GOLDEN EAGLE HOME RANGE, HABITAT USE, DEMOGRAPHY AND RENEWABLE ENERGY DEVELOPMENT IN THE CALIFORNIA DESERT

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Introduction

Golden eagle (*Aquila chrysaetos*) populations in North America are thought to be declining (Hoffman and Smith 2003, Smith et al. 2008; but see McCaffery & McIntyre 2005). This species is enigmatic and indicative of broad conservation value (Sergio et al. 2005), and, for the most part, poorly known. Populations west of the Mississippi River in the lower 48 states include approximately 21,000 – 35,000 individuals (Good et al. 2004, 2007). However, this estimate is based on limited sampling effort, broad scale extrapolation to unsampled habitats, and does not include birds in Canada or Alaska.

In California, golden eagles are listed as a species of concern by numerous state and federal agencies. The Department of Forestry and Fire Protection (CDF) lists the species as “Sensitive” (CDF-S), the Department of Fish and Game considers the species “Fully Protected” and puts it on its “Watch List” (DGF – FP/WL), their state NatureServe rank is G5S3, the US Fish and Wildlife Service puts the species on its “Birds of Conservation Concern” list (USFWS-BCC), and the BLM considers it “Sensitive.”

Golden eagle populations in California are comprised of both resident breeders, resident floaters (non-breeders, usually pre-adults), and wintering migrants. Dietary studies suggest that these birds forage on a diverse prey base, including black-tailed jackrabbits, rodents, upland game and other birds, reptiles and carrion (Carnie 1954, Bloom & Hawks 1982, Ziener et al. 1988-1990). Diet of *Aquila* eagles globally is more focused during the breeding season when food requirements are more stringent and more diverse during the non-breeding season. Likewise, home range and habitat requirements of breeders are also more restricted than those of floaters and wintering individuals (Watson 2010).

California’s golden eagles face a variety of threats. In particular, development of renewable energy is a rapidly emerging and important concern that has the potential to impact eagles at all stages of their life history. There is a known history of golden eagle conflict with California wind energy plants, primarily through direct mortality from collisions (Hunt 2002, Smallwood & Thelander 2008). More recently, growth of the solar energy industry presents additional indirect risk to birds, primarily through habitat conversion and loss (Fernandes et al 2010). Both solar and wind industry businesses are submitting large numbers of applications for energy projects on federal lands in California (Fernandes et al 2010), thus the environmental impacts of these programs are expected to grow with time.

BLM Solicitation L11PS01121 focused primarily on breeding adults inhabiting the Mojave and Sonoran Deserts. This solicitation addressed a number of key concerns, built around correlates of home range, including size, seasonality, habitat use and quality, and breeding biology. In addition, there are research questions linked to eagle demography of all age classes – productivity, dispersal behavior, trends in territory and nest occupancy and causes of eagle mortality.

Methodology

The BLM asked five research questions related to habitat use and home range and four related to population dynamics. We are addressing the questions of habitat use and home range with GPS-GSM telemetry and standard GIS analyses. We will address questions related to population dynamics with nest visits (productivity, occupancy), GPS-GSM telemetry (dispersal, mortality), and non-invasive genetic monitoring (occupancy trends).

Telemetry. Telemetry studies are essential to addressing research questions tied to home range, habitat use, dispersal and causes of mortality. Previous research on eagles in the western USA has used either conventional VHF telemetry systems or ARGOS satellite telemetry systems (e.g., Hunt 2002, McIntyre et al. 2008). VHF telemetry historically provided key insight into movements and threats, but it is now rarely used because of the extensive cost required for technicians to follow individuals, especially those that disperse away from a researcher’s study site. More recently ARGOS-based satellite telemetry studies have replaced VHF telemetry as the tool of choice for following wildlife. ARGOS systems are useful because they can track animals remotely. Thus, although costs are high, remote tracking is still cheaper than hiring staff to track eagles. Nevertheless, satellite telemetry systems are now considered outdated. They are severely limited by the quality and quantity of the data they provide – data are collected at 1-hour intervals with a maximum of about 15 points per day – and by the high costs of data collection after deployment.

