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Authors: Slater, Steven J., Keller, Kent R., and Knight, Robert N.

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INTERANNUAL GOLDEN EAGLE (*AQUILA CHRYSAETOS*) NEST-USE PATTERNS IN CENTRAL UTAH: IMPLICATIONS FOR LONG-TERM NEST PROTECTION

STEVEN J. SLATER[1]
HawkWatch International, Inc., 2240 South 900 East, Salt Lake City, UT 84106 U.S.A.

KENT R. KELLER
4764 West 3855 South, West Valley, UT 84120 U.S.A.

ROBERT N. KNIGHT
U.S. Army Dugway Proving Ground, Building 5330 Valdez Circle, Dugway, UT 84022 U.S.A.

ABSTRACT.—Land managers regularly use temporal nest protections to reduce the likelihood of raptor nest disturbance or abandonment, but guidelines are not consistent across management boundaries. We assessed alternative nest use (i.e., egg-laying) and nest spacing at 28 Golden Eagle (*Aquila chrysaetos*) territories that were monitored ≥25 yr between 1976 and 2013 (all except seven territories were monitored annually without interruption). Territories contained 1–8 nests ($\bar{x} = 2.9$), and average spacing between alternative nests was 0.5 km. Inspection of 21 territories monitored for 26–38 yr without interruption suggested eagles used individual nests an average of every 3.3 yr, laid eggs in any nest within territories an average of every 1.8 yr, and switched nests between 43.3% of consecutive nesting attempts (i.e., egg-laying in discrete breeding seasons). Protecting individual nests for 7 yr, or protecting all nests within a territory for 4 yr after the last documented use of any nest when alternative nests were considered would have protected >90% of all consecutive nesting attempts. These temporal protections are longer than individual nest protections commonly applied by land management agencies (e.g., 3 yr since last use), but shorter than those suggested by Golden Eagle data collected in southwestern Idaho in an area with more alternative nests per territory. We recommend that land managers take a territory approach to Golden Eagle nesting protection, including consideration of local alternative nest-use patterns when possible. Management decisions should be based on the last use of any nest within a territory, including all potential eagle nests within a biologically meaningful distance of one another (e.g., based on local alternative nest spacing) when nest-monitoring data are limited; longer protections should be applied when knowledge of alternative nests is likely incomplete.

KEY WORDS: *Golden Eagle*; Aquila chrysaetos; *alternative nest*; *egg laying*; *nest protection*; *nest spacing*; *territory*; *Utah*.

PATRONES INTERANUALES DE USO DEL NIDO DE *AQUILA CHRYSAETOS* EN EL CENTRO DE UTAH: IMPLICACIONES PARA LA PROTECCIÓN DE NIDOS A LARGO PLAZO

RESUMEN.—Los gestores territoriales utilizan habitualmente la protección temporal de los nidos para reducir la probabilidad de molestias o el abandono del nido, pero las directrices no son consistentes a través de los límites de los ámbitos de gestión. Evaluamos el uso alternativo del nido (i.e., puesta de huevos) y el espaciamiento entre nidos en 28 territorios de *Aquila chrysaetos* que fueron seguidos durante ≥25 años entre 1976 y 2013 (todos los territorios menos siete fueron seguidos anualmente sin interrupción). Los territorios albergaron de uno a ocho nidos ($\bar{x} = 2.9$) y el espaciamiento promedio entre nidos alternativos fue de 0.5 km. La inspección de 21 territorios seguidos entre 26 y 38 años sin interrupción sugirió que las águilas utilizaron nidos individuales una media de 3.3 años, hicieron la puesta en cualquier nido dentro de los territorios cada 1.8 años en promedio e intercambiaron nidos en el 43.3% de los intentos de nidificación consecutivos (i.e., puesta de huevos en estaciones reproductoras discretas). La protección de

