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STATUS OF NESTING BALD EAGLES IN ARIZONA

DANIEL E. DRISCOLL, RONALD E. JACKMAN AND W. GRAINGER HUNT
Predatory Bird Research Group, Long Marine Laboratory, University of California, Santa Cruz, CA 95060 U.S.A.

GREG L. BEATTY, JAMES T. DRISCOLL AND RICHARD L. GLINSKI
Arizona Game and Fish Department, 2221 Greenway Road, Phoenix, AZ 85203 U.S.A

THOMAS A. GATZ AND ROBERT I. MESTA[1]
U.S. Fish and Wildlife Service, 2321 West Royal Palm Road, Suite 103, Phoenix, AZ 85021 U.S.A.

ABSTRACT.—A small, isolated population of Bald Eagles (*Haliaeetus leucocephalus*) breeds along the desert rivers of central Arizona. The extent to which it followed the continental pattern of decline during the DDT era cannot be known because of the paucity of data before 1970 but, from 1970–93 the number of known breeding pairs increased from two to 34. Some of this growth was an artifact of increased surveys, but much was real. During 1987–93, territory occupancy rate was 90%, a higher than normal value for the species, but nest success (45%) and productivity (0.69 young per occupied site, SE = 0.08) were lower than reported for other populations in the coterminous U.S. Much of the annual variation in nesting success and productivity resulted from heat stress and flooding, factors that impacted many breeding areas simultaneously. We recorded 41 breeder fatalities or replacements during 262 monitored breeder/years, and additional fatalities and replacements likely went unrecorded. If replacements equated to fatalities, estimated maximum annual breeder survival was 0.84 (95% C.I. 0.78–0.88), a lower value than elsewhere estimated. Of 131 monitored pairings during the seven years of our research, 24 (18%) contained subadults. This higher than normal rate for Bald Eagles suggests a paucity of floaters (non-territorial adults), although other factors may be involved. Notwithstanding these suggestions of reduced demographic potential, a continuing upward trend in the number of territories is apparent.

KEY WORDS: Bald Eagle; Haliaeetus leucocephalus; *Arizona; nesting; population status; productivity; breeder turnover; subadult recruitment.*

El estatus de águilas calvas anidando en Arizona

RESUMEN.—Una pequeña y aislada población de águilas calvas (*Haliaeetus leucocephalus*) se reproduce a lo largo de los ríos del desierto en el centro de Arizona. Hasta donde está población siguió el patrón continental de disminucion poblacional durante la era del DDT, no se ha podido comprobar debido a la falta de informacion existente antes de 1970. Entre 1970–93 el número de parejas reproductivas conocidas aumentó de dos a 34. Parte de este aumento fué sobreestimado. Durante 1987–93 la tasa de ocupación del territorio fue del 90%, un valor mayor del normal para la especie, el éxito de anidación fue del 45% y la productividad de 0.69 juveniles por sitio ocupado, SE = 0.08; Lo cual fue mas bajo que lo reportado para otras poblaciones de Estados Unidos. Estas variaciones fueron atribuidas al impacto del estres causado simultáneamente por el calor y las inundaciones en varios sitios de reproducción. Registramos 41 fracasos de los reproductores o remplazos en 262 monitoreos de reproducción por año. Creemos que hubo mas fracasos que no pudieron ser registrados. Si los remplazos fueron iguales a los fracasos, la sobrevivencia anual de reproducción fue de 0.84 (95% C.I. 0.78–0.88), un valor mas bajo de lo estimado en otros lugares. De las 131 parejas monitoreadas durante los 7 años de nuestra investigación, 24 (18%) contenían individuos subadultos. Estas cifras son mas altas de lo normal para las águilas calvas. Lo anterior pudo ser ocasionado por el estancamiento de los individuos "floaters" (adultos sin territorio), aunque otros factores pudieron ser los causantes de esta situación. A pesar de esto y sin subestimar esta situación de reducido potencial productivo, se observa una tendencia creciente de territorios ocupados.

[Traducción de César Márquez]

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[1] Present address: U.S. Fish and Wildlife Service, 2493 Portola Road, Suite B, Ventura, CA 93003 U.S.A.

Figure 1. The distribution of breeding Bald Eagles in Arizona.

