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MIGRATION AND SURVIVAL OF JUVENILE BALD EAGLES FROM ARIZONA

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ABSTRACT.—During 1987–89, we placed VHF transmitters and colored identification bands on 15 nestling Bald Eagles (*Haliaeetus leucocephalus*) in central Arizona to determine the direction and extent of their post-fledging migration. Thirteen of the juveniles fledged successfully, and one transmitter failed; 11 eagles survived the post-fledging, premigration period which ranged from 18 to 65 d (mean = 44 d). One eagle was lost by trackers after departure, but 10 monitored eagles traveled north from 925 km to 1955 km before stopping for extended periods or until weather prevented further tracking. Habitats varied among stopping locations and included interior reservoirs and lakes, open ranchland, and the Pacific marine coast. Food at inland destinations included spawning fish (cutthroat trout [*Salmo clarki*]) and fish carrion (common carp [*Cyprinus carpio*] and white suckers [*Catostomus commersoni*]). At least nine of 13 fledged juveniles survived ≥1 yr (69%), and a minimum of six (46%) survived to breeding age.

KEY WORDS: *Bald Eagle*; Haliaeetus leucocephalus; *Arizona*; *migration*; *movements*; *survival*.

MIGRACIÓN Y SUPERVIVENCIA DE JUVENILES DE *HALIAEETUS LEUCOCEPHALUS* DE ARIZONA

RESUMEN.—Entre1987 y 1989, colocamos transmisores VHF y anillas de identificación de colores a 15 pichones de *Haliaeetus leucocephalus* en el centro de Arizona, para determinar la dirección y la extensión de sus migraciones luego del emplumamiento (abandono del nido). Trece de los juveniles emplumaron exitosamente y uno de los transmisores falló; 11 águilas sobrevivieron el período premigratorio posterior al emplumamiento, el cual duró entre 18 y 65 d (media = 44 d). Un águila no pudo ser seguida por los receptores después de su partida, pero las 10 águilas monitoreadas viajaron entre 925 y 1955 km antes de detenerse por períodos de tiempo extendidos o hasta que el clima impidió los seguimientos posteriores. Los ambientes de las localidades de parada variaron e incluyeron diques y lagos del interior, tierras ganaderas abiertas y la costa marina del Pacífico. Los alimentos en los lugares de parada del interior incluyeron peces desovando (*Salmo clarki*) y carroña de peces (*Cyprinus carpio* y *Catostomus commersoni*). Al menos nueve de los 13 juveniles que emplumaron sobrevivieron ≥1 año (69%) y un mínimo de seis (46%) sobrevivió hasta la edad reproductiva.

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Information on juvenile Bald Eagle (*Haliaeetus leucocephalus*) activity during the first few months after leaving the nest is important for understanding obstacles that may occur with food procurement and access to quality habitat. The post-fledging period is one in which raptors may undergo significant mortality, at rates possibly greater than at any other period in their life cycle (Cade 1960, Newton 1979). Juvenile Bald Eagles are large avian carnivores that need correspondingly large portions of daily food but have little experience in procuring them. If post-fledging movements of juvenile Bald Eagles are genetically controlled, they might therefore be expected to target any predictably abundant supply of carrion that existed within the wider landscape and within the evolutionary time frame. For example, Bald Eagles hatched in northern California migrated northward up to 2200 km to Pacific salmon (*Oncorhynchus* spp.) spawning habitats in Canada just weeks after fledging (Hunt et al. 1992, Linthicum et al. 2007). Likewise, some juvenile eagles moved westward from Yellowstone and Glacier national parks in Montana to the Pacific coast; others moved southward or more locally and found ungulate carrion, spawning fish (e.g., mountain whitefish [*Prosopium williamsoni*]), and waterfowl (McClelland et al. 1996, Harmata et al. 1999). However, for eagles fledged in Arizona, some 1300 km southeast of the California study area, it was not known what food sources and habitats were available for the birds when they migrated, nor how the quality of those resources might affect their survival.

The objectives of this study were to: (1) track post-fledging departures and migrations of radio-tagged juvenile Bald Eagles, (2) monitor their survival, and (3) assess their habitat use during initial migration and in seasonal use areas if they returned to Arizona.