[1] Email address: sslater@hawkwatch.org

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nidos individuales durante siete años, o la protección de todos los nidos dentro de un territorio durante cuatro años a partir del último uso documentado de cualquier nido considerando los nidos alternativos, hubiera protegido más del 90% de todos los intentos de nidificación consecutivos. Estas protecciones temporales son mayores que las protecciones de nidos individuales comúnmente aplicadas por las agencias de gestión territorial (e.g., tres años desde el último uso), pero menores que aquellas sugeridas por los datos obtenidos de individuos de *A. chrysaetos* en el suroeste de Idaho en un área con mayor número de nidos alternativos por territorio. Recomendamos que los gestores del territorio utilicen una estrategia de protección de nidos de *A. chrysaetos* con un enfoque territorial, incluyendo la consideración de los patrones de uso de nidos alternativos cuando sea posible. Cuando los datos de seguimiento de nidos son limitados, las decisiones de gestión deberían basarse en el último uso de cualquier nido dentro de un territorio, incluyendo todos los nidos potenciales de águila dentro de una distancia biológicamente significativa entre los mismos (e.g., basada en el espaciamiento de nidos alternativos a nivel local). Deberían aplicarse protecciones durante mayor tiempo cuando el conocimiento de los nidos alternativos fuera incompleto.

[Traducción del equipo editorial]

Golden Eagle (*Aquila chrysaetos*) nesting habitat in western North America often includes areas desirable for energy development (Smith et al. 2010, Pagel et al. 2013), recreation (Boeker and Ray 1971, Kochert et al. 2002, Steenhof et al. 2014), and other activities potentially disruptive to nesting eagles. As a result, land management agencies such as the Bureau of Land Management (BLM) and U.S. Forest Service (U.S.F.S.) often apply spatial and temporal nest protections to minimize the likelihood of "take", including nest abandonment and interference with normal breeding behavior, under the Bald and Golden Eagle Protection Act (16 U.S.C. 668-668c). For example, raptor management on Utah BLM lands is guided by best management practices, which prescribe a 0.8-km spatial buffer around recently "occupied" Golden Eagle nests (as inferred from signs of use ranging from fresh greenery to presence of adults) during a defined seasonal window (BLM Instruction Memorandum UT 2006-096). Similar protections are provided to eagles, or raptors generically, on much of the federally managed land in the West, but with considerable variation in timing and duration of enforced temporal protections. Current federal temporal protections for eagle nests also generally treat individual nests as the management unit of interest.

Protection of individual nests on relatively short time scales (e.g., only during the season or year of "use") may be insufficient because Golden Eagles often maintain alternative nests within a territory, exhibit nest-switching between years, and do not necessarily lay eggs in all or most years (McGahan 1968, Kochert et al. 2002, Kochert and Steenhof 2012, Millsap et al. 2015). Gaps in nesting attempts (defined as egg-laying in discrete breeding seasons) at individual nests in the Snake River Canyon of southwestern Idaho averaged 4.4 yr and were as long as 39 yr (Kochert and Steenhof 2012). In this study, we analyzed another long-term Golden Eagle nesting dataset collected by K. Keller in central Utah to compare findings with the Idaho study, one of the first to identify the need for protracted temporal protections for Golden Eagle nests. We sought to assess interannual patterns in nesting attempts and nest-switching to determine temporal nest protections that would have minimized disturbance of nesting eagles during most (i.e., >90%) consecutive interannual nesting attempts observed in central Utah between 1976 and 2013. From this information and previous work from Idaho, we provide recommendations for improvement of current nest protections afforded to Golden Eagles on public lands.

METHODS

Study Area. The study area included lands managed by the BLM and the Utah School and Institutional Trust Lands Administration, as well as accessible private lands in the Great Basin physiographic region of central Utah. Known Golden Eagle nests occurred primarily on cliffs (98%), with trees and human structures occasionally used. Nests occurred in desert and upland shrub, grassland, and pinyon (*Pinus edulis*)-juniper (*Juniperus* spp.) vegetation types. Invasive cheatgrass (*Bromus tectorum*) was established within much of the study area, contributing to increased wildfire frequency and shrub loss in recent decades (Slater et al. 2013). Black-tailed jackrabbits (*Lepus californicus*) were the primary prey species for Golden Eagles within the study area and surrounding region during this study

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(i.e., 59.7% of 26,349 prey items collected in nests), with cottontails (*Sylvilagus* spp.; 8.9%), and numerous other species of decreasing importance (K. Keller unpubl. data). Major land uses within the study area included motorized recreation, military training, and livestock grazing.

