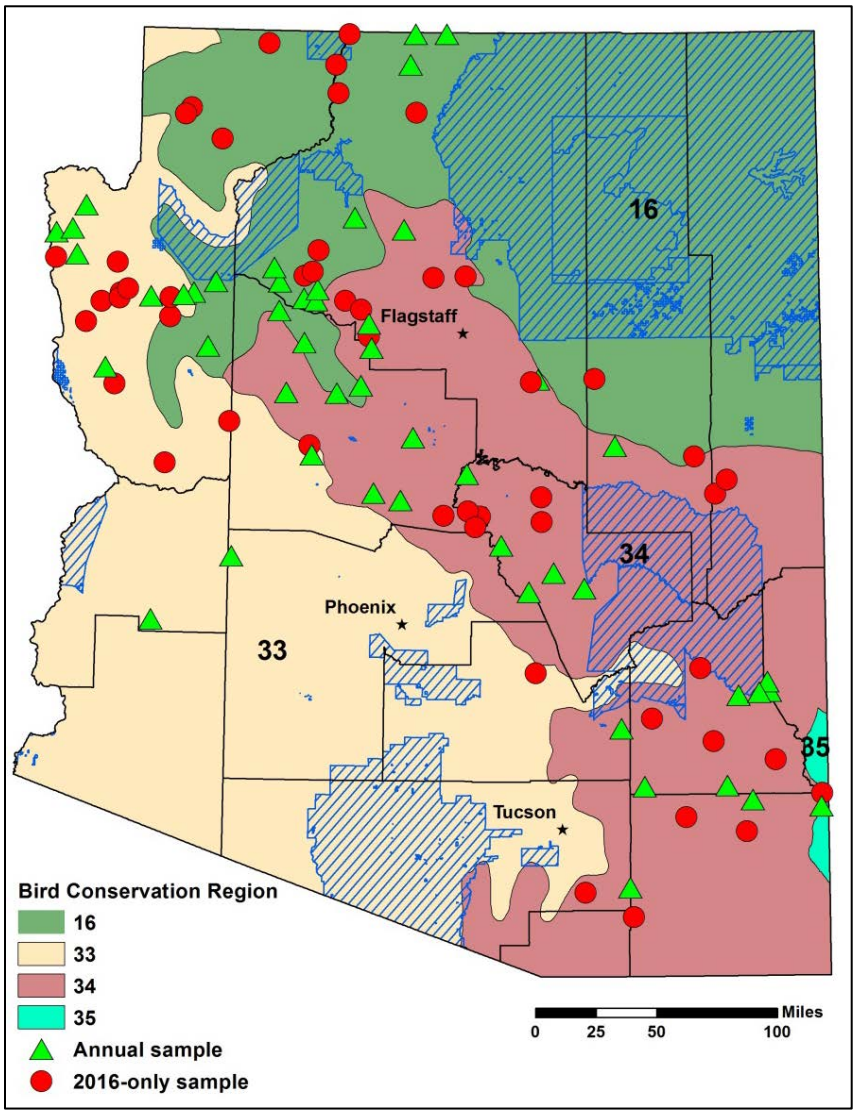

Figure 1. Distribution of golden eagle breeding areas (red circles and green triangles) randomly sampled for productivity in 2016. Native American lands blue shaded. County lines in black.

The surveyed areas included a variety of habitat types, characterized by eight biotic communities including Sonoran Desertscrub (Arizona Upland subdivision and Lower Colorado River Valley subdivision), Mohave Desertscrub, Great Basin Desertscrub, Semidesert Grassland, Plains and Great Basin Grassland, Interior Chaparral, Great Basin Conifer Woodland, and Rocky Mountain (Petran) Montane Conifer Forest (Brown 1994). Elevation ranged from approximately 600 m to 2,400 m (1,970 ft. to 7,875 ft.).

METHODS

Productivity assessments were conducted at golden eagle BAs across Arizona using a sampling strategy developed by the Department (Appendix A). Following this strategy, we selected a goal of at least 40% sampling rate. The 2016 sample included 100 BAs selected randomly from a pool of 246. Fifty of the sample BAs were to be surveyed annually, using 2015 as the first sampling year (McCarty et al. 2015). The other 50 BAs were surveyed in 2016 only and will be replaced by a different random subsample in 2017, excluding BAs already sampled in previous years.

For the productivity assessment, each BA was initially visited twice at approximately three weeks apart to determine its status. The first visit in mid to late February coincided with pre- and early-incubation behavior. The second visit occurred in early to mid-March to document occupancy of late-nesting pairs. All known nests were examined at each BA, and additional time was spent surveying for eagles and new nests if the known nests were empty. BAs found to be active after the first two visits were visited again in May and/or June to document the number of young reaching at least 80% of fledging age (7.5 weeks old). For golden eagles, measures of 80% of fledging age range from 51-56 days old (7.3-8 weeks) (Kochert et al. 2002, Driscoll 2010, Brown et al. 2013, Pagel et al. 2010). During the productivity assessment, additional non-sample areas were surveyed opportunistically for occupancy and/or new nests.

A two to three-person team of biologists conducted cliff-nest surveys by helicopter flown at approximately 60 m (200 ft.) above ground level and at 50-60 knots (approximately 60-70 mph). Altitude and speed were influenced by topography, ground-based obstacles (presence of high-tension wires, meteorological towers, etc.), and wind. Multiple aerial passes were sometimes necessary to accurately document occupancy and productivity. Some observations of final nest status were made via ground visits or fixed-wing aircraft instead of helicopters. A 1974 Cessna 185, 1981 Cessna 185, or 1977 Piper Super Cub PA-18 aircraft was utilized late in the season where the location, number and age of nestlings was already known and when they were older and more easily observed.

The minimum data recorded for all surveys included occupancy status, number of adults and their behavior, number of eggs and/or young, nestling age, and nest condition. At some sites we also documented size of nest, accessibility for ground and fixed-wing survey methods, and observations of other raptor species. Golden eagle nestlings were aged following Hoechlin (1976) and Driscoll (2010). The time and location of each nest observation were noted using a Garmin GPSMAP 62s unit. Digital photos were taken of active nests and most other large nests for further reference and archiving.

We followed operational definitions derived from Postupalsky (1974, 1983), Steenhof and Kochert (1982), and Driscoll (2010) to describe breeding status (Appendix B). An area was termed a "BA" only if it had been documented as occupied at least once within the last ten years. BAs with no documented occupancy for more than ten years were termed "historic BAs". However, in many cases a BA designated as historic reflects a lack of occupancy monitoring rather than a ten year period when the site was known to be unoccupied. Areas with one or more "large" nests but not enough observations to document positive occupancy status were termed as "potential BAs". All potential or historic BAs documented as occupied during nest surveys will be reclassified as BAs in future reports. "Large" refers to nests we considered having suitable qualities (e.g., large size and large sticks) for breeding golden eagles as compared to our experience with golden eagle nests in Arizona. "Medium" refers to nests that were not likely to have been large enough for golden eagle use.

RESULTS

The 2016 golden eagle productivity survey effort totaled 115.2 hours (6,909 minutes) of aerial surveys over 23 days (Appendix C), including 104 hours (6,240 minutes) of helicopter and 11.2 hours (669 minutes) of fixed-wing surveys. In addition, ground surveys were conducted for a total of five hours (300 minutes) over four days.

RESULTS OF PRODUCTIVITY ASSESSMENT AT SAMPLE BREEDING AREAS

We surveyed all of the selected BAs (n=100) for a sampling rate of 40.7% (100/246). In total, 67 of the BAs were occupied and 33 were unoccupied (Appendix D). Of the 67 occupied BAs, 58 were active. A total of 59 nestlings hatched at 43 of the active BAs, and 52 young fledged from 39 successful BAs. Productivity was 0.78 young fledged per occupied BA and mean brood size was 1.33 nestlings. Productivity was highest within BCR 16 (0.95, n=22 occupied) compared to BCRs 33 (0.67, n=12) and 34 (0.70, n=33) (Table 1).

Table 1. Summary of Arizona golden eagle productivity at sampled breeding areas in 2016.

