Notes

Natal Dispersal Distance of Golden Eagles in the Southwestern United States

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Abstract

Data on natal dispersal distances (NDDs) of golden eagle Aquila chrysaetos in North America are needed to define local area populations and inform decisions authorizing take (i.e., injury, death, or disturbance) of the species via federal permit. Sixteen golden eagles (6 males, 10 females) tagged with satellite transmitters as ~8-wk-old nestlings in the southwestern United States during 2010–2013 dispersed a mean of 55.3 km (SD = 29.7, median = 64.5), either 1) between their natal nest sites and nests where they first bred (n = 3 females, all subadults, i.e., in their fourth year of life), or 2) between natal sites and where they permanently settled as adults at least in their fifth year of life, but did not necessarily breed (i.e., exhibiting only gross natal dispersal). On average, females dispersed about 50% farther than males; mean NDD of males and females was 41.2 km (90% credible interval = 11.1–75.2) and 63.8 km (44.8–82.6), respectively. Median NDD of males and females was 41.5 and 65.8 km, respectively; in a Bayesian framework, the estimated difference in posterior median distributions of male and female NDDs was 22.2 km (15.7 to 57.3; P = 0.89), tentatively indicating that NDD of golden eagles in our study area may be female biased. Although our findings are based on a relatively small data set including both effective and gross natal dispersal records, they represent the first comparison of NDD between sexes of golden eagle in North America and the first published records on the continent of the species’ NDD based on telemetry methods. More work is needed to validate whether golden eagle NDD in at least some regions of North America is female biased, which could have important implications for authorizing take of the species.

Keywords: Aquila chrysaetos; golden eagle; natal dispersal distance; sex-biased dispersal; southwestern United States

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Introduction

Natal dispersal is the movement by individuals between their birth sites and breeding or potential breeding sites (Greenwood 1980). Knowledge of the process is fundamental to the understanding of avian population dynamics. A vital metric of the process, natal dispersal distance (NDD), is defined as the linear gap between these sites (Greenwood and Harvey 1982). Data on NDDs of golden eagle *Aquila chrysaetos* in western North America are crucial for managing the species, especially for defining local area populations to inform decisions authorizing take via injury, death, or disturbance, or damage or removal of the eagle’s nests (U.S. Fish and Wildlife Service [USFWS] 2013, 2016). Currently, the only data supporting such decisions are from Millsap et al. (2014), which was based on gross natal dispersal records, and for providing comparable data for the southwestern states, which were scarcely represented.

Study Area

As described by Murphy et al. (2017), natal nests of golden eagles in our study were distributed across the southern half of the Colorado Plateau physiographic province (Patton et al. 1991) and adjacent (to the east) parts of the Rocky Mountains’ southern terminus in southwestern North America (37°N, 106°W). This area included far southeastern Utah, northeastern Arizona, northwestern New Mexico, and southwestern Colorado. The southwestern half of the study area was arid to semiarid (mean annual precipitation, 25–35 cm), with sparse-to-moderate plant cover dominated by perennial grasses and low (<3-m-high) shrubs. The northeastern half was slightly less arid (annual precipitation, 35–40 cm) and dominated by big sagebrush *Artemisia tridentata* shrub-steppe and conifer woodland *Pinus edulis*, *P. ponderosa*, *Juniperus* spp. Parts of the latter area included irrigated pastureland, hayland, and cropland. Small mountain ranges and sandstone ridges, mesas, and outcrops occurred across most of the study area; elevations of these typically were 1,700–2,700 m in the southwest to 2,100–3,600 m in the northeast. Land use mainly was livestock ranching, recreation, and gas and oil extraction.

Methods

During late May through early July 2010–2013, we entered golden eagle nests when nestlings were 7–8 wk old (i.e., near fledging age) and fitted nestlings with platform terminal transmitters (PTTs; Solar Argos/global positioning system [GPS] models PTT-45 and PTT-70; Microwave Telemetry, Inc., Columbia, MD) that produced GPS-based fixes with ±20-m accuracy. We attached PTTs via “Y-harnesses” (Buehler et al. 1995) made with 0.64-cm-wide Teflon ribbon (Bally Ribbon Mills, Bally, PA). With harnesses attached, PTT-45 and PTT-70 units weighed about 55 and 90–100 g, respectively (Stahlecker et al. 2015), <3% of the nestlings’ mass. These PTTs
recorded fixes hourly during at least 0900–1600 hours daily, continuously for ~4–7 y; the number of years that a given eagle’s PTT yielded data depended mainly on the year the eagle was tagged relative to completion of our NDD data set in February 2018. About 0.1 mL of blood was drawn from the brachial vein of each nesting to determine sex via genetic analyses (Animal Genetics, Inc., Tallahassee, FL).