Eagle Nest Surveys. KRK conducted ground surveys of potential Golden Eagle nesting habitat on public and accessible private lands at 240 territories between 1976 and 2013 with the aid of 10×50 binoculars and a variable 15–60× spotting scope. Survey work included multiple visits to each nesting territory between mid-March and early July to document "occupancy" (i.e., two adult eagles present, or one adult engaged in reproductive-related activity), incubation/brooding, presence and age of nestlings, nest success (i.e., laying pair producing $\geq$ one fledging) and fledgling production (i.e., number of fledglings reaching 80% fledge age per laying pair; Steenhof and Newton [2007]). Within each nesting territory, KRK monitored individual nests until nest use was confirmed or all nests were found to be unused, and made regular searches for new nests. Nest locations were initially recorded on maps and later with handheld GPS units (models varied across years). Detailed notes on nest characteristics and photographs were taken at each nest. Individual eagle nests were grouped into nesting territories based on confined localities where no more than one eagle pair was known to have laid eggs in the same year (Steenhof and Newton 2007).

We selected a subset of territories monitored for $\geq$25 yr to describe nest spacing and interannual nest use. The subset was biased toward territories known relatively early in the survey history, conducive to ground observation, and within approximately 3 hr driving distance of the primary observer's residence. First, we used ArcMap© (Version 9.3.1, 2009; Environmental Systems Research Institute, Redlands, CA) to measure the distances between alternative nests (i.e., within-territory nearest-neighbor distances) used at least once within territories surveyed a minimum of 25 yr, regardless of annual survey continuity. Second, we inspected survey histories and used descriptive statistics (i.e., range, mean, and standard error [S.E.]) to describe patterns of nest-switching and gaps in nesting attempts across years on an individual nest and territory basis, but we restricted this analysis to territories with uninterrupted survey histories of $\geq$25 yr. We used chi-square analysis to assess the influence of nest success on subsequent-year nest-switching.

Assessment of Existing Nest Protection Stipulations. We compiled information on existing BLM raptor or Golden Eagle-specific nest protection stipulations from 12 western states representing the primary breeding range of the Golden Eagle (Kochert et al. 2002; see discussion section for BLM-focus rationale). We searched within all available Resource Management Plans (RMPs) for spatial and temporal protection guidance for nesting eagles in relation to potentially disturbing activities on typical multiple-use lands (we excluded special use area and monument lands). Most stipulations targeted mineral development, but some addressed motorized recreation and other activities. Potential future stipulations described in draft plans or plan revisions (i.e., plans lacking a Record of Decision) were not included in our assessment.

RESULTS

Twenty-eight Golden Eagle territories in central Utah were surveyed in $\geq$25 of the 38 survey-years between 1976 and 2013 and also supported at least one nesting attempt during the same period. All but seven of these territories were surveyed annually without interruption. Within these territories, 1–8 nests ($\bar{x} = 2.9$; S.E. = 0.36) were used for egg-laying across all survey years, but no more than one nest was used in any year. Spacing of alternative nests (i.e., within-territory nearest neighbors; $n = 48$) within all Golden Eagle territories containing two or more nests averaged 513 m (median = 216 m); 90% of all nests were within 1476 m of their closest alternative (maximum was 2665 m). Minimum horizontal spacing was <1 m (e.g., nests spaced vertically on the same cliff).

A subset of 21 territories was surveyed annually without interruption for 26–38 yr ($\bar{x} = 31.1$). Gaps between nesting attempts at the same nest ranged from 1–24 yr ($\bar{x} = 3.3$; S.E. = 0.21), and the time elapsed between nesting attempts at any nest within individual territories ranged from 1–10 yr ($\bar{x} = 1.8$; S.E. = 0.08; Table 1). Eagles made nesting attempts during 50.2% of territory-survey years ($n = 654$), and nest-switching occurred between 43.3% of subsequent nesting attempts. Nest success or failure in one year did not influence whether a pair switched nests in the following year ($\chi^2 = 2.87$, df = 1, $P = 0.09$, $n = 189$ consecutive-year nesting attempts).

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Table 1. Cumulative proportion of sequential nesting attempts (n = paired, sequential egg-laying in discrete breeding seasons) "protected" by hypothetical interannual temporal nest protections based on actual time elapsed between nesting attempts observed at the same nest or any nest (n = 66) within 21 territories monitored without interruption for 26–38 yr in central Utah.