	All sampled BAs	BCR 16	BCR 33	BCR 34
BAs examined	100	30	22	48
Occupied	67	22	12	33
Active	58	20	9	29
Failed breeding attempts	19	5	3	11
Successful breeding attempts	39	15	6	18
Young hatched	59	21	10	28
Young fledged	52	21	8	23
Nest success	0.58	0.68	0.50	0.55
Mean brood size	1.33	1.40	1.33	1.28
Productivity	0.78	0.95	0.67	0.70

Based on the observation of nestlings (aged by feather development), we estimated egg-laying and hatch dates for 43 of the active BAs, and fledge dates for 39 of those that were successful (Table 2). For this purpose, incubation period was considered to take 45 days and age at fledging to be 70 days old. Statewide, the average estimated start of egg-laying was February 17 (range

January 26 to March 12), average hatch date was April 2 (March 11 to April 26), and average fledge date was June 11 (May 20 to July 5). Estimated dates were the same for BCR 16 and BCR 33, with an average egg-laying date of February 15, hatch date March 31, and fledge date June 9. Timing in BCR 34 was four to five days later (Table 2). One sample BA included nests that were spread over BCR 34 and BCR 35, and was incorporated in the BCR 34 summary.

Table 2. Estimated egg-laying, hatching, and fledging dates at sampled breeding areas in 2016.

	Statewide total	BCR 16	BCR 33	BCR 34
Egg-laying	February 17 (n=43)	February 15 (n=15)	February 15 (n=7)	February 20 (n=21)
Hatch date	April 2 (n=43)	March 31 (n=15)	March 31 (n=7)	April 5 (n=21)
Fledge date	June 11 (n=39)	June 9 (n=15)	June 9 (n=6)	June 13 (n=18)

RESULTS OF OPPORTUNISTIC SURVEYS

Results of opportunistic surveys in 2016 included one or more visits to suitable golden eagle nesting habitat, potential BAs, historic BAs, or non-sample BAs. Notable findings include the documentation of five new BAs (Gold Star, Hodges, Martin Mountain 2, Paria River 2, Winchester Mountains 2) and three new potential BAs (Kaiser Spring, Mount Nutt, Redrock).

Areas worthy of discussion (new nests, eagle sightings) are described below. Nest locations are sensitive data, considered confidential by the Department, and omitted from this report. Management agencies requiring specific locations should contact the Department's Heritage Data Management System at (623) 236-7618.

Surveys in Suitable Nesting Habitat

Two new BAs were found while surveying suitable habitat in or near sample BAs, and a third new BA was discovered while in route to another survey location. Three new potential BAs consisting of eight nests were also identified (Table 3).

Gold Star (new BA). – On March 8, a golden eagle was incubating in a new cliff nest (#1). On May 9, one 5.5-week old nestling was observed (Figure 2).

Kaiser Spring (new potential BA). – On May 12, two new large nests (#1, #3) and one medium nest (#2) were found. No eagles were seen.

Martin Mountain 2 (new BA). – On May 9, a 4.5-week old nestling was found in a new nest (#1) (Figure 2). The new nest was located only 0.8 miles from another active golden eagle nest. On June 3, the nestling was 7-7.5 weeks old.

Mount Nutt (new potential BA). – On March 9, two new large nests (#1, #2) were spotted while in transit to a survey area. No eagles were seen.

Paria River 2 (new BA). – On February 23, we found two active golden eagle nests within an area we had previously considered as a single territory. We re-assigned several of the alternate nests to create a new breeding area, and also found three new nests (#7-9).

Redrock (new potential BA). – On February 16, we examined three nests discovered by SWCA Environmental Consultants (SWCA) in 2013. One large nest (#1) was observed. The other two nests (#2, #3) were possibly too small for use by eagles.

Figure 2. Gold Star (left) and Martin Mountain 2 (right) breeding areas. Photos by Kurt Licence.

Table 3. Summary of surveys in suitable nesting habitat in 2016.

Breeding area name	ID[1]	County	Dates surveyed	Comments
Gold Star	3GE075	Yavapai	3/8, 5/9	New BA. 3/8: Incubating in new nest #1. 5/9: One nestling 5.5 weeks old.
Kaiser Spring	3NE120	Mohave	5/12	New potential BA. Three nests found (#1-3).
Martin Mountain 2	3NE098alt	Yavapai	5/9, 6/3	New BA. 5/9: One nestling 4.5 weeks old. 6/3: Nestling 7-7.5 weeks old.
Mount Nutt	3NE121	Mohave	3/9	New potential BA. Two nests found (#1-2).
Paria River 2	2GE088	Coconino	2/23, 3/14, 5/14, 6/2	New BA. 2/23 & 3/14: Incubating in nest #7. 6/2: Nestling 8-9 weeks old.
Redrock	5NE130	Cochise	2/16	New potential BA. Three nests found (#1-3).

[1]Breeding area identification number.

Potential Breeding Areas

Two new BAs were confirmed out of nine potential BAs that were examined for occupancy (Table 4). Because observations were made opportunistically during other surveys, final status was not documented at either of the two new BAs. In addition, SWCA provided data on an additional potential BA (Cataract Canyon North 1) and confirmed occupancy and success at that site.

Aubrey Wilderness 2. – On February 18, four new large nests (#5-8) were found on cliffs.

Cataract Canyon North 1 (*new BA*). – Surveys were conducted by SWCA. On February 29, a golden eagle was incubating in nest #5. On April 27, there were two nestlings 4-4.5 weeks old. On May 25, the nestlings were 8-8.5 weeks old.

Hodges (*new BA*). – On June 2, a pair of golden eagles was perched between nests #1 and #2 (Figure 3), and greenery was seen in nest #2. Three new large nests (#3-5) were also found.

Parashant 6. – On February 23, a new large cliff nest (#5) was found.

Winchester Mountains 2 (*new BA*). – On March 7, a golden eagle was incubating in nest #1. One nestling was seen on May 10 and May 19 (Figure 3). The nestling was approximately eight weeks old on May 25.

Figure 3. Golden eagles at Hodges (left) and Winchester Mountains 2 (right), new breeding areas.

Table 4. Summary of potential breeding areas examined during nest surveys in 2016.

Location name	ID[1]	County	Dates surveyed	Comments
Aubrey Wilderness 2	3NE002	Mohave	2/18	All known nests empty. No eagles. New nests #5-8 found.
Cataract Canyon North 1*	2NE068	Coconino	--	2/29: Golden eagle incubating in nest #5. 5/25: Two nestlings 8-8.5 weeks old.
Clear Creek 2	2NE079	Navajo	2/24, 3/15	All known nests empty. No eagles.
Galiuro Mountains 10	5NE089	Graham	2/16	All known nests empty. No eagles.
Galiuro Mountains 8	5NE087	Graham	2/16	All known nests empty. No eagles.
Hardscrabble Cyn. 2	6NE033	Gila	2/17	All known nests empty. No eagles.
Hodges*	3NE117	Mohave	6/2	Pair of adult golden eagles perched. Some greenery in nest #2. New nests #3-5 found.
Little Table Mountain	5NE076	Pinal	2/16	All known nests empty. No eagles.
Parashant 6	2NE104	Mohave	2/23, 3/14	All known nests empty. No eagles. New nest #5 found.
Winchester Mtns. 2*	5NE045	Cochise	2/16, 3/7, 5/10, 5/19, 5/25	3/7: Golden eagle incubating in nest #1. 5/25: Nestling ≥8 weeks old.

[1]Breeding area identification number.
*Indicates a new breeding area was confirmed.

Historic Breeding Areas

Two historic BAs were examined, and one site was confirmed re-occupied (Table 5).

Hells Half Acre. – On April 21, two nestlings 4.5-5 weeks old were found in nest #3.

Table 5. Summary of historic breeding areas surveyed in 2016.				
Breeding area name	ID[1]	County	Dates surveyed	Comments
Big Spring Canyon	5GE011	Graham	2/16	All known nests empty. No eagles.
Hells Half Acre	3GE005	Mohave	4/21	Two nestlings 4.5-5 weeks old in nest #3.

[1]Breeding area identification number.

Breeding Areas

In addition to the 100 sample BAs surveyed for productivity, four non-sample BAs were opportunistically surveyed. Occupancy was confirmed at one of these additional BAs (Table 6). Because observations were made opportunistically, final status was not documented.