STUDY AREA

Arizona Bald Eagle breeding areas were located in desert habitat in the central portion of the state along the Salt and Verde rivers (Driscoll et al. 1999). Breeding areas were within the Upper and Lower Sonoran Life-Zones at elevations ranging from 329–1719 m. Mean annual precipitation ranged from 39 cm at higher elevations to 25 cm in the low desert where summer temperatures may reach 50° C (Lowe 1964).

METHODS

We radio-tagged 15 juvenile Bald Eagles (eight males, seven females) from nine different nesting territories in central Arizona (centered on ca. 34.0°N, 111.5°W) during 1987–89. Eagles (and their respective natal areas) included JZ01 and JZ02 (1987 male, female siblings; Orme Mountain, confluence of Salt and Verde rivers), JM03 (1987 male; Ft. McDowell, Verde River), JL20 (1987 female; mouth East Verde River), JZ24 (1988 male; Orme Mountain), JI26 (1988 female; middle Verde River), JP22 and JP23 (1988 male siblings; Verde River near Camp Verde), JW30 and JW31 (1988 female siblings; Tonto Creek), JO35 (1988 male; Horseshoe Reservoir), JD33 and JD34 (1988 male, female siblings; Saguaro Reservoir), and JC50 and JC51 (1989 male, female siblings; Bartlett Reservoir).

We fitted 9-wk-old nestlings with 64-g backpack transmitters (BioTrack, Wareham, Dorset, U.K.) having a 3-yr battery life and a mercury-triggered activity switch. Transmitter attachment utilized 1.3 cm Teflon ribbon, the ends stitched over the carina with waxed cotton thread, with 5-cm spacing between the transmitter and the eagle to accommodate future growth.

We fitted each nestling with a USGS band on the right tarsus, and a color anodized aluminum visual identification (VID) band (Acraft, Edmonton, Alberta, Canada) on the left tarsus. VID bands were engraved with a unique symbol in four locations surrounding the band. We determined eagle sex from standard morphological measurements (Bortolotti 1984).

We radio-monitored juveniles daily in their natal areas until migration and stationed observers on centrally located mountain peaks so that signals of soaring juveniles from multiple breeding areas could be monitored simultaneously. Initiation of migration was defined as the day eagles left their natal territories without returning. We tracked migrating juveniles by fixed-wing aircraft (e.g., Cessna 172) with Yagi antennas mounted on wing struts. Each bird was followed by one pilot and one tracker in one airplane, with the primary objectives of maintaining radio receiver contact with each eagle's transmitter and determining ultimate destinations. Therefore, exact locations along migration routes (e.g., roosting locations, fixes for ground speeds) were plotted opportunistically due to constraints associated with cross-country airplane travel (e.g., airport/fuel distribution, thunderstorm avoidance). To save fuel, we often landed ahead of migrating eagles along their anticipated courses. Relocations were aided by Loran receivers with accuracies of ca. 1 km. Where possible, we followed juveniles to their apparent destinations as determined by eagle presence within the same general area (ca. <100 km^2) for 3–12 d, or until weather prevented further airplane tracking. We conducted biweekly aerial surveys throughout Arizona from late September to May during 1987–90 to detect returns of migrant juveniles and monitor their subsequent regional movements and habitat use.

RESULTS

Premigration. Two of 15 radio-tagged juveniles (JD33, JD34) died of probable heat stress when 11 wk old during 5 d of temperatures exceeding 40° C in mid-May 1988. The remaining 13 young fledged at a mean age of 12 wk. A Great Horned Owl (*Bubo virginianus*) killed one juvenile (JP22) roosting on top of the nest cliff 4 wk after fledging; the transmitter of another eagle (JC51) failed in the natal area after fledging.

Departure. Eleven juveniles with functioning transmitters departed between 9 June and 30 July (median = 3 July) at intervals of 18–65 d post-fledging (mean = 44 d, SD = 13) at 16–20 wk of age (mean = 18.5 wk, SD = 1.7). Departure courses of 10 eagles ranged from 320° to 020° (true north). Three eagles (JP23, JW30, and JO35) exhibited "false starts," flying 25, 88, and 46 km from natal areas, respectively, before returning to natal areas 1–3 d post-departure.

Migration. We followed nine eagles as they traveled north, and briefly intercepted a tenth Arizona juvenile (JL20) as it passed through the Blue Mountains near Baker in NE Oregon (Fig. 1); we recorded only a departure direction from the remaining bird (JO35). Eight roosting locations were determined at the end of first migration days; average distance traveled was 203 km (range = 112–330 km; SD = 83).