Arizona supports a nesting population of Bald Eagles (*Haliaeetus leucocephalus*) primarily along the Salt and Verde Rivers in the central part of the state (Fig. 1). This small population is somewhat isolated from other centers of breeding activity and occupies habitat drier, warmer, and less vegetated than is typical for the species. Large trees are scarce along the desert rivers and many pairs use cliff nests. The population has been classified as threatened by the U.S. Fish and Wildlife Service (USFWS 1995), and there is concern that the rapidly increasing human population in Arizona may impact its numbers. Herein, we summarize data on occupancy and productivity, and discuss factors affecting survival and recruitment. Drawing upon historical records and reports, and upon field data obtained during 1987–93, we examine the evidence for population self-sustainability.

HISTORY OF OCCURRENCE

When the USFWS began monitoring nesting Bald Eagles in Arizona in 1970, only two occupied territories were known, both on the Verde River (Rubink and Podborny 1976). From 1970–93, the number of known territories increased to 34. To what extent this increase resulted from greater numbers of eagles is unknown, although it was clear that many territories had been newly established. Others may have been long occupied and simply found by greater search efforts and more extensive surveys, an uncertainty that has affected studies of other populations (Sprunt et al. 1973, Henny and Anthony 1989, Frenzel 1991). Newly discovered sites we examined often contained numerous old nests, but whether these were recently occupied or were remnants of many years past could not be determined since stick nests on cliffs in Arizona may persist for many decades.

Also uncertain, because of the paucity of data before 1972, is the extent to which the Arizona population followed the continental pattern of decline during the DDT era. DDT was applied extensively to cotton and vegetable crops in Arizona and adjacent regions, and the highest DDE levels recorded during the 1967–79 National Starling Monitoring Program were from nearby Maricopa, Arizona and Chaves, New Mexico (Hunt et al. 1986). Prey fish probably contained very little DDE because relatively few farms existed within the drainages occupied by breeding eagles; however, migratory and nomadic waterbirds were likely contaminated.

There is evidence for the existence of a nesting population of Bald Eagles in Arizona prior to 1970. Early sightings of individual eagles were reported by Coues (1866), Henshaw (1875), Willard (1916) and Hargrave (1939). Mearns (1890) described the first breeding record, a tree nest near Stoneman's Lake on the Mogollon Plateau. Bent (1937) reported breeding pairs at Fort Whipple and the Salt River Bird Reservation, an area flooded by Roosevelt Reservoir in 1911. According to Jenks and Stevenson (1937), Bald Eagles bred in the White Mountains and were resident in central eastern Arizona, primarily in the Transition and Upper Sonoran zones. Cited records of two nests in saguaro cacti (*Cereus giganteus*) on the lower Verde River in 1937 and a nesting pair on the Little Colorado River in 1951. Phillips et al. (1964) reported nesting records from the 1930–60s on the Salt and Verde rivers, including pairs breeding during 1930–36 near Saguaro Reservoir (constructed during 1928–30), since the early 1940s near Bartlett Reservoir (completed in 1939), and in the free-flowing Salt River Canyon in 1935, 1944, and 1949. C. McCollough (field notes) observed nesting on the Tonto Arm of Roosevelt Reservoir from 1951–55.

Rubink and Podborny (1976) described a nest on the upper Verde River in the 1960s and a pair near the mouth of the Verde River in 1968. L. Forbis (U.S. Forest Service, unpublished interview with F. Thompson 1979) noted three nests on the upper Verde River occupied during the early- to mid-1960s. G. Gibbons (pers. comm.) observed nesting at Canyon Reservoir on the Salt River in the 1950s and 1960s.

STUDY AREA

In Arizona, Bald Eagles breed mainly in open, desert landscapes of the Upper and Lower Sonoran Life-Zones (Lowe 1964) at elevations ranging from 329–1719 m. Annual precipitation averages from 39 cm at higher elevations to 25 cm in desert scrub habitats, where temperatures may reach 50°C. Livestock grazing, particularly during the close of the 19th century, created conditions leading to extreme loss of soils and vegetation, including formerly extensive riparian forests (Hayden 1965, Hastings 1959, Hastings and Turner 1965, Davis 1982). The resulting need for flood control and water storage prompted the construction of dams in the early 1900s (Hayden 1965). Considerable human recreational activity occurs along the water courses. Some Bald Eagle territories are easily accessible, while others are in remote canyons.