Grand Wash 3. – On April 6, a golden eagle was incubating in nest #3.

Table 6. Summary of non-sample breeding areas surveyed in 2016.				
Breeding area name	ID[1]	County	Dates surveyed	Comments
Bar Ten	2GE079	Mohave	5/17	All known nests empty. No eagles.
Grand Wash 3	3NE044	Mohave	4/6	Golden eagle incubating in nest #3.
Lost Spring	2NE018	Mohave	3/14	All known nests empty. No eagles.
Mailbox Mesa	6NE038	Gila	2/17	All known nests empty. No eagles.

[1]Breeding area identification number.

DISCUSSION

The 2016 results represent the second year of a multi-year assessment of golden eagle productivity in Arizona. While there are limitations to drawing conclusions based on two seasons of data, mean brood size, productivity, and occupancy rate were all higher this year compared to 2015 (Table 7). Further, BCR 16 showed higher productivity (by 33-42%) than either BCR 33 or 34 in both years. Overall timing of reproduction was comparable between 2015 and 2016, only differing by a few days. The estimated dates for egg-laying, hatching, and fledging occurred earlier in BCR 16 this year than in 2015. Real differences are likely to exist in reproductive parameters between the diverse assemblage of biological communities that occur in Arizona. These differences will be more confidently assessed after additional seasons of data have been gathered.

Productivity values in 2015-2016 fall within the ranges observed in other studies (Table 8). In west-central Arizona Millsap (1981) observed high productivity and abundant prey populations during a two-year study. Other examinations found that changes in food abundance and weather patterns lead to annual variation and have a significant influence on reproduction (Kochert et al. 2002, McIntyre and Adams 1999, Steenhof et al. 1997, Watson et al. 1992). Northern populations of golden eagles are noted as having smaller broods and fewer young fledged than more temperate populations for a variety of possible reasons, including harsher climate (Kochert et al. 2002). Breeding golden eagles in many parts of Arizona also face extreme climate in the form of heat stress which could lead to lowered productivity.

Table 7. Summary of golden eagle productivity at sampled breeding areas in 2015-2016.

	2015 total	2016 total	Combined
BAs examined	87	100	187
Occupied	45 (51.7%)	67 (67.0%)	112 (59.9%)
Active	42	58	100
Failed breeding attempts	17	19	36
Successful breeding attempts	25	39	64
Young hatched	34	59	93
Young fledged	28	52	80
Nest success	0.56	0.58	0.57
Mean brood size	1.12	1.33	1.25
Productivity	0.63	0.78	0.71

Table 8. Comparison of golden eagle productivity and brood size research.

Study	State	Years	Annual mean brood size	Brood size range	Mean annual productivity	Productivity range
This study	AZ	2	1.25	1.12 - 1.33	0.71	0.63 – 0.78
McIntyre 2002	AK	12	1.45	1.13 - 1.68	0.68	0.16 - 1.16
Phillips et al. 1990	MT/WY	11	1.30	1.1 - 1.8	0.78	0.37 - 1.5
Steenhof et al. 1997	ID	24	1.56	1.0 - 2.0	0.79	0.16 - 1.38
Phillips and Beske 1990	WY	5	1.48	1.33 - 1.65	0.81	0.52 - 1.16
Thompson et al. 1982	OR	16	1.70	1.42 - 2.0	1.08	0.20 - 1.67
Millsap 1981	AZ	2	1.58[a]	--	1.25	--

[a]Per active nest.

The observed occupancy rate of sampled BAs was 51.7% (n=45) of 87 BAs in 2015 and 67.0% (n=67) of 100 BAs in 2016 (Table 7). We also observed 56.0% (n=42) of 75 BAs were occupied in 2013, and 43.2% (n=32) of 74 BAs were occupied in 2014, but did not examine the same complement of BAs (McCarty et al. 2013, 2014). By comparison, McIntyre (2002) found an overall occupancy rate of 83.0% (ranging from 69.7% to 93.4%) in a long-term study of golden eagles in Alaska using a combination of foot, dogsled, and helicopter. Observed occupancy rates may be low in our study partially due to reliance on aerial surveys and the difficulty in detecting resident eagles that do not commence egg-laying. Due to the size of our study area, ground surveys are extremely time-intensive and often impractical.

The first two rounds of aerial surveys to document occupancy in 2016 were timed well and coincided with egg-laying in mid-February to mid-March for the majority of BAs. Occupancy surveys should continue to be scheduled around this time, although the start of the first round could potentially be moved a week earlier (February 12). Data on estimated dates for nesting chronology was combined for 2015 and 2016 and showed that 90% of egg-laying was estimated to occur February 5 to March 5 (n=69, average Feb 18) and 90% of hatching was estimated March 21 to April 19 (n=69, average April 3) (Figure 4). The combined data also revealed 90% of fledging was estimated to occur May 28 to June 28 (n=61, average June 12), meaning the timing of surveys to observe fledging success at occupied BAs should begin in mid-May when the first nestlings reach 80% of fledging age (Figure 4). Since we determined the age of nestlings by plumage development, this could have led to errors in estimation of nesting chronology. However, the use of digital photographs allowed examination of nestlings in greater detail,

improved the accuracy of ageing the young, and provided an archive of images for future reference.

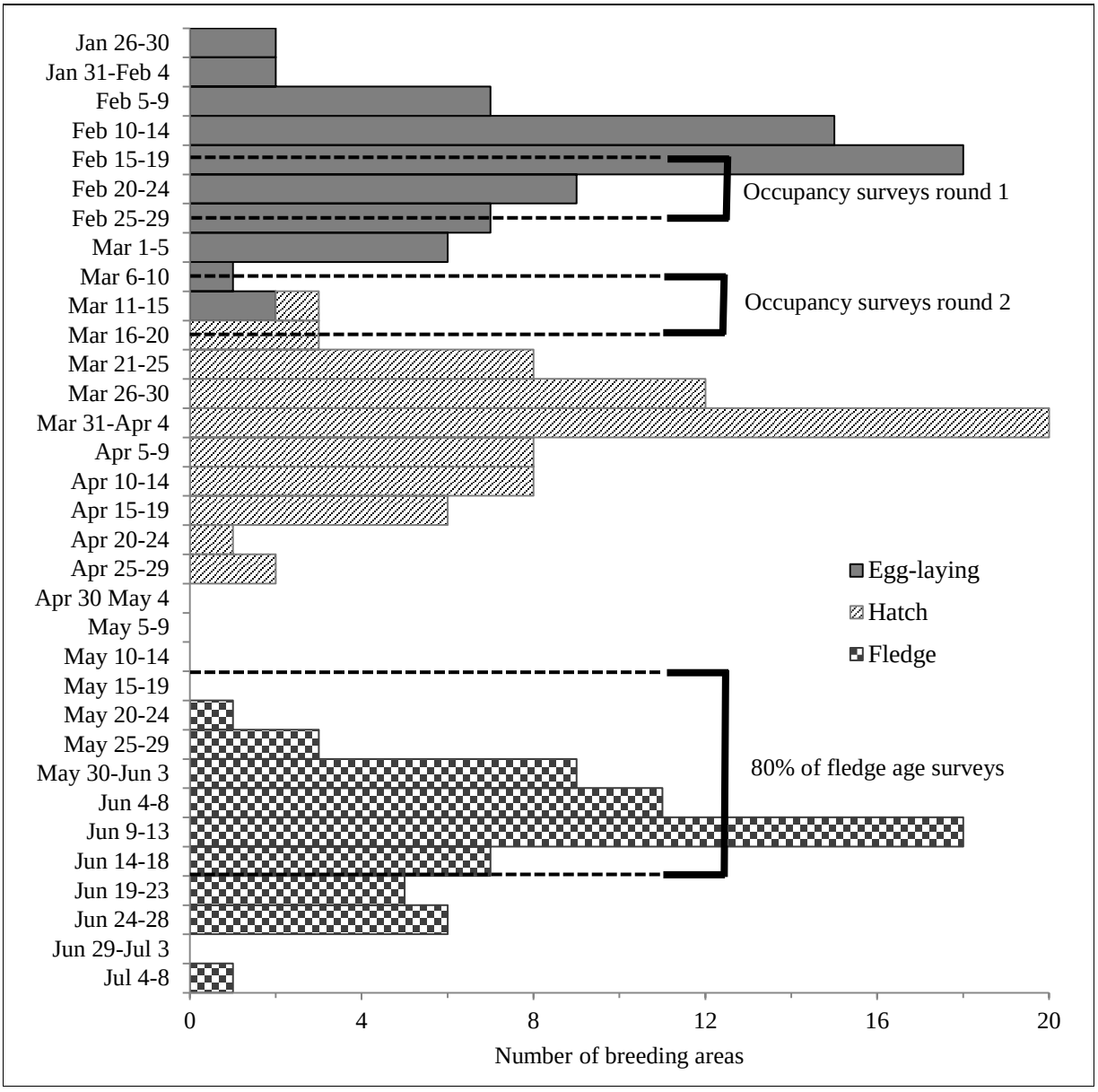

Figure 4. Estimated egg-laying, hatching, and fledge dates at sampled golden eagle breeding areas in 2015-2016, including recommended timing for future surveys.