Overall distances traveled per day varied, and storms and low clouds generally slowed the progress of migrants. Twenty-three recorded daily distances among eight individuals averaged 276 km (Range = 112–660 km, SD = 138). Average ground speeds calculated for five eagles (N = 36 total measurements) ranged from 29 to 45 km/hr (grand mean = 36 km/hr, SD = 13).

Habitat identified at roosting locations included riparian trees or cliffs along rivers and lakes (N = 12), conifers on steep mountain slopes (N = 5), conifers in flat or rolling country (N = 3), mountain or canyon cliffs (N = 6), and rocky outcrops or badlands (N = 3).

Juveniles migrated northward 925–1955 km before reaching their destinations or until weather prevented further tracking. On all but three occasions, the eagles traveled every day: JZ02 stopped for 2 d in association with heavy rainstorms; JM03 stopped to consume fish for 7 d at Lima Reservoir, Montana, before moving eastward to Yellowstone Lake; JP23 stopped migrating at noon one day in apparent response to stiff headwinds. Migration termini of four eagles were lakes or reservoirs: Lima Reservoir (thence to Yellowstone Lake), Montana (JM03); Swan Lake, Manitoba (JI26); Blackfoot Reservoir, Idaho (JW31); and Yellowstone Lake, Wyoming (JZ24). Spawning cutthroat trout (*Salmo clarki*) characterized the latter; the other water bodies also contained conspicuous fish carrion (e.g., common carp [*Cyprinus carpio*]; white suckers [*Catostomus commersoni*]). The paths of four eagles may have intersected with bodies of water containing salmon (*Oncorhynchus* spp.), at least historically, including coastal British Columbia, Canada (JZ02), the northwest coast (Oregon and California; JP23), and the Snake River in Idaho and eastern Oregon (JL20, JZ24).

Six of the eagles seen during migration were either soaring alone (N = 8) or perched alone at roosting sites (N = 3); the only other eagles seen by trackers were at destination foraging locations. Two sets of siblings were tracked; JZ01's (see above) sibling JZ02 migrated northwest to the Strait of Georgia, British Columbia where its signal was lost in poor weather. JW30 flew generally northeast to North Dakota (lost in poor weather near Lemmon), while JW31 migrated to Idaho. Both sets of siblings initiated migration separately: JZ01/JZ02 3 d apart; JW30/JW31 4 d apart.

During the first phase of migration, most juveniles deviated little from their initial courses (see Fig. 1). For example, JZ01 remained within one longitudinal degree over its entire journey from its nest to central Montana (Scapegoat Wilderness), where its signal was lost in poor weather. Maximum deviation from the 111° 41′W longitude line at the nest site was 53′ (77 km) east and 37′ (51 km) west. Migrating solitarily, JM03 also flew true north; the line of longitude passing through Lima Reservoir in Montana also bisected the bird's natal territory. However, of nine migratory paths we followed from Arizona, eight eagles either made radical course changes or stopped migrating between 44° 40′ and 47° 40′N (mean = 46° 10′N). The exception was JW31 that stopped in southern Idaho at about 43° N.

Return of Radio-tagged Juveniles to Arizona. Of 11 juvenile eagles that migrated from their natal territories with functioning transmitters, at least eight had returned to Arizona by autumn or winter