	Cumulative % of Sequential Nesting Attempts Protected			
Nest Protection (Yr)	n	Based on Nesting Attempts at the Same Nest	n	Based on Nesting Attempts at any Nest Within the Territory
1	94	36.0	189	61.0
2	64	60.5	62	81.0
3	29	71.6	25	89.0
4	18	78.5	17	94.5
5	10	82.4	4	95.8
6	16	88.5	8	98.4
7	8	91.6	2	99.0
8	6	93.9	1	99.4
9	3	95.0	0	99.4
10	2	95.8	2	100.0
11	3	96.9	–	–
13	1	97.3	–	–
14	2	98.1	–	–
15	1	98.5	–	–
17	1	98.9	–	–
19	1	99.2	–	–
23	1	99.6	–	–
24	1	100.0	–	–

We searched 111 current BLM RMPs available online and found 69.4% provided specific raptor or Golden Eagle spatial and/or temporal nest-protection guidance, but only 15.3% provided specific multiyear protections (Table 2). Multiyear protections prescribed that individual nests be protected for 2, 3, 5, or 7 yr since last use, with 3 yr most common (Table 2).

Discussion

Given the current uncertainty regarding the status of local and regional Golden Eagle populations (Farmer et al. 2008, Millsap et al. 2013, U.S. Fish and Wildlife Service 2016) and the potential for disturbance or take of nesting eagles resulting from energy development and other human activities (Boeker and Ray 1971, Kochert et al. 2002, Smith et al. 2010, Pagel et al. 2013, Steenhof et al. 2014), it is critical that temporal nest protections be based on the best available long-term information. We compare data from Golden Eagles nesting in central Utah with previous data published from southern Idaho (Kochert and Steenhof 2012) to help guide such protections.

Cliff-nesting eagles in central Utah laid eggs at an average of 2.9 nests per territory (range = 1–8 nests) over time compared to an average of 6.9 nests (range = 1–18 nests) per territory on cliffs along the Snake River in southwestern Idaho (Kochert and Steenhof 2012). Average spacing of alternative nests in central Utah was 512 m, compared to only 191 m in Idaho; we found that 90% of alternative nests in Utah were within 1.5 km of each other, compared to only 0.5 km in Idaho (Kochert and Steenhof 2012). Regional variability in alternative nest use may be related to nest-site availability, prey resources, parasites, or

Table 2. Golden Eagle temporal nest protection stipulations in 111 Bureau of Land Management Resource Management Plans (RMPs) in 12 western states widely overlapping eagle breeding habitat (Kochert and Steenhof 2002). Nest "use" refers to nest "activity" or "occupancy" (these terms were not defined in the RMPs).

Within-year Protection	Multiyear Protection	No. of RMPs	No. of States	States with RMPs
None	None	34	12	AK, AZ, CA, CO, ID, MT, NM, NV, OR, UT, WA, WY
Year-round	Not discussed	7	3	AZ, ID, MT
Seasonal	Not discussed	30	11	AK, AZ, CA, CO, ID, MT, NM, NV, OR, UT, WY
Seasonal, when used	Not discussed	23	8	AZ, CA, CO, ID, NM, NV, OR, UT, WY
Seasonal, when used	2 yr since last use	2	2	AZ, ID
Seasonal, when used	3 yr since last use	8	3	CO, UT, WY
Seasonal	3 yr since last use	2	1	WY
Seasonal	5 yr since last use	3	2	MT, NV
Seasonal	7 yr since last use	2	1	NM

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other factors (Watson 2010). The higher density and closer spacing of nests in Idaho is likely related to the relatively continuous cliff availability within the Snake River Canyon (Kochert and Steenhof 2012, Watson et al. 2014), compared with central Utah, where cliffs are restricted to more widely dispersed and isolated topographic features within basin and range geography. Although survey biases exist in the central Utah dataset (see Methods), a recent large-scale compilation of Golden Eagle nesting data from western and central Utah suggests similar nest spacing and alternative nest numbers as reported here (Utah Eagle Working Group unpubl. data). Reuse of individual nests was also shorter in Utah (3.3 yr) relative to Idaho (4.4 yr; Kochert and Steenhof 2012), as expected given the fewer alternative nests per territory in Utah.

Our results agree with previous studies that suggested nest-switching was not more likely following nest failure (Boeker and Ray 1971, Kochert and Steenhof 2012). Nest-switching may convey fitness benefits to eagles by reducing nest parasites or may reinforce territory ownership, may guard against future nest loss, or may result from turnover of individuals (Watson 2010, Kochert and Steenhof 2012, Millsap et al. 2015). Regardless of the cause, current eagle nest protection and management on federal lands does not adequately consider alternative nest use dynamics (Millsap et al. 2015).

