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SHORT COMMUNICATIONS

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HOME RANGE AND USE AREA SIZES OF TERRITORIAL GOLDEN EAGLES TRACKED WITH TAIL-MOUNTED SATELLITE TRANSMITTERS

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ABSTRACT.—Recent use of satellite-tracked platform transmitter terminals (PTTs) has increased knowledge of movements of Golden Eagles (*Aquila chrysaetos*) and virtually all have been attached via backpack harnesses. To avoid reported negative effects of backpack harnesses on eagle behavior, survival, or reproduction, ten resident, territorial adult Golden Eagles were tagged with one of two PTT configurations mounted dorsally or ventrally on two center rectrices. Eagles retained PTTs a mean of 5.2 mo. Three male eagles forcibly removed tail-mounted PTTs prior to molt. Tracked eagles accrued a mean of 498 (SE = 93.9) fixes over a mean 160 d (SE = 21.8). Kernel density estimates of 95% area (home range) and 50% area (core use) were 123.8 (SE = 62.9) km^2 and 7.9 (SE = 4.1) km^2, respectively. Area comparisons with similar cohorts of Golden Eagles with PTTs attached by backpack harnesses showed Montana, USA eagles ranged as extensively as those in other ecoregions but concentrated activity in smaller areas. Attaching smaller, lighter-weight PTTs to the right central rectrix of non-juvenile eagles during periods other than late summer/early fall will likely improve retention time over this study, especially for males. Tail-mounted PTTs performed equally well as PTTs attached via backpack harnesses. When study objectives or resources limit data needs to <3 yr, tail mounts are encouraged.

KEY WORDS: *Golden Eagle*; Aquila chrysaetos; *backpack harness*; *core use area*; *GPS*; *home range*; *PTT*; *tail mount.*

ÁREA DE CAMPEO Y TAMAÑOS DEL ÁREA DE USO DE INDIVIDUOS TERRITORIALES DE *AQUILA CHRYSAETOS* SEGUIDOS CON TRANSMISORES SATELITALES MONTADOS EN LA COLA

RESUMEN.—El uso reciente de emisores satelitales (PTT) ha aumentado el conocimiento de los movimientos de *Aquila chrysaetos* y prácticamente todos los transmisores se han sujetado mediante arneses torácicos. Para evitar los efectos negativos reportados de los arneses torácicos en el comportamiento, la supervivencia o la reproducción de las águilas, se marcaron diez individuos adultos territoriales residentes con una de dos configuraciones de PTT montados dorsal o ventralmente en dos rectrices centrales. Las águilas retuvieron los PTT una media de 5,2 meses. Tres águilas macho se quitaron por la fuerza los PTT montados en la cola antes de la muda. Las águilas seguidas acumularon una media de 498 (EE = 93,9) posiciones durante una media de 160 días (EE = 21,8). Las estimaciones de densidad de kernel del 95% del área (área de campeo) y del 50% del área núcleo de uso fueron 123,8 km^2 (EE = 62,9) y 7,9 km^2 (EE = 4,1), respectivamente. Las comparaciones de área con cohortes similares de *A. chrysaetos* con PTTs sujetos por arneses torácicos mostraron que las águilas de Montana, EEUU presentaron áreas de campeo tan extensas como las de otras ecorregiones, pero concentraron la actividad en áreas más pequeñas. Colocar PTTs más pequeños y livianos en la rectriz central derecha de águilas no juveniles durante períodos distintos a los de finales de verano o principios de otoño probablemente mejorará el tiempo de retención durante este estudio, especialmente para los machos. Los PTTs montados en la cola funcionaron igual de bien que los PTT sujetos mediante arneses torácicos. Cuando los objetivos del estudio o los recursos limitan las necesidades de datos a <3 años, se recomiendan los emisores montados sobre la cola.