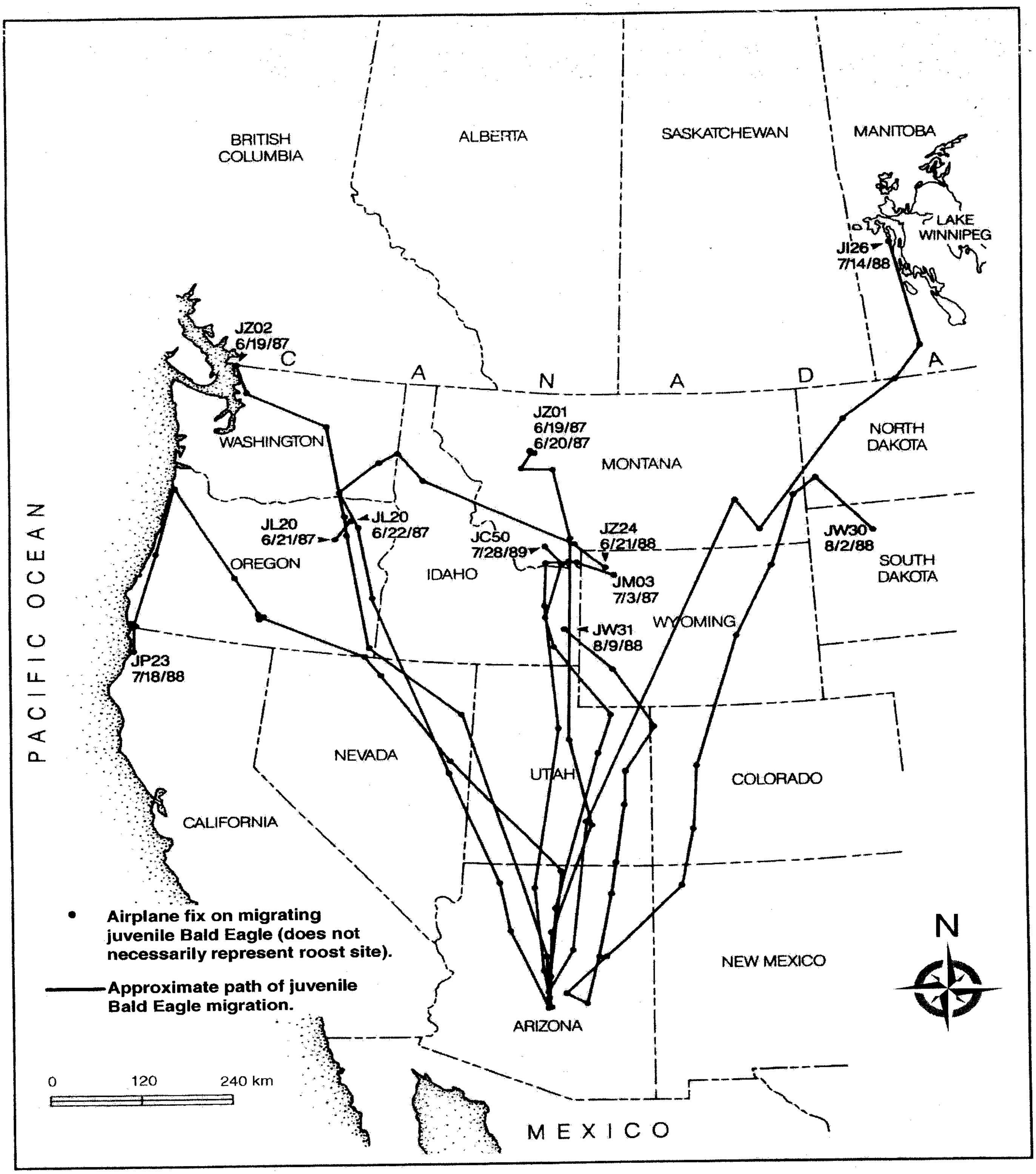

Figure 1. Migrations of 10 Arizona juvenile Bald Eagles, 1987–89.

of the same year. They moved around often and frequented reservoirs throughout central Arizona, particularly inflow areas, but also zones of open water. Known prey utilized at these reservoirs included waterfowl and fish carrion. Nomadic eagles also were attracted to two tributaries (East Verde River and Tonto Creek) with large populations of nonmigratory fish (Hunt et al. 2002).

Survival. Of the eight eagles that returned to Arizona after their first migration, at least seven survived to their second calendar year. Two others were later identified by VID bands as adults, increasing minimum survival of ≥1 yr to 69% (9 of 13). JC51 was located breeding in Arizona in 1994 (J. Driscoll pers. comm.). JI26 was rescued from fishing net on El Novillo Reservoir, Sonora, Mexico, in March 2002, at 14 yr of age and was assumed to be breeding there (R. Mesta unpubl. data). Of the 13 radio-tagged nestlings that fledged successfully, at least six (46%; JI26, JC51, JP23, JZ24, JW30, JW31) survived to breeding age (J. Driscoll pers. comm.).