The newest and most cost-effective way to track wildlife is use of GPS-GSM telemetry systems. GSM is a mobile phone communications standard (the acronym stands for "Global System for Mobile Communications"). These telemetry systems can, when required, collect data at 1-second intervals, providing up to 3600 times more data than satellite telemetry. They can also be pre-programmed to collect data at different rates in different places or at different times, such as when a bird enters a renewable energy site, when it is perched at its nest, or once per multi-day interval.

The telemetry units we deployed for this project were manufactured by Cellular Tracking Technologies, LLC (CTT). They are programmed to collect data at 15-minute intervals during the day. One out of every 10 days these units collect data at 30-second intervals for the entire day. This allows us to get a good understanding of eagle ranging behavior but also, for a subsample of days, to understand intimate details of how eagles fly across the landscape. This approach provides unparalleled insight into eagle behavior, but it also can capture potentially rare behaviors that may be missed by less frequent data collection and that could change our perception of risk that eagles encounter from renewable energy projects. In addition to the GPS-GSM system, our telemetry units also have an on-board VHF-transmitter. This secondary unit is always on regardless of the duty cycle of the units other systems. Use of a secondary VHF unit is essential to identify causes of mortality, should an eagle go down out of GSM phone coverage (e.g., in a steep remote canyon) and it can be used to find the bird from the ground.

Nest visits. Nest visits are essential to assess eagle nest productivity and may be used to provide first cut data on territory and nest occupancy. We visit a selected subset of active eagle territories (n = 10-40) in the California Desert District and monitor reproductive output at these nests. When possible, productivity counts are obtained via observation through a spotting scope. However, when required, we climb to nests and assess productivity directly. Nest visits occur late in the breeding season, 70-80% into the nestling cycle, before chicks are able to fly but after they are old enough that the nest can be considered "successful" (Steenhof & Newton 2007). When nests are climbed, biologists also collect genetic samples from eagle chicks that can be used to corroborate results of non-invasive feather collection.

Preliminary Results & Discussion

In solicitation L11PS01121 the BLM asked a number of specific research questions. Here we repeat each of these research questions, we describe the data we have collected to date to address these questions, and we briefly describe our next steps in data analysis to more fully address these questions. Our analysis to date is concentrated on the breeding season because it is the one season for which we have a complete data set and because that season provides us with a concise, biologically relevant and easy to interpret period. Future reports will include other periods of the year.

I. Summary of telemetry and nest visit activities

In January 2012, our contractors trapped and telemetered four adult eagles. In April they captured and telemetered another three adult eagles. For these birds, date of capture, unit identifiers and current status are listed in table 1a, below. Data on nest locations are not provided in this report but are available to BLM staff as we are instructed by the agency.

In May 2012, a highly experienced eagle field research team including WVU staff and partners visited nests, collected samples from birds and outfitted 7 eagle chicks with telemetry units. For these birds, banding and telemetry date, unit identifiers and current status are listed in table 1b, below.

Finally, in October 2012, we recaptured one of the eagles caught in January. The original telemetry unit on that bird had failed; upon capture this bird was given a new telemetry unit and released. This is noted in table 1a.

As of 01 December 2012, we have continuous data on 6 of the 7 adult eagles we trapped. We are unsure of the status of the seventh. Of the 6 chicks telemetered, three are confirmed dead, the status of another is unknown, and the other two are providing continuous data. This is all detailed in table 1a and b.

We visited or collected data on 14 nests. Two nests were used but failed before the number of chicks could be assessed. Of the 12 remaining nests, one (Cross Mountain) had two chicks and 11 had 1 chick. These chicks would have been counted as “fledged” using the standard methodology cited above (but in at least three cases, chicks subsequently died just before or just after fledging).

We collected a huge number of GPS-telemetry data on these eagles. Included in this dataset are 28,537 data points collected at 15-minute intervals and 69,936 data points collected over 17 days of 30-second data collection. These 30-second data provide unparalleled insight into the specific paths and altitudes that eagles use throughout a given day of flight within their home range.