[Traducción del equipo editorial]

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INTRODUCTION

Use of satellite-tracked platform transmitter terminals (PTTs; i.e., Argos Doppler units, global positioning system [GPS] units or global system for mobile communications [GSM] units) has increased knowledge of movements of Golden Eagles (*Aquila chrysaetos*) since the late 20th century (e.g., Brodeur et al. 1996, McIntyre et al. 2008, Brown et al. 2017). Much of this knowledge relates to home range and movements of territorial pairs in the breeding range (Moss et al. 2014, Watson et al. 2014, Crandall et al. 2015) and virtually all PTTs have been attached to Golden Eagles by backpack harnesses (BPH; see Brown et al. 2017). Despite a recent report of null effects of BPH on physical status of *Aquila* species (Garcia et al. 2021), evidence exists that BPH may affect eagle behavior, survival, or reproduction (Gregory 2003, Moss et al. 2014, Stahlecker et al. 2015). Although BPH may have a distinct advantage of monitoring eagles over long time periods (≤8 yr; D. Stahlecker pers. comm.), tail-mounted PTTs intuitively offer a less restrictive alternative attachment technique with fewer negative effects than BPH. Other than forcible removal (Harmata 2016), no negative effects of tail-mounted PTTs on Golden Eagles have been reported. Here, Golden Eagle area use metrics recorded with tail-mounted PTTs were compared with similar metrics reported in studies using BPH attachments to evaluate differences.

METHODS

Free-flying Golden Eagles were captured using net launchers (Coda Enterprises, Inc., Mesa, AZ, USA) or padded leg-hold traps (Miner 1975) at baits placed within 0.75 km of recently occupied (≤3 yr) nest sites or habitually used perches during the breeding season. Eagles were tagged in southwestern Montana, USA roughly between 45.22°N and 47.17°N and between 110.48°W and 112.20°W. Focus was on capturing resident, territorial adults and males were prioritized for tagging because female ranges usually are contained within the male's range (Watson et al. 2014, M. Lockhart pers. comm.). Captured eagles were sexed by size (Harmata and Montopoli 2013) and aged by plumage (table 1 in Bloom and Clark 2001).

Captured adult eagles were tagged with one of two PTT configurations (NorthStar Science and Technology LLC, King George, VA, USA): a 32-g battery-powered unit attached ventrally to two central rectrices that produced only Doppler locations; or a 22-g solar-powered unit attached dorsally to two central rectrices that produced both Doppler and GPS locations (see Harmata 2016 for details). Duty cycles were 6 hr on, 2 d off for both PTT configurations. Both units provided up to seven eagle locations between 0800 and 2200 H Mountain Standard Time.

Behavior and movements of tagged eagles post-capture confirmed residency and mated status. Eagles present within Montana between 15 April and 15 October were considered residents. Resident adults observed engaged in breeding behavior or commonly associated with nest sites or another adult eagle of distinctly dissimilar size (i.e., the opposite sex) were considered territorial and mated. Resident adult eagles not commonly observed associated with nest sites or another adult eagle and which ranged widely were considered floaters (Brown 1969, Hunt 1998), assumed to be unmated, and not included in analyses.

PTT-generated latitude-longitude coordinate location data (hereafter fixes) were used to depict ranges and use areas of resident, territorial adult Golden Eagles. Only Doppler quality 3 and 2 fixes (accuracy ± 250–500 m) and all GPS fixes (accuracy ± 20 m) for eagles with ≥60 d of tracking were analyzed. Latitude and longitude coordinates for each fix were tabulated sequentially in STAT (Doppler fixes; Coyne and Godley 2005) and PTT Tracker (GPS fixes; GeoTrack 2011). Sequential data were imported to Excel spreadsheets and fix locations displayed in 3D Maps (Excel) module.

Locations for some eagles also were classified by season for the purposes of comparison with other studies. Seasons were spring (21 March–20 June), summer (21 June–20 September), fall (21 September–20 December), and winter (21 December–20 March). Any location occurring between seasonal dates included that eagle in that season.