We measured NDD differently for two groups of eagles. For the first group—those exhibiting effective natal dispersal—we initially suspected breeding (i.e., eggs laid) by noting a shift in telemetry data to more stationary GPS fixes on a cliff face or tree about the time golden eagles in our study area normally initiated nesting. We then verified breeding by direct observation. We determined NDD for each of these individuals by measuring the straight-line distance between the natal nest and the nest used in the respective eagles’ first year of breeding. The second group of eagles—those only exhibiting gross natal dispersal—did not show clear evidence of breeding. For each eagle in this group, we measured distance from its natal nest to the centroid of its core area of use during 16 December–15 February, corresponding to the peak of courtship through nest initiation period of golden eagles breeding on our study area. During this period, youngest eagles in the group were about 4.75 y old, based on a median estimated hatch date of 13 April for golden eagles on our study area (Murphy et al. 2017); the 4.75-y criterion was used by Millsap et al. (2014) as an age cutoff for natal dispersal estimation. Other eagles in the group were monitored 1 to 2 y longer and were represented in our data set by data collected when they were either 5.75 or 6.75 y old, respectively, because many NDD records used by Millsap et al. (2014) were from adults beyond their fifth year of life. We used 50% kernel density estimates (Worton 1989) to characterize the spatial extent of core areas, with least squares cross-validation for bandwidth and 500 for cell size (Beyer 2015; R Core Team 2015). The centroid of a given core area was derived from all polygons and represented the kernel density area’s center of mass. We considered a nonbreeding adult eagle permanently settled if its 16 December–15 February core area overlapped that of the previous year by $\geq 33\%$.

Following the approach in Millsap et al. (2014), we used a Bayesian version of a t-test (Kéry 2010) to evaluate whether NDD was greater among females than males, because published literature indicates this difference as typical for birds in general (Greenwood 1980; Greenwood and Harvey 1982), including raptors (Newton 1979). For example, Millsap et al. (2014) found this to be the case for bald eagles Haliaeetus leucocephalus in the coterminous United States. We also used a standard, 1-tailed t-test to compare male versus female NDD.

### Results

We documented three cases of effective natal dispersal by golden eagles; all were females first breeding at 3.75 y of age (i.e., subadults; Table 1). Thirteen other golden eagles were monitored through their fifth, sixth, or seventh year of life and had settled, but did not exhibit evidence of breeding even though nest structures were present near centers of core areas of at least two of the eagles. When data from all eagles were pooled, mean and median NDD values were roughly similar and suggested an overall NDD of about 60 km (Table 1). The range (9–124 km) was considerable, however, and females dominated the sample. Moreover, females dispersed about 50% farther than males, on average; the mean for males and females was 41.2 km (90% credible interval = 11.1–75.2) and 63.8 km (44.8–82.6), respectively. Median NDD of males and females was 41.5 and 65.8 km, respectively; the estimated difference in posterior distributions was 22.2 km ($-15.7$ to 57.3; $P = 0.089$; Figure 1). Frequentist statistics also implied that NDDs of females were greater than those of males ($t_{14} = 1.54, P = 0.07$).

### Discussion

We provide the first NDD data set for North American golden eagles based on tracking of individuals tagged with telemetry devices as nestlings and followed until their first breeding or when settled at adult age, but not necessarily breeding. Although our sample size is small, our preliminary comparison of NDDs between sexes is unique for golden eagles in the published literature. We found evidence that NDDs of golden eagles in at least some regions of the western United States might be female biased, as is the case for birds in general (Greenwood and Harvey 1982). Indeed, mean and median NDD values of females in our sample were about 50% greater than those of males. Murphy et al. (2017) found no between-sex differences in juvenile dispersal distances of golden eagles from our study area, although Soutullo et al. (2006) found evidence of female-biased juvenile dispersal among golden eagles in Spain. In a study of the congeneric Spanish imperial eagle Aquila adalberti by González et al. (2006) in Spain, effective NDD between males and females did not differ, although the sample size was small ($n = 7$ males and 4 females).

Based on a data set with sexes pooled, the median NDD we documented (64.5 km) for golden eagles in the Colorado Plateau-Southern Rocky Mountains region exceeds the 45.3-km median reported by Millsap et al. (2014) for the western United States. This likely is due, in part, to the predominance of females in our data set. Moreover, the southwestern region of the United States where we documented golden eagle NDDs is more arid than western U.S. regions that were better represented in Millsap et al. (2014), possibly prompting eagles we studied to move farther to more successfully compete with conspecifics for presumably scarcer prey resources. In contrast with median values, the 76.4-km mean golden eagle NDD in Millsap et al. (2014) was much greater than the mean (55.3 km) we found. Close proximity of median and mean values in our study suggests a relatively normal distribution of NDDs. Millsap et al. (2014) reported a lognormal distribution for NDDs, with 10% of the values extending from about 120 to 510 km.
Table 1. Natal dispersal distances of 16 golden eagles *Aquila chrysaetos* tracked by satellite telemetry from nestling age through age at first breeding or at least adult age (≥4.75 y) in the Colorado Plateau-Southern Rocky Mountain region of the southwestern United States, 2010–2018.