Fixed-wing aircraft proved to be an effective survey method this year, with caveats. Helicopters are superior tools early in the breeding season, when all known nests must be located and the ability to view cliffs from various heights and angles is required for methodical searching. Helicopters also excel at slow, stable flight and provided better platforms from which to photograph nestlings and determine nestling ages. We only used fixed-wing aircraft late in the season to document success at breeding areas where the number of nestlings had already been

determined and the young were large, dark and observable from greater distances and at greater speeds (nestlings at least 80% of fledging age). Fixed-wing aircraft allowed us to more quickly re-visit breeding areas across a wide geographic area, and at much less cost than helicopters.

Currently in Arizona, there are 255 known golden eagle BAs, 47 historic BAs, and 422 potential BAs with 757 large nests, excluding those that occur on Native American lands (Figure 5, Table 9).

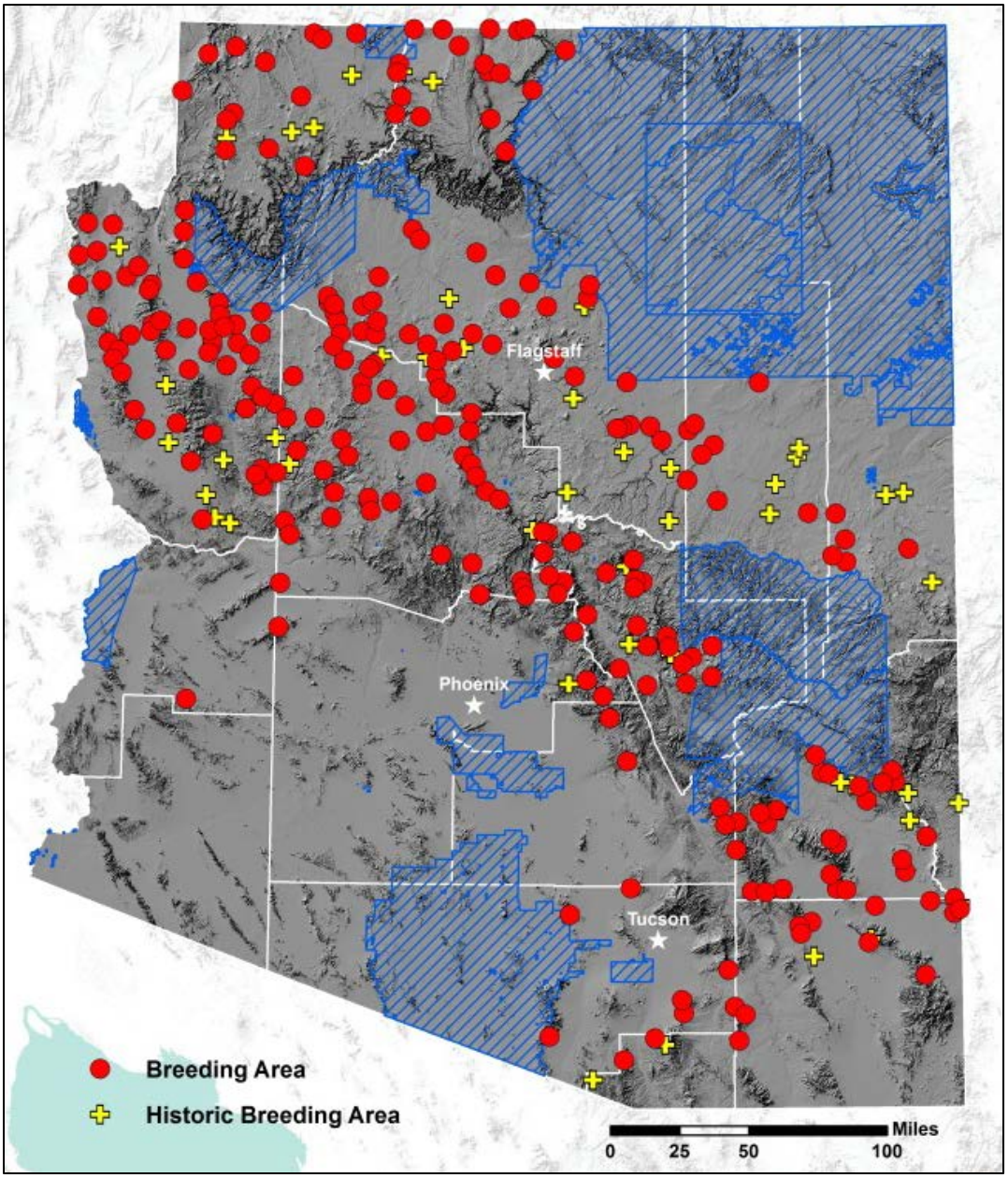

Figure 5. Distribution of current (red circles) and historic (yellow crosses) golden eagle breeding areas in Arizona, excluding Native American lands (blue shaded). County lines in white.

Table 9. Number of known, historic, and potential golden eagle breeding areas (BAs), and large nests within potential BAs, by Bird Conservation Region as of 2016.

BCR number	BAs	Historic BAs	Potential BAs	Large Nests
16	78	13	83	154
33	55	9	147	296
34	121	24	190	300
35	1	1	2	7
Total	255	47	422	757

MANAGEMENT RECOMMENDATIONS

1. Schedule the first round of aerial surveys in mid to late February for all BCRs to document occupancy and egg-laying. Schedule the second round of aerial surveys in early to mid-March to document occupancy and/or activity at breeding areas that were unoccupied during the first round of surveys. Schedule aerial surveys as appropriate starting in mid-May to document success (nestlings at least 80% of fledging age) or failure of each breeding attempt.
2. Incorporate ground surveys into the monitoring plan whenever possible. Ground surveys would be most beneficial in mid-March at BAs where occupancy was not detected after the first round of aerial surveys, and would also be useful to confirm fledging success later in the season. Ground surveys should be strategically planned to occur only at BAs with easy access (good roads/tracks nearby and/or short hikes).
3. Continue to utilize fixed-wing aircraft for late-season nest checks where ground or helicopter surveys are not suitable due to limited access and/or large distances between survey sites.
4. Future nest survey efforts should focus on unsurveyed segments of suitable habitat within each of Arizona's three main BCR's.
    a. In BCR 16, the Grand Wash Cliffs north of Grand Canyon, Andrus Canyon, Kanab Creek and tributaries (Grama and Hack Canyons), Kaibab Plateau, Saddle Mountain Wilderness Area, Marble Canyon, Grand Canyon National Park.
    b. In BCR 33, portions of Yuma Proving Ground, Barry M. Goldwater Range, Organ Pipe National Monument, Kofa and Cabeza Prieta National Wildlife Refuges, and Buckskin, Dome Rock, Eagletail, Gila Bend, Rawhide, and Trigo Mountains.
    c. In BCR 34, portions of the Superstition Wilderness, southern Tonto National Forest, Mule Mountains, Coconino National Forest (Sedona area), Coronado National Forest (including portions of Atascosa, Chiricahua, Huachuca, Patagonia, Pinaleno, and Santa Catalina, and Santa Rita Mountains), and Apache-Sitgreaves National Forest (San Francisco and Blue Rivers).
5. Partner with tribes and Department of Defense whenever possible to conduct nest inventory or occupancy surveys to fill in gaps of golden eagle distribution.
6. Continue to re-visit potential BAs in order to document occupancy. Highest priority includes areas where a single golden eagle was found near a large nest, and those areas with multiple large nests in fair to good condition.
7. Investigate additional research methods (including nest cameras) to identify causes of early nesting cycle failures, nest attendance, productivity, provisioning, and diet of golden eagles.
8. Develop a plan to effectively survey for golden eagle nests in trees.