Kernel density estimates (KDE, Getz et al. 2007) of 95% and 50% fixes were constructed using *plugin* bandwidth estimator within the geospatial modeling environment (Beyer 2014). Graphic contours represented the smallest area where probability of relocating an individual was equal to 95% or 50%. KDE of 95% represented an individual's home range and 50% KDE represented core use area (CUA). For eagles with both Doppler- and GPS-capable PTTs, use area values were calculated from only GPS fixes.

Group differences were tested using nonparametric procedures (Mann-Whitney *Z*, Kruskal-Wallis *H*, Kendall *T* statistics) in STATISTICA version 13.3 (TIBCO Software Inc. 2017). Measures of central tendency are presented as both mean and median to aid in comparisons with other studies.

Satellite-tracked PTTs were not used in many earlier studies cited by Katzner (2020) so to compare attachment methods with efficacy of data return, comparative analysis here was restricted to easily accessible data sets from studies with methods most similar to those deployed in Montana. Results were compared with two other studies using satellite tracking technology and KDE data analysis methods. Braham et al. (2015) studied ranges of Golden Eagles with BPH in the Mojave Desert of California, USA and analyzed ranges using KDE methods as did Moss et al. (2014) tracking Golden Eagles in boreal forests of Sweden. Descriptive statistics were gleaned from Braham et al.

Table 1. Home range (95% kernel density estimate [KDE]) and core use [50% KDE]) areas of resident, territorial Golden Eagles wearing tail-mounted satellite-tracked platform transmitter terminals in Montana, USA. Bolded, italicized areas were calculated using GPS fixes; others were calculated with Doppler fixes.

		Tracking			Area	
Eagle ID	Sex	Inclusive Seasons	Days	Fixes[a]	Home Range	Core Use
RC64	M	W, Sp (2012)	60[b]	138	65	8
HD67[c]	M	W, Sp (2013)	81[b]	111/205	***543***	***43***
BC64	M	W, Sp (2012)	101	161	36	6
Cp56[c]	M	W, Sp, Su (2011)	124	545	7	0.6
WCM66	M	F, W, Sp (2011–2012)	161[b]	323	6	0.5
BC68[c]	F	F, W, Sp, Su (2013–2014)	176	128/468	***0.4***	***0.01***
NC71	M	W, Sp, Su (2015)	181	307/914	***445***	***12***
RD56[c]	M	F, W, Sp, Su (2014–2015)	192	345/959	***25***	***2***
YD63[c]	F	W, Sp, Su, F (2014)	242	563	11	1
RG63	F	F, W, Sp, Su (2011–2012)	277	700	100	6
Mean			160	498	123.8	7.9
SE			21.8	93.9	62.9	4.1
Median			169	507	30.5	4.0

[a] Doppler/GPS.
[b] PTT forcibly removed by eagle.
[c] Fledged ≥1 young during the year tracked.

(2015; supplementary material, table A.1) and combined n, mean, and SD statistics calculated as follows:

$$n_{95\%/50\%(\text{combined})} = 117/108,$$

$$\text{mean}_{(\text{combined})} = \frac{\sum_{i=1}^{n} x_i}{n},$$

$$\text{SD}_{(\text{combined})} = \sqrt{\frac{\sum x^2 - \frac{\left(\sum x\right)^2}{n}}{n-1}},$$

Similar statistics were calculated from data presented in Moss et al. (2014; fig. 2; KDE; for eagles with >1 breeding season of data [2 of 14], only one was included). Multiple t-test comparisons were used to test for differences in home range and core use area among studies and P-values Bonferroni corrected (P-value/3).