We also use table 1 to show the difference between the data that we have collected with our novel telemetry systems in comparison to the much more limited data that would have been collected with older-style GPS-ARGOS telemetry systems. Those telemetry platforms only collect data at 1-hour intervals and are completely unable to collect data at either 15-minute intervals or at 30-second intervals.

II. Addressing BLM research questions

a) What is the home range of the golden eagle in the Mojave and Sonoran (Colorado) Deserts?

Home range analysis is typically accomplished with kernel density estimators (KDEs; Laver & Kelly 2008). KDEs built using data collected at 15-minute intervals are a useful preliminary descriptor of animal movement. Ultimately we will evaluate these movements with non-parametric tools – e.g., adaptive local convex hulls (aLoCoH; Getz et al. 2007) – which can be implemented within the statistical package R (adehabitat; Calenge 2011) and visualized in ArcGIS. Finally, data collected at 30-second intervals do not require home range analysis – they describe the animal’s actual movements.

For this report we characterize breeding season home ranges of our seven adult eagles with two techniques – minimum convex polygons (MCP; Mohr 1947) and KDEs. Here we only consider data collected between January and June and data are subsampled to 30-minute intervals. This partially addresses the problem of potential autocorrelation among closely spaced data (but see deSolla et al. 1999). To more completely utilize our full dataset, final analyses will use convex hulls (as described above) which are more appropriate for closely spaced autocorrelated data. Data are presented in tabular format (Table 2) and examples of eagle home ranges are provided, which show locations of eagle nests and MCP (Fig. 1) and KDE (Fig. 2) estimators. In addition, we show the average distance from eagle nests to the nearest and farthest edge of their home ranges.

Sizes of home ranges varied widely among individual eagles, but did not appear to differ between sexes. The smallest home range was for the male in the Margaretville territory. However, this transmitter failed prematurely during the early part of the breeding season, so only a portion of his home range may have been recorded. The three largest territories are from eagles that, when breeding attempts failed, changed their behavior and dramatically increased the amount of space used. MCPs are generally larger than KDEs; this is to be expected because of the way the two estimators are calculated. The largest MCP home ranges include locations from long-distance movements from desert breeding territories into adjacent mountains. KDE home ranges include the general areas used by eagles (90% KDE) and core home ranges (50% KDE). The 90% KDEs show some overlap among eagles, but core areas (50% KDEs) do not overlap. These home ranges are generally on the large size for eagles (e.g., Marzluff et al. 1997), perhaps to be expected because of the relatively low prey densities in the Mojave.

Table 1. Dates of telemetry, band and telemetry numbers and current status of (a) adult (male (M), Female (F)); and (b) nestling (N) golden eagles telemetered in the course of BLM-funded WVU field work in California. Also shown are the actual numbers of telemetry data points that were collected at 15-minute and 30-second intervals and an estimate of the number that *would have been collected* had traditional GPS-ARGOS satellite telemetry systems been used for the period January to June 2012.

					# of data points collected (interval)			
	Date Captured	Bird Name	Band #	Telemetry #	15-minute	30-second	1-hour (est.)	Current Status
(a) ADULT EAGLES								
1	13 Jan 2012 (24 Oct 2012)	Margaritaville M	0679-04941	32216993 (05882885)	3794	8826	923	Telemetry failed, recap. 24 Oct 2012, bird & telem both normal
2	17 Jan 2012	Stoddard Tower M	0679-04938	32204387	7188	21,340	2008	bird & telem both normal
3	23 Jan 2012	New Deal Mine F	0679-04942	32217546	6825	15,656	1898	bird & telem both normal
4	31 Jan 2012	Stoddard Ridge F	0679-04939	32205277	4197	9381	1181	bird & telem both normal
5	06 May 2012	Whitehorse M	0679-04953	05884451	1670	3067	479	bird & telem both normal
6	07 May 2012	Fry Mountain F	0679-04955	32205350	2154	5541	626	last data from 23 Jul 12
7	11 May 2012	Ridgecrest Tower F	0679-04943	32204767	2705	6130	733	bird & telem both normal
(b) NESTLING EAGLES								
1	17 May 2012	Margaritaville N	0679-04349	05798008	343	673	100	bird & telem both normal
2	17 May 2012	Whitehorse N	0679-04350	05880582	0	0	0	chick died before fledging
3	18 May 2012	Fry N	0679-04351	32224161	0	0	0	chick died before fledging
4	18 May 2012	Ridgecrest Tower N	0679-01943	32204932	536	5172	535	chick died after fledging
5	19 May 2012	Paradise N	0679-01942	32224385	1098	230	295	last data from 10 July 2012
6	19 May 2012	Calico N	0679-01939	05867837	601	576	182	bird & telem both normal