Our data suggest temporal protection of individual nests for 7 yr, or protection of all nests within a territory for 4 yr after the last documented eggs were laid at any nest, would have protected >90% of all historical, consecutive nesting attempts (Table 1). In contrast, Kochert and Steenhof (2012) reported that 10 yr of nest protection would have protected only 51% of southern Idaho nests for their entire histories, with the remainder being unused for a longer interval at some point in time and then reused. However, the Idaho study focused on individual nests as the sample units (i.e., 49% of nests were reused at >10-yr interval at some point in their history, even though most reuse intervals were shorter at each nest). In contrast, our sample units were each pair of consecutive nesting attempts to reflect the reality that multiyear BLM nest management is guided by last known nest use (see Table 2), and long-term histories are generally lacking for management decisions. Despite these methodology differences, the higher number of alternative nests available (i.e., more nest-switching opportunities) and the longer average time between nest reuses in Idaho suggest that longer individual nest protection is warranted in Idaho compared to central Utah.

Considerable variation exists in current temporal protections provided to Golden Eagles nesting on BLM lands, both within and across years (Table 2). We focused our examination on BLM stipulations given the disproportionate value of BLM lands for Golden Eagles nesting on public lands and the greater potential for conflict with energy development and recreation. However, similar nest-protection stipulations are written into guidance from other federal land management agencies (e.g., U.S.F.S.). Many BLM plans were currently under revision, did not specifically address eagles due to low potential for nesting or nest conflict, or provided only generic statements regarding protection of sensitive species and other wildlife. It was not clear if multiyear protection was precluded or assumed in plans that failed to address the issue. Regardless, only two plans prescribed the 7 yr of temporal protection for individual nests suggested by our data, and none provided longer temporal protections suggested by data from Idaho (Kochert and Steenhof 2012).

Nearly all large-scale or long-term surveys of nesting Golden Eagles may have missed early-season nest failures or overlooked alternative nests. These two sources of error would both lead to the overestimation of interannual gaps in nest use. However, we point out that these same errors are likely to occur in the application of the temporal nest protection recommendations suggested by the Utah and Idaho datasets. Furthermore, both of these nesting datasets were collected by eagle experts with many years of experience within their study areas and fewer "errors of omission" likely exist than would be expected in survey efforts by less experienced observers or in areas with less complete historical territory information.

Management Implications. Our data suggest a minimum of 7 yr of temporal protection should be extended to individual nests with confirmed eagle egg-laying when the location and historical use of alternative nests is unknown. Temporal nest protection may be shorter (i.e., 4 yr) when alternative nests are well known, monitored collectively, and the protection of all nests is based on the last use of any nest within the territory. In contrast, when alternative nests are not considered, or when alternative

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nest opportunities are more abundant, longer protections (>10 yr) of individual nests are recommended (e.g., Kochert and Steenhof 2012, Millsap et al. 2015). We suggest nest management include efforts to identify and monitor all alternative nests within a biologically meaningful distance of known nests based on available regional information on territory size or alternative nest spacing (e.g., this study, Kochert and Steenhof 2012, Watson et al. 2014). Further, we recommend treating all suspected eagle nests within locally informed nest-spacing distances as potential alternative nests when adequate nest histories are lacking. Temporal decisions regarding nest management (e.g., when to classify a nest as "abandoned") should take into account the history of all potential nests within a territory, with greater caution taken when information may be incomplete (Millsap et al. 2015). Additionally, managers may wish to adjust temporal nest protections upward to protect >95% of consecutive nesting attempts (our recommendations are based on >90% protection). Finally, dramatic declines in habitat condition and/or prey availability and increased disturbance may cause eagles to forgo egg-laying for extended periods, and these factors should be considered when applying temporal protections.

We encourage managers to incorporate multiyear protections and consideration of alternative nest use dynamics in land-use plans to address temporal disturbance concerns related to nesting Golden Eagles. Alternative nests should be given the same temporal protection as used nests in land-use planning (Watson et al. 2014, Millsap et al. 2015). Nests should be protected outside the nesting season from development activities (e.g., establishment of roads, well pads, etc.) that will result in potential disturbance during subsequent nest seasons within the temporal protection period.

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