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APPENDIX A: PROPOSED METHODOLOGY FOR GOLDEN EAGLE BREEDING AREA OCCUPANCY AND PRODUCTIVITY ASSESSMENTS

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Background

Implementation of the Bald and Golden Eagle Protection Act (BGEPA) has been revised to authorize issuance of permits for the limited take of bald and golden eagles, where take is associated with otherwise lawful activities. Permit thresholds for golden eagles are currently set at the Bird Conservation Regions level and will not exceed one percent of the annual productivity. Few long-term studies of golden eagle populations in North America have been undertaken, and only estimates of abundance are available. Hamerstrom et al. (1975) reported that there were as many as 100,000 individuals in North America, and Olendorff et al. (1981) estimated the wintering population of golden eagles in the western U.S. at 63,242 birds, with a potential 20,500 North American breeding pairs. Watson (1997) estimated the number of breeding pairs at 20,000-25,000 in North America. More recently, WEST, Inc. (Nielson et.al. 2009) estimated the golden eagle population across much of the western United States at 24,734. Due to the limited information on the population status nationally and locally, the United States Fish and Wildlife Service (USFWS) is deferring implementation of new permits until data shows that populations can withstand additional take. State agencies need to collect this information on golden eagle populations so that the USFWS can ultimately allow for golden eagle take associated with otherwise lawful activities.

Compounding the need for current information on golden eagle populations is the increased mandate on renewable energy resource development. This renewable energy development has placed a significant demand on land and wildlife managers to assess these projects and their impacts. These projects, specifically wind and solar, will have long term effects on golden eagles (e.g., mortality through collisions, habitat fragmentation, reductions in prey base). Federal and local permitting agencies will have to address those effects on the local population within approximately 10-miles of each project as well as the project's effect on the regional population within 140 miles, per the BGEPA. Without baseline nest location, occupancy, and productivity data with which to evaluate these effects, permitting agencies are unable to ensure compliance with federal law.

In Arizona, little was known about golden eagle distribution or their status. Surveys were conducted in the 1970s, but fell far short of being comprehensive or statewide. In 2006, the Arizona Game and Fish Department (AZGFD) attempted to assess the golden eagle population by examining from the ground 85 historic nest locations recorded in the Heritage Database Management System (HDMS). Only 14 were found to be occupied. Many of the nest sites had not been visited since the 1970s and because no follow-up surveys were conducted, we were unsure if pairs moved their nest location since originally documented or if the pairs had abandoned the areas altogether. The 2006 effort and results made it clear that any revived ground surveys would be time/cost inefficient, and a helicopter nest survey was needed to establish a new baseline of nest locations statewide. In 2010, the AZGFD acquired funding to conduct a two-year (2011-2012) statewide aerial survey for golden eagle cliff nests. The nest search efforts resulted in the discovery of 328 potential breeding areas with unknown occupancy status and 67 newly discovered occupied breeding areas. Building upon the results of the nest search, the AZGFD began a 2-year (2013-2014) statewide occupancy assessment to determine current occupancy status of all known breeding areas, historic breeding areas, and potential breeding areas (areas with 1 or more eagle sized nests).

Objectives

1. Develop methodology that provides estimates on number of golden eagle breeding areas and productivity estimation;

2. Quantify breeding area occupancy and productivity rates for golden eagles in Arizona's 3 Bird Conservation Regions;
3. Update Arizona's Heritage Data Management System with location, occupancy, and productivity data of golden eagles for the use in evaluating proposed project's effects on golden eagles, and;
4. Provide the USFWS with the statewide golden eagle demographic data necessary for issuance of BGEPA take permits.

Approach

The approach for developing golden eagle breeding area abundance, productivity, and occupancy estimates will depend on the availability and extent of current golden eagle information for a given area. For places like Arizona where recent, nearly statewide, nest searches and occupancy assessments have been conducted, a simple stratified random sampling of the known breeding areas, paired with continued nest searches will provide demographic occupancy and productivity estimates that can be extrapolated to the larger population. For areas without an extensive breeding area list, we also designed a stratified random sampling scheme to provide a search grid for identifying new golden eagle territories in conjunction with occupancy and productivity assessments.

In order to determine the sample size necessary to yield productivity estimates representative of the greater population, we used bald eagle productivity data from 2002 to 2013 as a training data set. Although the annual variation of occupancy and reproductive output within the bald and golden eagle populations likely differ, both eagle species have the same reproductive output potential (e.g. 0 to 3 fledglings). When available, use of golden eagle productivity data is recommended. Additionally, this sample size analysis should be repeated once adequate golden eagle productivity data is available.

The bald eagle population ranged from 46 (2002) to 68 (2013) breeding areas which is approximately ¼ the number of Arizona's known golden eagle breeding areas. We bootstrapped this productivity and demographic occupancy data at five sampling rates (20, 30, 40, 50 and 60%). We pulled five replicates at each bootstrapping rate and calculated the mean and variance for productivity and demographic occupancy. We then calculated difference between the yearly mean estimates at each sample rate with the actual calculated rate with the 100% yearly sampling rate (*Figures 1and 2*).

Productivity

The 20% mean productivity (fledglings/occupied BA) sampling rate differed by 0.0707± and the 30% by 0.06142 ± from the actual rate, while the 40%, 50% and 60% rates differed by 0.05354±, 0.05182± and 0.0500± respectively. The 40%, 50% and 60% productivity sampling rates differed from the actual rate at similar levels (5%). Therefore, we recommend the 40% sampling rate as it provides an estimate of productivity indistinguishable from the two higher sampling rates. This sampling rate will provide an estimate of productivity within approximately 0.05 of the actual productivity (100% sampling rate). It is important to note that the 20% and 30% sampling rates varied by only 0.07 and 0.06 from the actual rates. Thus, these lower productivity sampling rates could also be applied if limited resources only allow for a 20% or 30% sample rate.

Demographic Occupancy

As with productivity, demographic occupancy sampling rates provide an estimate of the sample structure needed to represent 100% sampling rates. The difference between sampling rates and the actual demographic occupancy were 0.06813±, 0.04672±, 0.03676±, 0.03329± and 0.02745± at 20, 30, 40, 50 and 60% sampling rates, respectively. Once the sampling rate was increased past 20% they varied at less than 5% from the actual estimated demographic occupancy. Therefore, we recommend sampling rates of at least 30%. We can further reduce the error in demographic occupancy to 4% if a sampling rate of 40% is utilized. As with the productivity estimates we recommend a sampling rate of 40% for the maximum accuracy with the least effort. It is also possible to use the 20% and 30% sampling rates when resources are limited with the assumption that accuracy will be lower.