| Eagle no. | Sex | Hatch year | Age (y) when natal dispersal measured | Distance (km) to natal nest | Distance measurement basis |
|-----------|-----|------------|--------------------------------------|----------------------------|---------------------------|
| 103743    | Male| 2011       | 6.75                                 | 19.1                       | *g*                       |
| 117644    | Male| 2012       | 5.75                                 | 36.1                       | *g*                       |
| 117655    | Male| 2012       | 5.75                                 | 8.6                        | *g*                       |
| 117659    | Male| 2013       | 4.75                                 | 76.0                       | *g*                       |
| 121724    | Male| 2013       | 4.75                                 | 78.2                       | *g*                       |
| 121742    | Male| 2013       | 4.75                                 | 29.4                       | *g*                       |
| 49059     | Female| 2010       | 5.75                                 | 72.3                       | *g*                       |
| 49139     | Female| 2010       | 5.75                                 | 70.6                       | *g*                       |
| 49060     | Female| 2011       | 3.75                                 | 65.6                       | *e*                       |
| 103739    | Female| 2011       | 4.75                                 | 29.3                       | *g*                       |
| 117642    | Female| 2012       | 5.75                                 | 70.7                       | *g*                       |
| 117648    | Female| 2012       | 3.75                                 | 18.5                       | *e*                       |
| 117649    | Female| 2012       | 5.75                                 | 64.9                       | *g*                       |
| 117656    | Female| 2013       | 4.75                                 | 58.3                       | *g*                       |
| 121726    | Female| 2013       | 3.75                                 | 123.6                      | *e*                       |
| 121737    | Female| 2013       | 4.75                                 | 64.0                       | *g*                       |
| Mean      |             |            |                                      | 55.3                       |                           |
| SD        |             |            |                                      | 29.7                       |                           |
| Median    |             |            |                                      | 64.5                       |                           |

*a* Age corresponding to courtship through early incubation period of a given year.

*b* e = distance from natal nest to nest where first breeding occurred (i.e., effective natal dispersal record); g = distance from natal nest to centroid of 50% kernel density estimate of core area of use during the 2-mo period encompassing courtship through early incubation in a given year, for individuals that did not breed by at least their fifth year of age (i.e., gross natal dispersal record). Data used for the latter were those available from the most recent adult year.

*c* Data from transmitter received intermittently such that 50% kernel density estimate of core area was based on 97 global positioning system location records versus about 400 records for other individual eagles.

Figure 1. Posterior median distributions of natal dispersal distance (NDD) of platform terminal transmitter–tagged male and female golden eagles *Aquila chrysaetos* in the Colorado Plateau-Southern Rocky Mountains region of the western United States, 2016–2018 (A) and posterior distribution of the intersexual difference in NDD (B); a difference of zero is outside the range of credible values.

Management Implications

To manage take of golden eagles via permits, the USFWS currently uses the 90th quantile value of the distribution of NDDs in Millsap et al. (2014) to represent, from a point or area on a given landscape, the radius of a circle encompassing the eagle’s local area population. Population size for the area can be projected from estimates of density for subunits corresponding to Bird Conservation Regions (U.S. North American Bird Conservation Initiative Committee 2007), and then maximum level of authorized take can be determined (USFWS 2016). The 90th quantile NDD value currently used for golden eagles, 175 km, was chosen by the USFWS as a conservative metric, considered appropriate given the golden eagle’s tentative population status in the United States (USFWS 2016). However, if NDDs of golden eagles are female biased, a male-based metric would be even more conservative than the metric currently used for managing the species, with sexes pooled in the supporting data set (Millsap et al. 2014). Additional data on NDDs of golden eagles from current studies in the western United States that are using satellite- or Global...
Systems for Mobile Communications–based telemetry could strengthen the base for management decisions in this vein, and possibly even reveal region-specific differences in the species’ NDDs.

**Supplemental Material**

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**Reference S1.** U.S. North American Bird Conservation Initiative Monitoring Subcommittee. 2007. Opportunities for improving avian monitoring. U.S. North American Bird Conservation Initiative Report. Arlington, Virginia: Division of Migratory Bird Management, U.S. Fish and Wildlife Service.

Found at DOI: https://doi.org/10.3996/052018-JFWM-039.S1 (4.71 MB PDF); also available at http://www.nabci-us.org/assets/resources/monitoringreportfinal0307.pdf.

**Reference S2.** [USFWS] U.S. Fish and Wildlife Service. 2013. Eagle conservation plan guidance: Module 1 – Land-based wind energy version 2. Washington, D.C.: U.S. Fish and Wildlife Service, Division of Migratory Bird Management.

Found at DOI: https://doi.org/10.3996/052018-JFWM-039.S2 (2.02 MB PDF); also available at https://www.fws.gov/migratorybirds/pdf/management/eagleconservationplanguidance.pdf.

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Found at DOI: https://doi.org/10.3996/052018-JFWM-039.S3 (3.64 MB PDF); also available at https://www.fws.gov/migratorybirds/pdf/management/EagleRuleRevisions-StatusReport.pdf.

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