Results

Seventeen adult Golden Eagles were captured and tagged with tail-mounted PTTs between February 2011 and January 2015 (Table 1). One migrated to central British Columbia, Canada, three were classified as floaters, two removed PTTs in <16 d, and transmissions stopped for one eagle at 50 d. Area use metrics were calculated for ten adult eagles (7 ♂, 3 ♀) that were members of 10 territorial pairs and tracked ≥60 d (median = 169 d; Table 1). Six eagles (4 ♂, 2 ♀) wore Doppler PTTs and four eagles (3♂, 1 ♀) wore PTTs that provided Doppler and GPS fixes. Eagles wore PTTs from 16–76% of the year (mean = 43%) and an average of three seasons (range = 2–4 seasons; Table 1). Five eagles (4 ♂, 1 ♀) were members of productive breeding pairs that fledged ≥1 eaglet during the year tracked.

Three tail-mounted PTTs were recovered after eagles forcibly removed them prior to molt. All were males, two wore heavier ventral Doppler units, and one wore a solar GPS unit. Two males that removed PTTs were members of productive breeding pairs during tracking. Three eagles (2♀, 1♂) molted PTTs that were recovered, two eagles (1♀, 1♂) molted PTTs that were not recovered, and two PTTs failed (1♀, 1♂) and were not recovered.

Home ranges and CUAs of territorial Golden Eagles were not related to the number of fixes obtained or number of days or seasons tracked for either Doppler (n = 6) or GPS (n = 4) PTTs ($P > 0.05$). Home ranges and CUAs were directly and positively correlated for both Doppler and GPS PTTs (Kendall $T = 0.94$, $P < 0.01$). No difference was found between paired Doppler- or GPS-detected home range or CUA ($P > 0.52$) and data were pooled for analysis. Pooled Doppler and GPS home range and CUA did not differ by sex (Kruskal-Wallis $H_{(1,10)} < 1.31$, $P > 0.25$) or productivity (Kruskal-Wallis $H_{(1,10)} < 0.89$, $P > 0.34$). CUAs of all tracked eagles were located within 55 km of a nest site for the duration of tracking.

No differences in home range size were detected among Golden Eagles in Montana (this study), California (Braham et al. 2015), or Sweden (Moss et al. 2014) ($t > -1.72$, $P > 0.05/3$). A difference was detected between the CUAs of

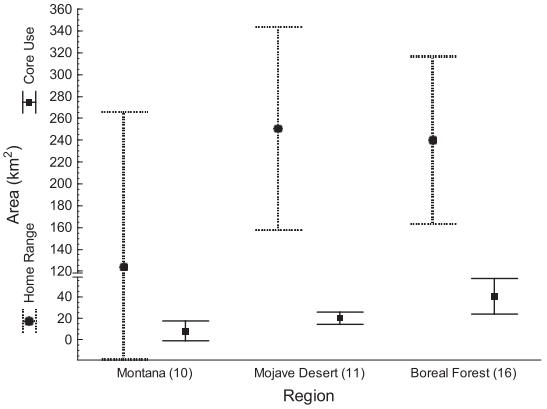

Figure 1. Mean (± 95% CI) adult Golden Eagle home range (95% kernel density estimate [KDE]) and core use (50% KDE) areas for three studies (n) using satellite-tracked platform transmitter terminals and similar analysis methods. Data for California from Braham et al. (2015; Supplementary Material, table A.1); for boreal forest, Sweden, from Moss et al. (2014; fig. 2), and for Montana, this study. Note y-axis break.

Montana and boreal forest eagles in Sweden ($t=-3.10$, $P<0.05/3$) but not California eagles ($t=-0.77$, $P>0.05/3$). Montana eagles appeared to range as far as those in other ecoregions but concentrated their use in smaller areas than those in the boreal forest (Fig. 1).

DISCUSSION

Various data analysis differences, sample sizes, presentation methods, and disimilar ecoregions (Bailey 1989) make direct comparison of Golden Eagle home range metrics among most published studies (see Katzner et al. 2020) tenuous but not uninformative. No differences among home range metrics were found (Fig. 1) and similarity of results may indicate no effect of PTT attachment method (tail-mounted vs. BPH) for defining extent of wide-ranging behavior common to the species. The larger sizes of boreal forest eagle CUAs vs. Montana eagle CUAs, and the similarity of Montana and California eagle CUAs may be influenced by a variety of factors but are likely related to overall habitat differences (e.g., density of naturally associated vegetation affecting prey availability).