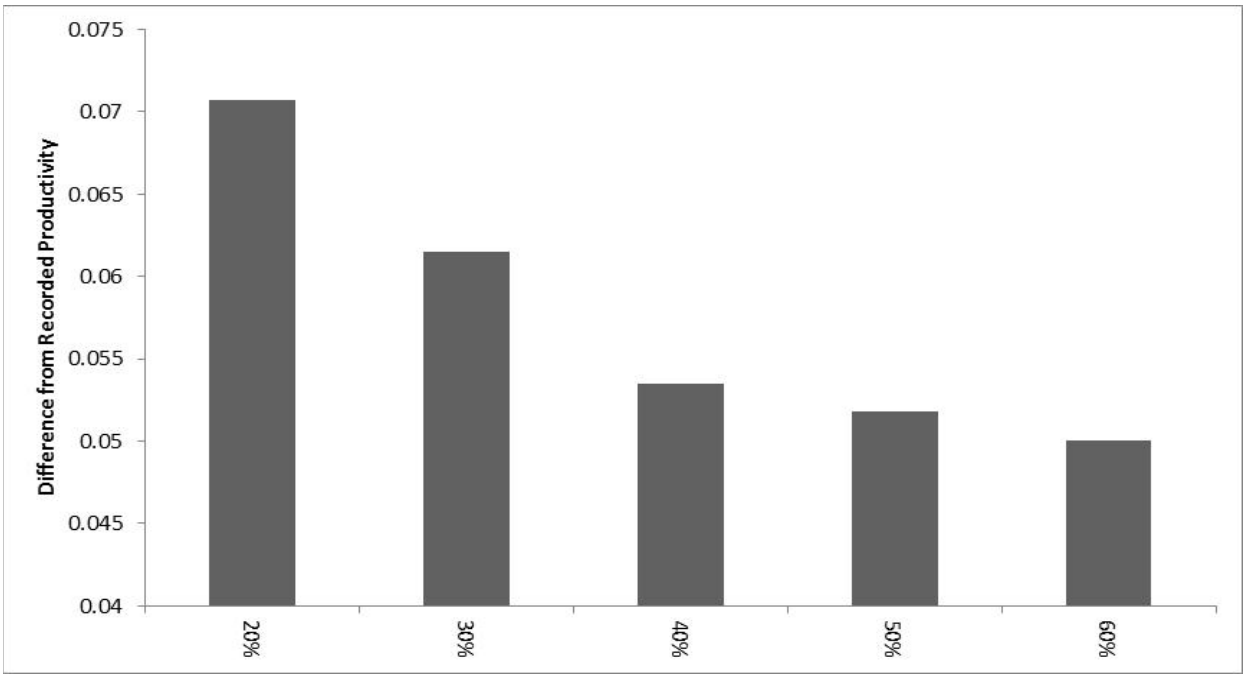

Figure 1. Comparison of sampling based on 20, 30, 40, 50 and 60% sampling rates of Bald Eagle productivity data.

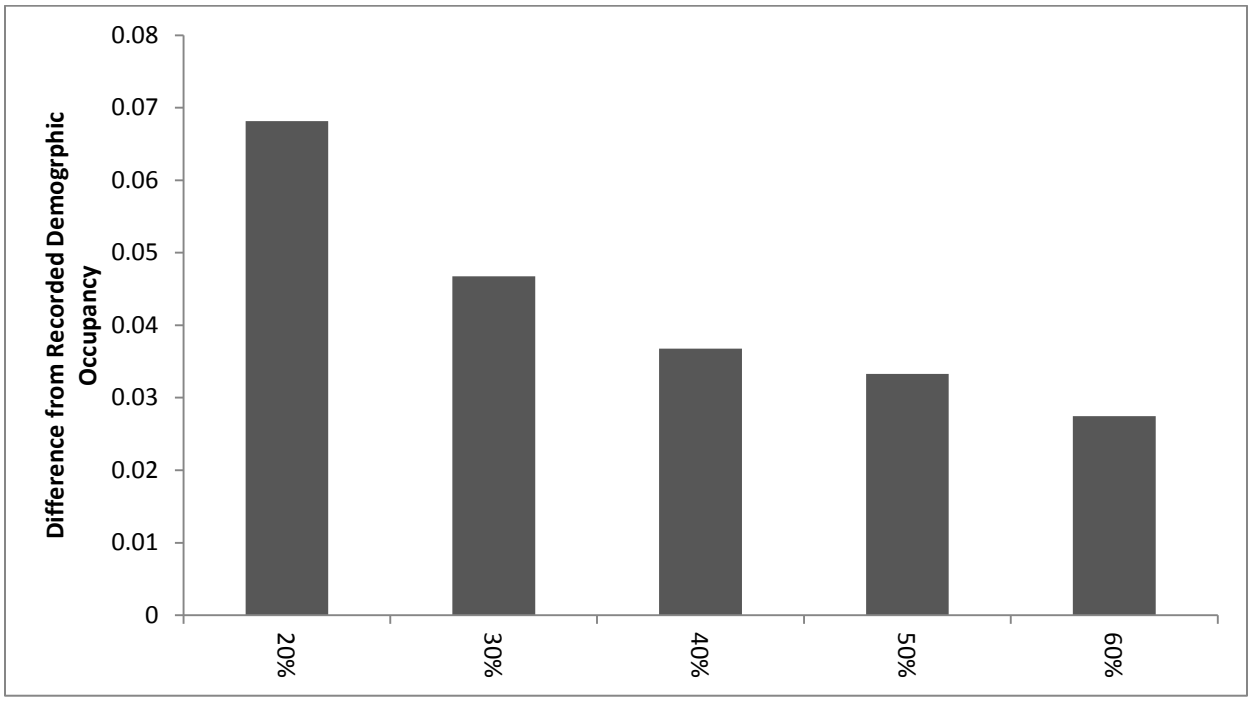

Figure 2. Comparison of sampling based on 20, 30, 40, 50 and 60% sampling rates of Bald Eagle demographic occupancy data.

Given these findings for productivity and demographic occupancy, we recommend using this 40% sampling rate as the basis for a stratified random sample of known golden eagle breeding areas. Sampling will be stratified across the three BCRs in Arizona (*Figure 3*). Within each sampling year (not necessarily consecutive), we will randomly select 40% of the known golden eagle breeding areas within each strata. Since golden eagle occupancy and productivity

rates are anticipated to have significant annual variation, we need to ensure that any documented variation in occupancy and productivity rates are actual and not just an artifact of the random sampling approach. As such, we will randomly select 20% of the known golden eagle breeding areas within each strata to be surveyed during each round of monitoring, without replacement. We will then select an additional 20% of known breeding areas to be monitored only in year one, without replacement, for a total of 40% sampling rate. In year 2, we will continue to sample the original 20% sample and select a new 20% sample from the remaining non-surveyed breeding areas. By year 4, the original 20% will have been sampled over 4 monitoring periods and the remaining 80% of the known breeding areas will have been monitored at least once. Newly discovered territories will be added to the random selection on the year of discovery. After a full round of monitoring, we will evaluate the necessity of maintaining the original 20% sample as part of the occupancy and productivity rate assessment. If deemed unnecessary, future surveys will be sampled by randomly selecting 40% of the known breeding areas during year one, and without replacing these breeding areas back into the sample, in year two we will continue to sample another 40%. By year three of the sampling, we automatically select the remaining 20% of breeding areas and randomly select an additional 20% from those breeding areas sampled in year one. This staggered sampling pattern will insure that no breeding area is selected in consecutive years. This sampling method will also ensure that after the third sampling year each year's productivity will be based on 20% of the original sample and 20% of a new sample group. The occupancy and productivity assessments will be conducted following the terminology and guidelines outlined in Appendix A. These methods will provide a statistically and biologically defensible golden eagle sampling strategy and provide reliable productivity and demographic occupancy rates across years and BCRs.

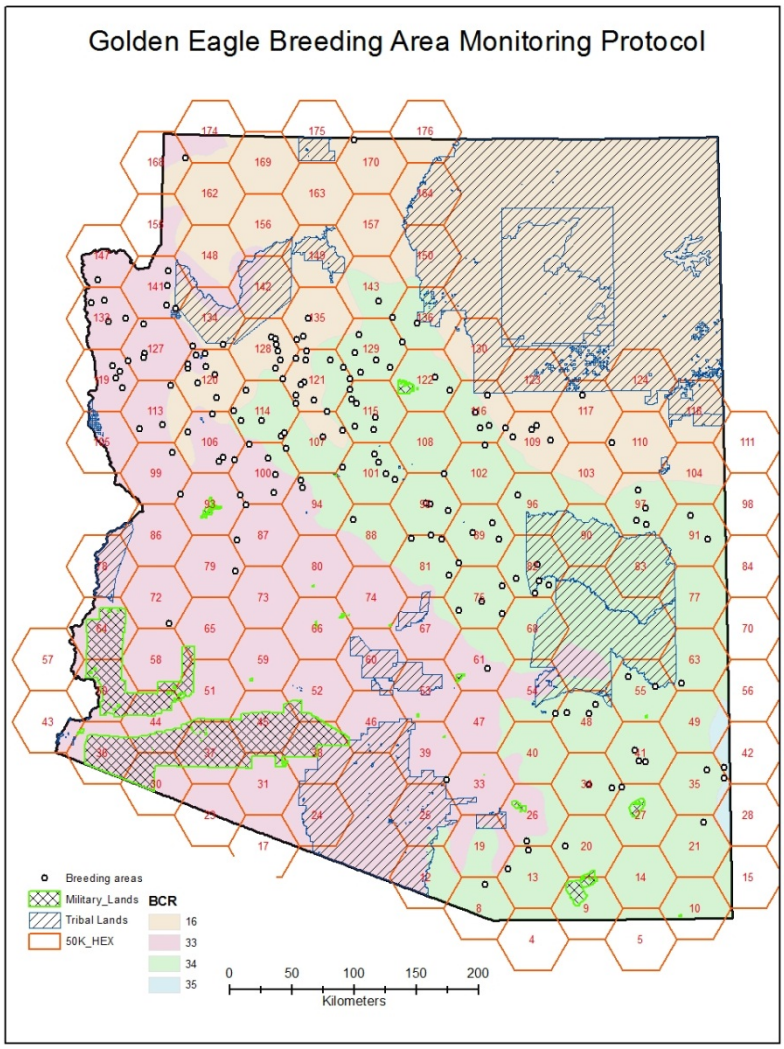

Figure 3. Golden eagle known breeding areas and the sampling grid for unknown cells within the state of Arizona.