DISCUSSION

The magnitude and direction of post-fledging movements of Bald Eagles differ with natal origin. Charles Broley (1947), who banded over 1000 nestling Bald Eagles in Florida during the 1930s and 1940s, was first to identify migration of Bald Eagles native to southern portions of the U.S. Broley's bands were recovered in all states east of the Mississippi River, but most recoveries indicated that eagles moved northward up the east coast, some as far as Canada. One Florida nestling was encountered 322 km north of Winnipeg, Manitoba, Canada (Broley 1950). Wood (1992) radio-tagged Florida juveniles and found similar migration patterns to those described by Broley. Encounters of juvenile eagles wing-marked in southeast Texas also implied long-distance northward migrations in summer (Mabie et al. 1994), as demonstrated in the routes of radio-tagged nestlings from northern California (Hunt et al. 1992, Linthicum et al. 2007). In contrast, juvenile Bald Eagles in Maine and Chesapeake Bay did not embark on long migrations but rather dispersed relatively short distances (McCollough 1986, Buehler et al. 1991), whereas populations in the far north moved southward post-fledging (e.g., Saskatchewan [Gerrard et al. 1978]; southeast Alaska [Hodges et al. 1987]; Labrador [Laing et al. 2005]). Arizona juveniles traveled greater distances per day than Montana eagles, which occasionally stopped to feed (87–98 km/d; McClelland et al. 1996), and even northern California eagles (130 km/d in coastal conditions, 184 km/d in the mountainous interior; Hunt et al. 1992).

Juvenile survival rates may be affected by long-distance migrations (Buehler 2000). The apparent survival rate for Bald Eagles through the first year of life in our Arizona study (69%) was similar to those estimated in other regions where long distance post-fledging translatitudinal migrations occur: Florida (63%; Wood 1992), California (77%; Jenkins et al. 1999). In contrast, in the Chesapeake Bay area, where juveniles disperse only short distances, 100% of radio-tagged young survived their first year (Buehler et al. 1991). Reported first-year survival was also higher for two populations showing mostly east-west, local, or more leisurely (i.e., feeding stops) movements post-fledging: Montana (91%; McClelland et al. 1996) and Yellowstone National Park (87%; Harmata et al. 1999). Even so, survival to breeding age (4.5–5 yr) among our Arizona sample (minimum 46%) was comparable to estimates in Florida (50%; Wood 1992), the Chesapeake Bay region (55%; Buehler et al. 1991), and Alaska (61% to 4 yr of age; Bowman et al. 1995).

The relatively small angle collectively subtended by all courses of the Arizona migrants, the comparatively long distances covered over short periods, and the close fidelity to initial courses all indicate an adaptively functional migration (as opposed to random dispersal) involving remote habitat destinations, most likely food-related. The fact that the eagles showed these characteristics while migrating solitarily is evidence for genetic control. In each case where investigations were possible at destinations, an abundant source of carrion or spawning fish was discovered. While migrations of most California juveniles (Hunt et al. 1992, Linthicum et al. 2007) seemed well-timed and directed to exploit summer runs of salmon in British Columbia in late July and August, many Arizona birds did not have salmon runs as a principal destination. Although the routes of four eagles might have taken the birds to salmon, the paths of six others would not have led to salmon runs, historic or active. More recent studies of post-fledging migrations by Arizona juvenile Bald Eagles conducted in 2002–05 using satellite telemetry (SBEMC 2009) found a similar pattern; six eagles migrated to potential salmon runs, while seven others migrated elsewhere (e.g., southwest U.S., North Dakota, Wyoming, Minnesota).

The median departure date (July 2) among our sample of juveniles migrating from Arizona was one month earlier than that observed in the northern California study (2 August; Hunt et al. 1992), and two months earlier than in Montana (9 September; McClelland et al. 1996); the differences may reflect latitudinal effects on breeding phenology (see Buelher 2000). However, while the post-fledging/premigration period was similar for Arizona and Montana juveniles (ca. 6 wk), northern California eagles were younger when they migrated (premigration period of ca. 4 wk; Hunt et al. 1992, Linthicum et al. 2007), which may have been related to parental food provisioning or the timing of targeted salmon runs in British Columbia.

Migratory timing and flight direction of Arizona juveniles doubtless evolved during presettlement times when food distribution and abundance differed from those at present. Food supplies available to inexperienced juveniles at latitudes they visited in summer still likely include: (1) nesting and molting waterfowl, (2) spawning salmon and other fishes (e.g., cutthroat trout), and (3) wild ungulate calves including stillborns. Together, in the undisturbed habitat of presettlement, these may have acted as a selective force to maintain the adaptation among southern eagles to migrate northward. Regardless, there now are many reservoirs in the modern landscape with introduced fish species such as carp. These, together with domestic livestock, likely buffer the widespread loss of salmon runs, hoards of bison (*Bison bison*), and other resources that once offered foraging opportunities for migrant eagles.

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