Table 2. Breeding season home range size of golden eagles in the Mojave Desert of California. Average size is presented by sex (M/F), for each of two techniques (kernel density estimators [KDE] and minimum convex polygons [MCP]). Also included are average distances from the nest to the nearest and farthest edge of the home range. Data were collected from January to June 2012. Data are presented in (a) metric and (b) standard units.

(a) *metric units*

Sex	n	Mean Home Range Size (±SD, ha)	Range of Home Range Sizes (ha)	Distance from nest to edge of home range (nearest, farthest [km])
Minimum Convex Polygon				
Male	3	145,395 (223,287)	6,107 – 402,938	10.0, 27.8
Female	4	193,368 (211,882)	13,964 – 451,053	5.4, 52.0
90% Kernel Density Estimator				
Male	3	11,491 (9,697)	1,093 – 20,298	1.7, 26.8
Female	4	13,401 (11,109)	3,511 – 28,998	1.6, 50.9
50% Kernel Density Estimator				
Male	3	1,490 (1,777)	117 – 3,497	0.8, 4.7
Female	4	1,431 (1,273)	354 – 3,258	3.0, 13.7

(b) *standard units*

Sex	n	Mean Home Range Size (±SD, mi^2)	Range of Home Range Sizes (mi^2)	Distance from nest to edge of home range (nearest, farthest [mi])
Minimum Convex Polygon				
Male	3	561 (862)	24 – 1,556	6.2, 17.3
Female	4	747 (818)	54 – 1741	3.4, 32.3
90% Kernel Density Estimator				
Male	3	44 (37)	4.22 – 78	1.1, 16.7
Female	4	52 (43)	14 – 112	1.0, 31.6
50% Kernel Density Estimator				
Male	3	5.8 (6.9)	0.5 – 14	0.5, 2.9
Female	4	5.5 (4.9)	1.4 – 12.6	1.9, 8.5