Reservoirs and riverine sections contain both native and introduced fishes. Species most commonly eaten by Bald Eagles are catfish (*Ictalurus punctatus* and *Pylodictis olivaris*), sucker (*Catostomus clarki* and *C. insignis*), common carp (*Cyprinus carpio*), and perciforms (*Pomoxis nigromaculatus, Morone mississippiensis* and *Micropterus salmoides*) (Haywood and Ohmart 1986, Grubb 1995, Hunt et al. 1992). Of those listed, only the suckers are native to Arizona. In winter, waterfowl are important prey of the breeding population, especially at reservoirs.

METHODS

During 1987–93, we collected occupancy and reproductive data both on foot and by monthly helicopter flights throughout the breeding season (January–June). Data recorded during the flights included the number of adults seen, location of new nests, number of nestlings and their approximate age. At many territories, nest wardens of the Arizona Bald Eagle Nest Watch Program (ABENWP) reported the exact dates of egg laying, hatching and fledging, and recorded observations of disturbance and fatalities (Forbis et al. 1985). Status terminology followed Postupalsky (1974). Using techniques described in Hunt et al. (1992) and Jackman et al. (1993, 1994), we radiotagged 15 juveniles, eight subadults and 12 breeders at 10 territories. We monitored survival of radio-tagged eagles by airplane. Breeder replacement was determined on the basis of identifying characteristics (e.g., bands on right versus left tarsi, adults preceding subadults, and known deaths of unmarked pair members [Gould and Fuller 1995]). Except in cases where our activities might have jeopardized nestling survival, we entered all occupied nests during 1987–93 and banded all eaglets surviving to 6 wk of age ($N = 119$) with standard USGS tarsal bands and similarly-sized, color-anodized aluminum visual identification (VID) bands engraved with various symbols.

We recorded standard body measurements of breeding eagles as described by Bortolotti (1984a, 1984b) and Garcelon et al. (1985), including hallux length, culmen length, beak depth, tarsus width, length of tail and eighth primary, and weight. A cloth tape was used to measure wing chord length across the dorsum. We compared the means for each measurement (t-test) from Arizona (10 males, 4 females), northern California (9 males, 11 females) and the Greater Yellowstone Ecosystem in Wyoming and Montana (12 males and 6 females; A. Harmata unpubl. data).

RESULTS AND DISCUSSION

Reproduction. Over the 7-year period of our study (1987–93), the occupancy rate in central Arizona was 90% (183 of 204 known territory/years) as compared to a mean of 71% for numerous other North American populations reviewed by Stalmaster (1987). Nest success in Arizona was 45%, mean brood size 1.5 young and productivity 0.69 young (SE ± 0.08) per occupied site (Table 1). Except for brood size, these figures are the lowest reported in a sample of nine other populations in the coterminous U.S. for roughly the same period (Table 2).

On average, only 11.9 (range = 9–16) of the 23–30 pairs were productive in any one year (Table 1). For the most part, the low productivity resulted not from failure to lay eggs but from loss of eggs or young. These results were surprising in view of the nest protection and frequent enhancement of nestling survival by the ABENWP, active since 1978. Young blown from nests by high winds and those threatened by impending inundation or the loss of a parent were replaced or fostered into other nests (Grubb 1984).

Egg Mortality. During our 7-yr study, 73 (31%) of 237 known eggs perished or were infertile, a figure comparable to the 25% reported by Stalmaster (1987) for other North American populations. Of 24 eggs (in 13 clutches) for which we knew the mortality cause, 11 involved human disturbance, four (two clutches) were lost to nest inundation by filling reservoirs, six (three clutches) to a polygynous relationship where the male assisted only his primary mate, two when a female ceased incubating because of apparent physiological distress, and one involving an exceptionally small egg.

Seven addled eggs we collected during 1986–89 averaged 5.5 ppm DDE (range = 2.3–9.5) and 2.2

Table 1. Known productivity at Arizona bald eagle breeding areas during 1970–93.[1] Terminology follows Postupalsky (1974).