While the above sampling strategy provides a methodology to estimate the productivity and demographic occupancy of known golden eagle breeding areas, it does not allow for the discovery of new breeding areas. For aerial based surveys, potential nest site habitat and historic breeding areas will be surveyed while in transit between the randomly selected breeding areas. For ground based surveys, nest search efforts need to be incorporated. To facilitate these ground and/or aerial based nest search efforts, golden eagle breeding habitat models may be developed to prioritize survey locations. Although not random, this approach provides opportunity for the known breeding area list to grow and maximizes efficiency of aerial survey time.

For areas without an extensive breeding area list, we designed a stratified random sampling scheme to provide a search grid for identifying new golden eagle territories in conjunction with occupancy and productivity assessments. As an example, we developed a 50 km tessellated grid for the entire state of Arizona totaling 133 grid cells (*Figure 3*). We will randomly select 15 grid cells in each BCR stratum (45 total cells per year) for golden eagle breeding area searches. By the third re-sample the entire state will have been searched and we will begin the resampling process anew. The sampling rate may be increased or decreased as dictated by available resources. Once a full round of sampling has occurred, a robust statewide breeding area and potential nest site list will have been compiled and the 40% stratified sampling approach may be implemented. The nest search, occupancy, and productivity assessments will be conducted following the terminology and guidelines outlined in Appendix A with the one exception, that nest searches should be timed during the early pair bonding and early occupancy period of the breeding season. This allows for time to perform a second occupancy visit and a final productivity visit once nestlings reach 80% of fledging age (~8 weeks). Use of this stratified random sampling scheme provides a framework to initiate golden eagle population surveys with data outputs that should be representative of the greater area. Consequently, initial survey results can be used to provide estimates of the greater population.

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APPENDIX B: TERMINOLOGY AND RAPTOR REPRODUCTIVE STATUS CRITERIA

Breeding Area (BA): An area containing one or more nests within the range of a mated pair of birds displaying occupancy as described below. Operationally, once a BA is established, we consider it a BA whether it is occupied by eagles in a given year or not, until or unless it is designated historical (i.e., ten consecutive years unoccupied).

Historic BA: A BA documented as having been unoccupied for ten consecutive years prior to the current year.

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

a. Young were raised.
b. Eggs were laid.
c. One adult sitting low in a nest, presumably incubating.
d. Two adults present on or near the nest.
e. One adult and one bird in immature plumage at or near a nest, if mating behavior was observed (display flight, nest repair, copulation).

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

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

Successful nest: An active nest from which at least one young fledged during the breeding season under consideration. Nests were successful if at least one young was raised past 80% of fledging age.

Failed nest: An active nest from which no young fledged regardless of cause.

Productivity: The number of young fledged per occupied BA.

APPENDIX C: AREAS SURVEYED IN 2016.

Table 10. Summary of aerial survey areas and survey time in 2016.

Date	Duration (min)	Survey type	Areas of Arizona surveyed	Sample BAs[1]
2/16	420	helicopter	Southeast, BCR 34.	16
2/17	426	helicopter	Central, primarily BCR 34.	17
2/18	402	helicopter	West and northwest, primarily BCR 33.	16
2/22	366	helicopter	North-central, BCR 16 and BCR 34.	28
2/23	372	helicopter	North, primarily BCR 16.	15
2/24	192	helicopter	East-central, BCRs 16 and 34.	7
3/7	444	helicopter	Southeast, BCR 34.	19
3/8	378	helicopter	Central, primarily BCR 34.	18
3/9	384	helicopter	Northwest, primarily BCR 33.	24
3/14	360	helicopter	North and north-central, BCRs 16 and 34.	21
3/15	276	helicopter	East-central, BCRs 16 and 34.	16
5/9	330	helicopter	Central, primarily BCR 34.	14
5/10	336	helicopter	Southeast, BCR 34.	12
5/12	288	helicopter	Northwest, primarily BCR 33.	19
5/16	198	fixed-wing	Central and east-central, BCRs 16, 33, 34.	6
5/17	264	helicopter	North, BCR 16.	9
5/18	96	helicopter	North-central, BCRs 16 and 34.	7
5/19	270	helicopter	Southeast, primarily BCR 34.	5
5/25	246	fixed-wing	Central, east, and southeast. BCRs 16, 33, 34.	6
5/26	216	helicopter	Northwest and west. BCRs 16, 33, 34.	9
6/2	264	helicopter	North and northwest, BCRs 16, 33, 34.	12
6/3	156	helicopter	Central, BCR 34.	7
6/14	225	fixed-wing	Central and north-central, BCRs 16 and 34.	4
Total	6,909			

[1]Number of productivity sample BAs surveyed.

Table 11. Summary of ground survey time in 2016.

Date	Duration (min)	Breeding areas surveyed (ID[1])
4/26	30	Mustang Mountains (5NE051)
5/27	60	Mustang Mountains (5NE051)
6/7	30	Dutch Mountain (1GE017)
6/17	180	Alchesay Canyon (6GE002)
Total	300	

[1]Breeding area identification number.

APPENDIX D: 2016 GOLDEN EAGLE PRODUCTIVITY

Table 12. Golden eagle breeding area summary at sampled BAs, 2016 (continued next page).