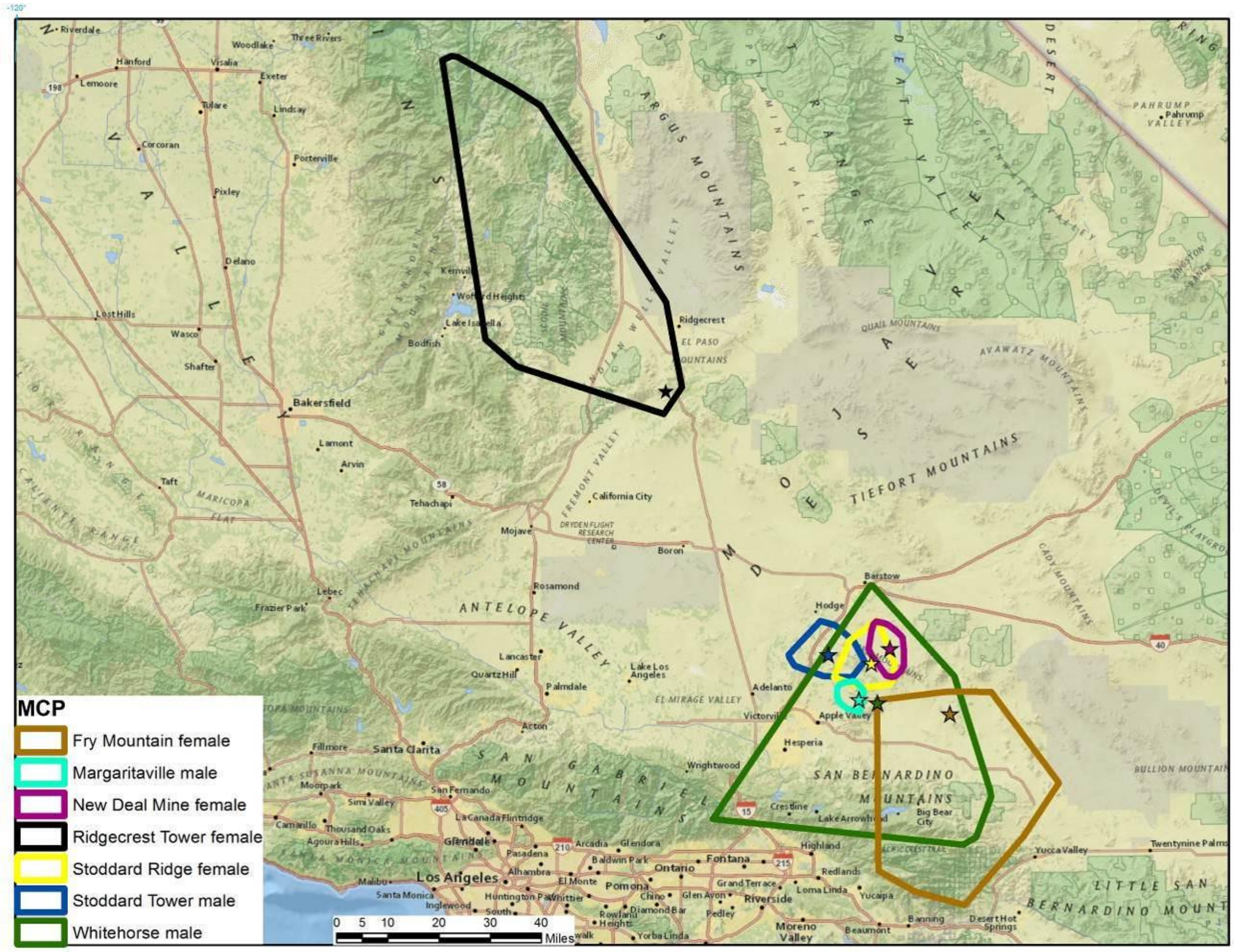

Figure 1. Breeding home ranges (Minimum Convex Polygon) of golden eagles telemetered in the BLM California Desert District. MCP ranges include mountain areas distant from nest sites (stars) for some territories.