YEAR	KNOWN BREEDING AREAS	OCCUPIED NESTS	SUCCESSFUL NESTS	YOUNG FLEDGED	% NEST SUCCESS	MEAN BROOD SIZE	PRODUCTIVITY
1970	2	2	2	3	100.0	1.5	1.50
1971	3	3	3	4	100.0	1.3	1.33
1972	4	3	0	0	0.0	0.0	0.00
1973	6	5	5	7	100.0	1.4	1.40
1974	8	5	3	6	60.0	2.0	1.20
1975	9	7	4	5	57.0	1.2	0.71
1976	9	5	4	7	80.0	1.7	1.40
1977	9	7	3	6	42.9	2.0	0.86
1978	11	10	6	9	60.0	1.5	0.90
1979	12	10	4	6	40.0	1.5	0.60
1980	12	9	3	5	33.3	1.7	0.56
1981	13	10	8	16	80.0	2.0	1.60
1982	14	13	8	14	61.5	1.7	1.07
1983	15	13	7	13	53.8	1.9	1.00
1984	18	17	8	15	47.1	1.9	0.88
1985	20	19	13	22	68.4	1.7	1.16
1986	21	16	12	17	75.0	1.4	1.06
1987	26	24	11	20	45.8	1.9	0.83
1988	27	23	15	24	65.2	1.6	1.04
1989	28	25	9	13	36.0	1.4	0.52
1990	28	26	9	14	34.6	1.6	0.54
1991	29	26	13	20	50.0	1.5	0.77
1992	32	30	10	14	33.3	1.4	0.47
1993	34	29	16	22	55.2	1.4	0.76

[1] Data from 1970 through 1985 from Rubink and Podborny (1976), Hildebrandt and Ohmart (1978), Hildebrandt (1981), Ohmart and Sell (1980), Haywood and Ohmart (1980, 1981, 1982, 1983), Grubb et al. (1983), Grubb (1984, 1986).

Table 2. Productivity comparison of bald eagle populations within the coterminous United States over a similar period.

REGION	PERIOD	OCCUPIED NESTS	PERCENT NEST SUCCESSES	MEAN BROOD SIZE	PRODUCTIVITY	SOURCE
Florida	1988	399	69	?	1.1	Wood et al. 1990
Louisiana	1988	36	67	?	1.1	Wood et al. 1990
Texas, Southeast	1981–90	193	64	1.5	0.98	Mabie et al. 1994
Colorado + Wyoming	1981–89	85	63	1.9	1.21	Kralovec et al. 1992
South Carolina	1988	50	82	?	1.4	Wood et al. 1990
Virginia	1988	84	77	?	1.4	Wood et al. 1990
Chesapeake Bay	1981–90	1448	70	1.7	1.21	Buehler et al. 1991
Maryland	1988	97	79	?	1.4	Wood et al. 1990
California	1987–93	69	58	1.6	0.90	Jackman (unpubl. data)
Arizona	1987–93	183	45	1.5	0.69	(this study)

ppm PCBs (range = 1.2–3.9) wet weight (Jenkins et al. 1994). No DDE effect on productivity was apparent in the breeding areas from which eggs were obtained, although Wiemeyer et al. (1984) reported that DDE levels of this magnitude were associated with a 50% depression of productivity in a 14-state study during 1969–79. A mean thinning rate of 6.9% for 156 eggshell fragments (including membrane) was well below the 10% level associated with reduced productivity in other bald eagle populations (Wiemeyer et al. 1984, Nisbet 1989). These findings are similar to those reported by Grubb et al. (1990) for Bald Eagles in Arizona from 1977–85.

Nestling Fatalities. During our study, 37 (22.6%) nestlings died among the 164 known to have hatched, as compared with 15% reported by Stalmaster (1987) for other populations. However, few studies were likely to have monitored nests as closely as those in Arizona where many were watched continuously throughout the breeding season. We recorded an additional six fatalities around the time of first flights from the nest. Weather-related factors were the apparent cause of death in 23 (53%) of the 43 total cases. In 1988 and 1989, heat stress appeared to be the primary agent in the death of 11 young (see Nelson 1969, Beecham and Kochert 1975, Hayes and Gessaman 1980). During 1992 and 1993, heavy rains and flood conditions were the apparent cause of 11 fatalities and the destruction of 10 nests. Additional causes of death included Mexican chicken bug (*Haematosiphon inodorus*) infestations ($N = 5$) (see also Grubb et al. 1986), falling from (or being blown out of) nests ($N = 4$), human disturbance before self-thermoregulation ($N = 3$), Great Horned Owl (*Bubo virginianus*) predation ($N = 2$), entanglement in monofilament fishing line ($N = 2$), and bacterial infections ($N = 2$).