Breeding Area[1]	ID[2]	Status[3]	Nest number	Eggs[4] / Young / Fledged			Estimated date of:		
							Egg-laying	Hatch	Fledge
Bird Conservation Region 16									
Aubrey Cliffs 1	3NE063	F	1	1	--	--	2/22-3/15	--	--
Aubrey Cliffs 3	3GE044	S	3	1	1	1	2/22-3/15	3/15-5/12	>6/2
Austin Peak	3NE001	O	--	--	--	--	--	--	--
Big Bud Tank	3GE063	U	--	--	--	--	--	--	--
Boquillas	3GE040	U	--	--	--	--	--	--	--
Cataract Canyon North 2	2NE069	S	4	1	1	1	<5/16	<5/16	>5/25
Cherokee Point	3NE073	F	3	1	--	--	<2/22	--	--
Clear Creek	2GE075	U	--	--	--	--	--	--	--
Colton Crater	2NE054	F	7	1	--	--	<2/23	--	--
Granite	2GE049	S	5	2	2	2	1/29-3/18	3/18-4/21	>5/26
Hidden Canyon	2GE007	F	7	1	--	--	<2/23	--	--
Juniper Mountains 1	3NE059	S	1	1	1	1	2/22-3/15	3/15-5/12	>6/14
Juniper Mountains 3	3GE071	F	2	2	--	--	2/22-3/15	--	--
Kaibab 1	2NE011	U	--	--	--	--	--	--	--
Little Spring	2GE084	S	5	2	2	2	<2/23	3/14-5/17	>6/2
Little Sullivan Tank	3GE067	O	--	--	--	--	--	--	--
Loco Point	2GE009	S	6	3	3	3	<2/23	3/14-5/17	>6/2
Lost Spring 2	2NE019	U	--	--	--	--	--	--	--
Mount Floyd	3GE041	U	--	--	--	--	--	--	--
Parashant 1	2GE080	U	--	--	--	--	--	--	--
Paria River	2NE021	S	1	1	1	1	<2/23	3/14-5/17	>6/2
Peacock Mountains South	3NE065	S	2	1	1	1	<2/22	3/9-5/12	>6/2
Round Mountain	3GE042	S	4	1	1	1	<2/22	3/15-5/18	>5/26
Shinarump Cliffs	2GE046	S	6	1	1	1	<2/23	3/14-5/17	>5/17
Shivwits	2GE081	S	4	2	2	2	<2/23	3/14-5/17	>6/2
Sullivan Buttes	3NE095	S	1	2	1	1	<2/22	3/9-5/12	>5/26
Sumac	3GE068	S	2	2	2	2	<2/22	3/15-5/18	>6/2
The Canal	1GE009	S	2	1	1	1	<2/24	3/15-5/16	>5/25
Top Rock	2GE010	S	4	2	1	1	<2/23	3/14-5/17	>6/2
Two Mile	2GE077	U	--	--	--	--	--	--	--
Bird Conservation Region 33									
Aubrey Peak Wilderness	3GE001	S	9	1	1	1	2/18-3/9	3/9-5/12	>5/26
Black Mtns 3	3NE028	U	--	--	--	--	--	--	--
Black Mtns 9	3NE036	O	--	--	--	--	--	--	--
Black Mtns 23	3NE021	S	7	2	2	2	<2/18	3/9-5/12	>6/2
Black Mtns 28	3NE026	U	--	--	--	--	--	--	--
Black Mtns 32	3GE072	U	--	--	--	--	--	--	--
Black Mtns East	3GE025	U	--	--	--	--	--	--	--
Black Mtns North	3GE032	S	1	2	2	2	<2/18	3/9-5/12	>5/26
Black Mtns South	3GE034	U	--	--	--	--	--	--	--
Burro Creek Wilderness 1	3GE065	U	--	--	--	--	--	--	--
Cerbats 2	3NE039	U	--	--	--	--	--	--	--

[1]Shaded BAs are to be monitored annually.
[2]Breeding area identification number.
[3]F=failed; S=successful; O=occupied; U=unoccupied.
[4]Represents minimum number of eggs laid.

Table 12 (continued).

Breeding Area[1]	ID[2]	Status[3]	Nest number	Eggs[4] / Young / Fledged			Estimated date of:		
							Egg-laying	Hatch	Fledge
Cerbats East	3NE040	S	3	1	1	1	<3/9	3/9-5/12	>6/2
Cerbats West	3GE027	U	--	--	--	--	--	--	--
Grand Wash 7	3NE069	O	--	--	--	--	--	--	--
Harquahala	4GE001	F	1	1	--	--	2/18-3/8	--	--
Kirkland Peak	3NE099	S	1	1	1	1	<2/22	3/8-5/9	>5/16
Kofa	4GE002	U	--	--	--	--	--	--	--
Long Mountain	3NE049	F	1	1	--	--	2/18-3/9	--	--
Peacock Mountains North	3NE066	O	--	--	--	--	--	--	--
Rincon	6GE028	F	5	2	2	--	2/17-3/8	3/8-5/10	--
Wright Canyon	3GE052	S	4	1	1	1	<2/22	3/9-5/12	>6/2
Young Mountain	3GE073	U	--	--	--	--	--	--	--
Bird Conservation Region 34									
Agua Fria 1	6NE024	F	1	1	--	--	<2/17	--	--
Alchesay Canyon	6GE002	F	1	1	1	--	2/17-3/8	3/8-5/9	--
Bear Canyon	5GE010	O	--	--	--	--	--	--	--
Black Canyon	1NE004	F	2	1	1	--	<2/24	3/15-5/16	--
Boulder Canyon	5NE041	S	1	1	1	1	2/16-3/7	3/7-5/10	>5/25
Bryce Mountain	5GE019	S	3	1	1	1	<2/16	3/7-5/10	>5/19
Camp Wood	3GE060	U	--	--	--	--	--	--	--
Cerbats North 2	3GE074	S	2	1	1	1	2/18-3/9	3/9-5/12	>5/26
Cherry Creek	3GE062	F	1	1	--	--	<2/22	--	--
Deadman Creek	6GE036	U	--	--	--	--	--	--	--
Double A Knoll	2GE052	S	1	1	1	1	<2/22	3/14-5/18	>6/6
Dutch Mountain	1GE017	S	2	2	2	2	<2/24	3/15-5/16	>6/7
Eagle Nest Mountain	2GE050	U	--	--	--	--	--	--	--
East Cedar Mountain	6GE033	F	2	1	1	--	<2/17	3/8-5/9	--
Engine Mountain	5GE003	U	--	--	--	--	--	--	--
Fagan 1	5GE029	S	1	1	1	1	2/17-3/7	3/7-5/10	>6/21
Fisher	5GE036	S	5	2	2	2	<2/16	3/7-5/10	>5/10
Flat Mesa	2GE004	S	2	2	2	2	2/22-3/14	3/14-5/18	>6/21
Galiuro Mts 9	5NE088	U	--	--	--	--	--	--	--
Gila Peak	6GE007	U	--	--	--	--	--	--	--
Grapevine	2GE074	F	9	2	2	--	<5/3	<5/3	--
Grapevine 2	2NE074	F	2	1	--	--	<2/24	--	--
Haigler Creek	6GE037	S	2	1	1	1	2/17-3/8	3/8-5/9	>6/14
Hardscrabble Canyon 1	6GE031	S	3	1	1	1	<2/17	3/8-5/9	>6/3
Hot Springs Canyon	5GE009	U	--	--	--	--	--	--	--
Johnson Canyon	2NE034	U	--	--	--	--	--	--	--
Jumpoff	6GE045	F	3	1	--	--	2/17-3/8	--	--
Martin Mountain	3NE098	S	4	1	1	1	<3/8	3/8-5/9	>6/3
Mazatzal Wilderness 5	6NE070	S	3	2	1	1	<2/17	3/8-5/9	>5/25
Midnight Mesa	6GE038	U	--	--	--	--	--	--	--
Mustang Mountains	5NE051	S	3	1	1	1	2/17-3/7	3/7-4/26	>5/27
Oak Spring Canyon	6GE018	F	1	1	--	--	<2/17	--	--
Parker Creek	6GE025	S	4	1	1	1	<2/17	3/8-5/9	>6/3

[1]Shaded BAs are to be monitored annually.
[2]Breeding area identification number.
[3]F=failed; S=successful; O=occupied; U=unoccupied.
[4]Represents minimum number of eggs laid.

Table 12 (continued).

Breeding Area[1]	ID[2]	Status[3]	Nest number	Eggs[4] / Young / Fledged			Estimated date of:		
							Egg-laying	Hatch	Fledge
Peloncillo Mountains	5GE018	S	11	2	2	2	<2/16	3/7-5/10	>5/19
Pinaleno 2	5GE033	O	--	--	--	--	--	--	--
Pinaleno 4	5GE039	U	--	--	--	--	--	--	--
Poland Creek	6GE041	S	2	1	1	1	2/17-3/8	3/8-5/9	>6/14
Rattlesnake Wash 1	2NE070	F	2	1	--	--	2/22-3/14	--	--
Red Butte	2GE005	S	1	1	1	1	2/23-3/14	3/14-5/17	>6/16
Red Mountain	2NE055	U	--	--	--	--	--	--	--
Santa Teresa Mtns 1	5NE064	U	--	--	--	--	--	--	--
Severin Canyon	5GE022	S	3	2	2	2	<2/16	3/7-5/10	>5/19
Spring Creek	6NE039	U	--	--	--	--	--	--	--
Table Mountain	5NE077	O	--	--	--	--	--	--	--
Turtle Mountain 1	5NE038	F	5	1	--	--	<2/16	--	--
Whetstone Mountains 3	5GE035	U	--	--	--	--	--	--	--
Whitlock Mountains 3	5NE021	U	--	--	--	--	--	--	--
Ziegler Mountain	1GE002	O	--	--	--	--	--	--	--

[1]Shaded BAs are to be monitored annually.
[2]Breeding area identification number.
[3]F=failed; S=successful; O=occupied; U=unoccupied.
[4]Represents minimum number of eggs laid.