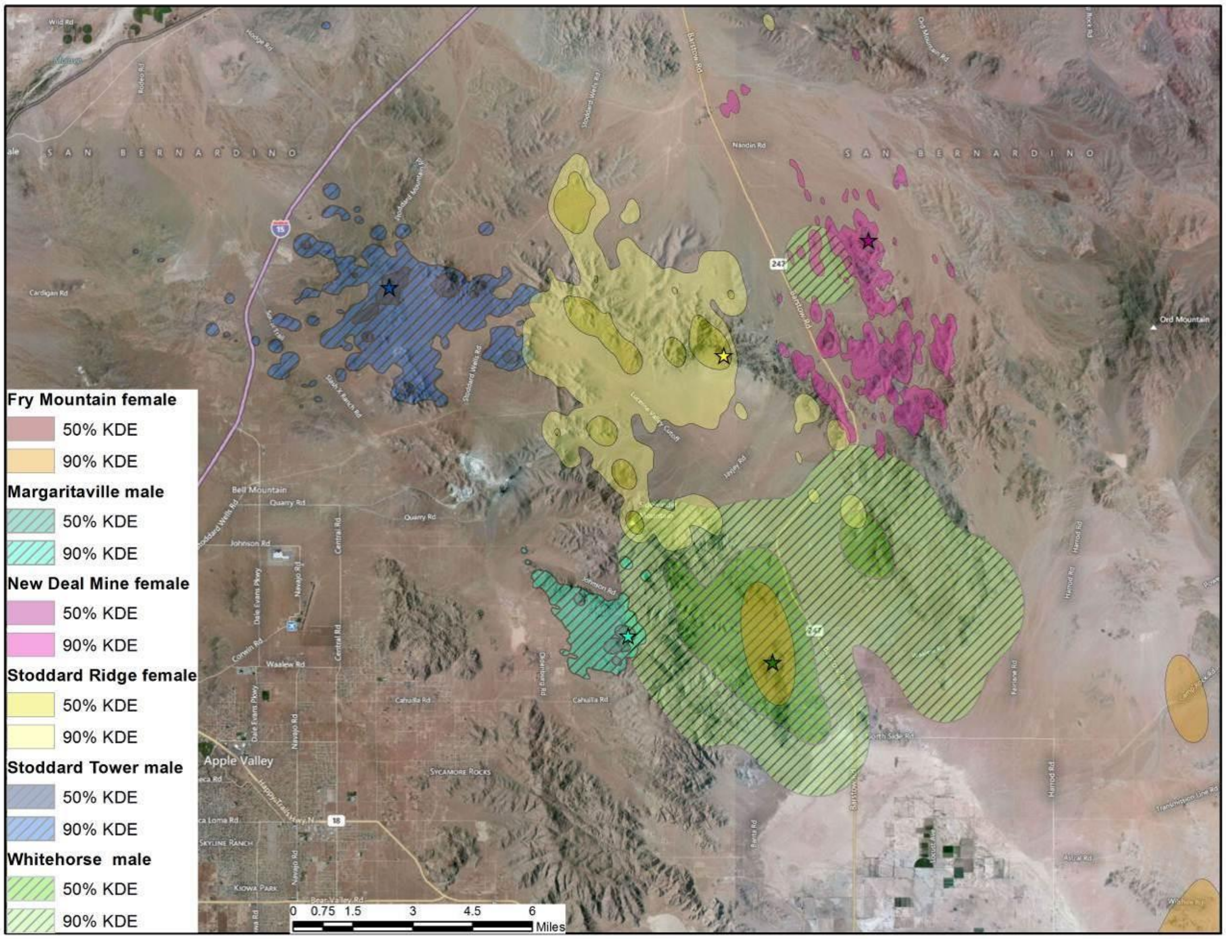

Figure 2. Breeding home ranges (KDE) of golden eagles in the Granite Mountains of California, between Apple Valley and Barstow. Complete home ranges (darker 50% core and lighter 90% general) are shown for five eagles with a small portion of the Fry Mountain female's home range (90% KDE) encompassed with in the core of the Whitehorse male's home range. Stars depict nest locations.

Edges of eagle home ranges were 1.6 to 40.6 km from nests. The large difference between closest and farthest edge of home ranges (MCP, 90% kde) shows that eagles do not necessarily nest in the middle of their home range. Their movements are in some cases limited by barriers (likely topographic features that mark intersections of defended territories), but in other cases may extend for much longer distances. Likewise, core areas of the home range (50% kde) include areas close to the nest as expected, but also include regions quite distant from nests. These distant core areas suggest that important resources such as food sources that may not always be obtained near nest sites.

b) Do the size and/or area of home range use change seasonally, and are changes correlated with habitat quality, specific habitat features, human use, wind patterns, or other factors?
c) How do breeding and nesting affect home range size from year to year??
d) Does use within a home range change post-construction of a renewable energy facility?

All three of these questions address a fundamental research problem – how does habitat use and home range behavior change with habitat (including topography), seasonality, breeding status and anthropogenic impacts (including renewable energy development). Thus, all three can be addressed in a similar manner.

We will model home range size as a function of habitat and environmental variables using linear mixed models or generalized estimating equations (Koper & Manseau 2009). Habitat selection will be assessed with compositional analysis (Aebisher et al. 1993) that incorporates home range characteristics and includes renewable energy development and other anthropogenic impacts. Fluctuations in habitat use and usage of available habitat will be assessed with statistical models as described in our proposal (mixed models, CCA and multivariate regression, as appropriate). We also will model eagle movement as a function of meteorological data, to understand how weather drives eagle movements.