Heavy rains not only directly caused nestling mortality, they also transformed rivers and creeks into muddy torrents, reducing fish availability (Grubb 1995). Only two of 14 breeding pairs on free-flowing river reaches successfully raised young in 1992, a flood year. We examined prey remains from the two successful nests and found significantly higher mammalian numerical composition ($\chi^2 = 18.4$, df = 1, $P < 0.005$ and $\chi^2 = 7.4$, df = 1, $P < 0.01$) compared to remains we collected during 1986–90 from these same nests.

Breeder Fatalities and Turnover. Thirteen fatalities were documented for Arizona Bald Eagle breeders from 1951–93. Two were killed by other Bald Eagles, one by a Golden Eagle (*Aquila chrysaetos*), one by a Peregrine Falcon (*Falco peregrinus*), five were shot, one died of impact injuries, and three died of unknown causes. We infer an additional 46 breeder fatalities (24 males, 21 females, 1 unknown) from replacement of pair members (Gould and Fuller 1995). No marked breeder was seen after its replacement. The two oldest known breeders were 14 years old in 1993, with site tenures of 11 and 10 years.

Considering only the 1987–93 period, we recorded 41 fatalities or replacements during 262 monitored breeder/years. If replacements equate to fatalities, the (maximum) point estimate of breeder survival becomes 0.84 (95% C.I. = 0.78–0.88) (Trent and Rongstad 1974), a figure somewhat lower than that reported in three other studies (i.e., 0.88 by Bowman et al. (1995) in Alaska, 0.93 by Hodges et al. (1987) in Alaska and 0.93 by Gerrard et al. (1992) in Canada. Because some deaths and replacements in Arizona likely went undetected, our estimate was doubtless biased toward higher survival, as may have been the case with the estimate of Gerrard et al. (1992). The estimates for Alaska were based on samples of radio-tagged eagles.

Breeding Eagles in Subadult Plumage. Bald eagles normally defer first breeding until at least 5–8 years of age (Hansen and Hodges 1985, Buehler et al. 1991, Gerrard et al. 1992, Bowman et al. 1995). Healthy raptor populations typically contain many floaters unable to obtain breeding territories because suitable habitat is saturated by breeding pairs (Newton 1979). However, during the seven years of our study, the Arizona population appeared to contain relatively few floaters, as evidenced by a high incidence of breeding eagles displaying subadult (nondefinitive) characteristics (24 of 131 monitored pairings, 18.3%). This and the incidence of replacements by young eagles (≥44%) were far higher than reported elsewhere (Herrick 1924, Bent 1937, Gerrard et al. 1978, Sherrod et al. 1976, Stalmaster 1987, Mabie et al. 1994, Anthony et al. 1994). In a long-term study involving thousands of Bald Eagle pairings in Saskatchewan, Gerrard et al. (1983) noted only two subadults paired with full-adults and neither pair laid eggs. Among hundreds of pairs at Chesapeake Bay, Buehler et al. (1991) observed no subadults and Hansen and Hodges (1985) remarked that subadults were not known to breed in southeastern

Alaska. Swenson et al. (1986) noted five subadults paired with full-adults in 11 years of data for 40–50 pairs in the Greater Yellowstone Ecosystem (1972–82); only two such pairs repaired a nest or laid eggs and none reproduced.

Some of the pairings and replacements in Arizona by eagles in subadult plumage may reflect a possibly atypical delay in the acquisition of full adult (definitive) plumage. J. Driscoll noted that six of 23 eagles of known age (5 females, 1 male) retained eye-stripes at greater than five years of age, and two of these still displayed eye-stripes at seven years of age. McCollough (1986) reported that two of 13 individuals in Maine retained eye-stripe remnants at six to eight years.

Pairs with members displaying subadult plumage in Arizona were more productive than those in other studies. Among the 40 pairings containing subadults at 35 occupied nests since 1970, 16 (46%) successfully fledged young, three (9%) hatched young that died in the nest, four (11%) laid eggs that did not hatch, and the remaining 12 (34%) apparently did not lay eggs. Of the five pairs with both members in subadult plumage, three apparently did not lay eggs and two hatched two young each. Although significantly more full-adult pairs laid eggs than did subadult or mixed pairs ($\chi^2 = 8.0$, df $= 1$, $P < 0.005$), we found no significant difference in nest success or productivity.

Relationship to Other Populations. There is some evidence that the Arizona Bald Eagle population may be augmented by immigration from other regions. We were able to read the bands of 14 of 29 banded breeders during 1987–93. All 14 had been banded as nestlings in Arizona. Six of the unidentified birds were banded on the left tarsus, but according to banding records, only four Arizona nestlings had been so banded. Thus, at least two breeders may have originated from outside Arizona. In 1994, an eagle banded as a nestling by Mabie et al. (1994) in southeast Texas (1410 km away) bred at a high altitude reservoir (2438 m) in the pine-forested mountains of eastern Arizona near the New Mexico border.