All PTTs forcibly removed by eagles in this study were removed by males. Males may have been especially sensitive to discomfort imparted by excessive PTT bulk and weight (relative to body mass) on the two central rectrices, which may have had differential molt sequences, provoking attention to removal efforts. High-performance, solar-charged GPS transmitters that are substantially smaller and lighter than those used in this study with capabilities rivaling the most technologically advanced BPH-mounted transmitters currently in use have recently been developed (e.g., 5-g Icarus transmitter, https://www.icarus.mpg.de/28874/sensor-animals-tracking). One central rectrix of a Golden Eagle could serve as a mounting base, eliminating differential stress on the two rectrices and promoting maximum retention commensurate with normal molt, especially for males.

Captive Golden Eagles ($n=14$) had mean retention time of 2 yr for the right central rectrix, which lies atop the left central rectrix when the tail is closed (Ellis and Kery 2004, Ellis and Lish 2006). PTT retention of 5-g PTTs could approach 2 yr if they were attached to the proximal region of the right central rectrix and the upper tail coverts trimmed as described in Harmata (2016). PTTs might be retained ≥2.2–2.4 yr if attached to inner rectrices (e.g., rectrice #3, #4), which are typically retained longer than central rectrices (Ellis and Kery 2004) with the vane of the adjacent overlapping rectrix trimmed to expose the PTT solar panel to sunlight.

Deployment of PTTs on newer, "hard-penned" rectrices (<1 yr old) at appropriate times (September–April) also would promote maximum retention. Mid-summer to early fall generally is the least suitable time to attach transmitters via tail-mount on non-juvenile eagles because rectrices are most likely to be absent or developing at that time (Jollie 1947, Ellis et al. 2006, A. Harmata unpubl. data). However, attachment at this time would maximize retention on juvenile eagles.

Tail-mounted PTTs performed equally well as PTTs attached via BPH. Thus, when study objectives or resources limit data needs to <3 yr, use of tail-mounted PTTs may be desirable to avoid documented detrimental effects of BPH.

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LITERATURE CITED

Bailey, R. G. (1989). Explanatory supplement to ecoregions map of the continents. Environmental Conservation 16:307–309.

Beyer, H. (2014). Geospatial Modeling Environment Version: 0.7.2 RC2 https://pdf4pro.com/cdn/geospatial-modelling-environment-spatial-156afa.pdf.

Bloom, P. H., and W. S. Clark (2001). Molt and sequence of plumages of Golden Eagles and a technique for in-hand ageing. North American Bird Bander 26:97–116.

Braham, M., T. A. Miller, A. E. Duerr, M. Lanzone, A. Fesnock, L. LaPre, D. Driscoll, and T. Katzner (2015). Home in the heat: Dramatic seasonal variation in home range of desert Golden Eagles informs management for renewable energy development. Biological Conservation 186:225–232.

Brodeur, S., R. Décarie, D. M. Bird, and M. Fuller (1996). Complete migration cycle of Golden Eagles breeding in northern Quebec. The Condor 98:293–299.

Brown, J. L., B. Bedrosian, D. A. Bell, M. A. Braham, J. Cooper, R. H. Crandall, J. DiDonato, R. Domenech, A. E. Duerr, T. E. Katzner, M. J. Lanzone, et al. (2017). Patterns of spatial distribution of Golden Eagles across North America: How do they fit into existing landscape-scale mapping systems? Journal of Raptor Research 51:197–215.

Brown, J. M. (1969). Territorial behavior and population regulation in birds: A review and re-evaluation. Wilson Bulletin 8:293–329.