Arizona adults were, on average, smaller in all morphological characteristics than those from Alaska, California, or the Greater Yellowstone region, a finding that supports an affinity of the Arizona population with those in the southeastern U.S. as proposed by Amadon (1983), Stalmaster (1987), and Palmer (1988). Arizona males were significantly smaller in 13 of 16 measurements (Table 3) and females in eight of 16 comparisons, a difference probably arising from the small number of females sampled. Morphological measurements of two adults from the Rio Yaqui, Sonora, Mexico did not differ from those in Arizona.

These results suggested that the Bald Eagle population in the southwest either rebounded from a depleted population or derived from immigration from the southeastern U.S., or both. If gene flow into Arizona from north or west (where eagles are larger) had recently occurred, it should at least be reflected in the overall variance of mensural characters, assuming that the environmental component of such variation is weak compared with the genetic component. We examined this hypothesis by comparing coefficients of variation for the various characters we measured in the four populations, but found no suggestion of greater variance within the Arizona sample.

SUMMARY OF STATUS

Despite the uncertainty of determining whether newly discovered pairs equate to newly occupied territories, the weight of evidence indicates a continuing upward trend in the number of Bald Eagle pairs in Arizona since 1970. This trend is occurring with little direct evidence of augmentation by immigrants and despite relatively low estimates of productivity and breeder survival. The substantial incidence of pairs containing members in subadult plumage suggests a deficient age structure in the floating segment and thus a relatively small recruitment buffer (Hunt 1998). A paucity of floaters may, in part, result from continued population expansion (i.e., eagles that would otherwise become floaters are founding new territories). However, we do not discount the role of low vital rates (e.g., breeder survival) in retarding floater accrual. We therefore recommend monitoring of breeding sites and continuation of population-wide VID banding. Because of the proven benefit of the ABENWP in enhancing reproduction, we recommend its continuance at sites where human disturbance is considered significant.

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Table 3. Means and standard deviations for selected measurements (mm) and weights (kg) of adult male Bald Eagles from Arizona, northern California, Alaska (data from T. Bowman and P. Schempf), and the Greater Yellowstone Ecosystem (Wyoming and Montana, data from A. Harmata).

MEASUREMENT	ARIZONA	CALIFORNIA	ALASKA	YELLOWSTONE
Hallux (arc)	37.4 ± 1.3 (N = 10)	40.4 ± 0.4 (N = 7)***	41.3 ± 1.1 (N = 33)***	41.0 ± 1.5 (N = 7)***
Tarsus width (lateral)	12.4 ± 0.6 (N = 9)	13.0 ± 0.5 (N = 9)*	13.2 ± 0.6 (N = 33)**	13.8 ± 0.8 (N = 12)***
Tail length	237.0 ± 19.6 (N = 8)	265.1 ± 10.1 (N = 9)**	278.8 ± 18.1 (N = 33)***	273.0 ± 9.2 (N = 8)***
Culmen (arc)	48.3 ± 1.1 (N = 10)	52.4 ± 1.1 (N = 9)***	52.4 ± 1.7 (N = 33)***	51.3 ± 1.4 (N = 12)****
Weight	3.3 ± 0.2 (N = 12)	4.1 ± 0.3 (N = 10)***	4.7 ± 0.3 (N = 32)***	4.1 ± 0.3 (N = 10)***

Comparisons (t-test) with Arizona samples: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

access to remote breeding areas for nest climbs. We thank M. Greenburg and T. Noble (SRP) and C. Thelander (BioSystems Analysis, Inc., BSAI) and numerous BSAI employees for their assistance during our study. We acknowledge the work of D. Rubink (USFWS), R. Ohmart, T. Hildebrandt, D. Haywood and R. Sell (Arizona State University), T. Grubb, W. Eakle and L. Forbis (USFS), and the hundreds of ABENWP personnel who have watched over Arizona's nesting eagles since 1978. We acknowledge D. Bland, L. Kiff, and R. Risebrough for work concerning eggshell thinning and contaminants. We thank J. Linthicum, T. Hunt, and two anonymous reviewers for valuable comments on the manuscript.

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