Coyne, M. S., and B. J. Godley (2005). Satellite Tracking and Analysis Tool (STAT): An integrated system for archiving, analyzing and mapping animal tracking data. Marine Ecology Progress Series 301:1–7.

Crandall, R. H., B. E. Bedrosian, and D. Craighead (2015). Habitat selection and factors influencing nest survival of Golden Eagles in south-central Montana. Journal of Raptor Research 49:413–428.

Ellis, D. H., and M. Kéry (2004). Variable retention times for rectrices at different loci in a Golden Eagle. Journal of Raptor Research 38:270–275.

Ellis, D. H., and J. W. Lish (2006). Thinking about feathers: Adaptations of Golden Eagle rectrices. Journal of Raptor Research 40:1–28.

Ellis, D. H., J. W. Lish, M. Kery, and S. M. Redpath (2006). Short-term oscillations in avian molt intensity: Evidence from the Golden Eagle *Aquila chrysaetos*. Journal of Avian Biology 37:642–644.

García V., J. J. Iglesias-Lebrija, and R. Moreno-Opo (2021). Null effects of Garcelon harnessing method and transmitter type on soaring raptors. Ibis 163:899–912.

GeoTrack, Inc. (2011). PTT Tracker. Ver. 1.0.0.1.4. NorthStar Science and Technology. geotrakinc.com/ptt-tracker.html.

Getz, W. M., S. Fortmann-Roe, P. C. Cross, A. J. Lyons, S. J. Ryan, and C. C. Wilmers (2007). LoCoH: Nonparameteric kernel methods for constructing home ranges and utilization distributions. PLoS ONE 2(2): e207. https://doi.org/10.1371/journal.pone.0000207.

Gregory, M. J. P., A. G. Gordon, and R. Moss (2003). Impact of nest-trapping and radio-tagging on breeding Golden Eagles *Aquila Chrysaetos* in Argyll, Scotland. Ibis 145:113–119.

Harmata, A. R. (2016). Retention, impact, and utility of tail-mounted satellite tracked transmitters on Golden Eagles. Journal of Raptor Research 50:265–275.

Harmata, A., and G. Montopoli (2013). Morphometric sex determination of North American Golden Eagles. Journal of Raptor Research 47:108–116.

Hunt, W. G. (1998). Raptor floaters at Moffat's equilibrium. Oikos 82:191–197.

Katzner, T. E., M. N. Kochert, K. Steenhof, C. L. McIntyre, E. H. Craig, and T. A. Miller (2020). Golden Eagle (*Aquila chrysaetos*), version 2.0. In Birds of the World (P. G. Rodewald and B. K. Keeney, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.goleag.02.

McIntyre, C. L., D. C. Douglas, and M. W. Collopy (2008). Movements of Golden Eagles (*Aquila chrysaetos*) from interior Alaska during their first year of independence. The Auk 125:214–224.

Moss, E. H. R., T. Hipkiss, F. Ecke, H. Dettki, P. Sandström, P. H. Bloom, J. W. Kidd, S. E. Thomas, and B. Hörnfeldt (2014). Home-range size and examples of post-nesting movements for adult Golden Eagles (*Aquila chrysaetos*) in boreal Sweden. Journal of Raptor Research 48:93–105.

Stahlecker, D. W., T. H. Johnson, and R. K. Murphy (2015). Preening behavior and survival of territorial adult Golden Eagles with backpack satellite transmitters. Journal of Raptor Research 49:316–319.

TIBCO Software Inc. (2017). STATISTICA ver. 13.3 1984–2017. Palo Alto, CA, USA. https://docs.tibco.com/products/tibco-statistica-13-3-0.

Watson, J. W., A. A. Duff, and R. W. Davies (2014). Home range and resource selection by GPS-monitored adult golden eagles in the Columbia Plateau Ecoregion: Implications for wind power development. Journal of Wildlife Management. 78:1012–1021.

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