As a first look at eagle movements in regards to habitat, for this preliminary report we evaluate descriptive statistics on flight altitude within eagle home ranges. Flight altitude is typically a response to habitat and topography, as these two variables drive availability of subsidized lift and thus determine how high a bird actually flies. Finally, flight altitude is a critical component of understanding risk to eagles in the context of development or renewable energy – especially wind energy, whose spinning blades span a "rotor-swept zone" of a fixed height and diameter.

From January to June, the altitude above ground level (AGL) of flying golden eagles averaged 180 – 268 m (Table 3). We estimated AGL by subtracting National Elevation Dataset (NED; Gesch 2007) ground elevation values from GPS-measured above sea level flight altitude (ASL). We calculated average AGL values in two ways. Full season averages (average AGL of all flight locations [n = 1844 – 7849] for each eagle) give equal weight to each eagle location, with summary statistics based upon either 3 males or 4 females. Because each location is weighted equally, full season averages give disproportionately more weight to days when more locations were recorded – that is, days when data were collected at 30 second intervals. Daily averages (average AGL of flight locations [n = 160 - 170] by day for males and females) give equal weight to each day that eagles were tracked. This reduces the influence of larger number of samples on days when 30-second data were collected. Full season average AGL (180 – 250 m) was only slightly lower than daily average AGL (183 – 269 m). We suspect we observed this trend because on days when locations are recorded every 30 sec, more data were collected at lower flight altitudes, when eagles are initiating or finishing a short flight. Full season median values (184 – 237 m) are greater than average values, confirming that the majority of measurements are higher than averages and that lower altitude flight occurs less often than higher altitude flight. Daily medians (152 – 165 m) are less than daily averages, which shows that eagle flight varies among days, likely in response to changes in weather.

Understanding eagle behavior, especially the influences on in-flight AGL, is vital to understanding eagles' risk of colliding with wind turbines. All average and median flight altitudes are greater than the rotor-swept zone of modern wind turbines (61 – 79 m tall towers with rotor diameters 45 – 79m; National Wind Coordinating Collaborative Birds and Bats fact sheet; http://www.nationalwind.org/publications/bbfactsheet.aspx?). However, sometimes eagles fly within the rotor-swept zone. Flight above this zone occurs more often, which illustrates the need to record less common events and the value of high-frequency data collection (i.e., record locations every 30 sec).

An important component of this project is to understand how eagles move on a given day within their home range and what portions of their home range may be more or less important to eagles and more or less risky to eagles if wind energy is developed. To accomplish this goal we are mapping individual movements of eagles based on data collected at 30-second intervals. Although we have not yet fully evaluated movements of eagles throughout the annual cycle, the 30-second data provides a great deal of information on how eagles move within their territory. As an example of this, we show a map of movements of one eagle (the margaritaville male) within its territory on a day when data were recorded at 30-second intervals (Fig. 3, below). Points on this figure are connected by lines illustrating likely flight routes and also color coded to show flight altitudes below, between and above 50 and 150m (approximate elevations of modern horizontal axis turbines). For comparative purposes, we also show our best guess at the 1-hour data that would have been collected by traditional GPS-ARGOS satellite telemetry and we estimate flight altitudes based on those data. These figures clearly show that the detail from 30-second data collection provides estimates of flight routes and a better representation of aerial habitat use than would 1-hour data. Additionally, over the 2-day period considered here, hourly locations did not correspond with flight altitudes greater than 50 m AGL, whereas 30-second data showed a wide range of flight altitudes above and below the rotor swept zone of a modern turbine.

e) What are the most critically important migration, wintering, and breeding areas in the desert?

Migration, wintering and breeding areas in the Sonoran and Mojave deserts will be mapped based on telemetry data, once this data collection process is finalized. This approach will identify key habitat for desert eagles.

To evaluate the scale of habitat use by non-local eagles, we initiated region-wide surveys on paved and unpaved roads. We use a double-observer method and distance sampling to account for variation in detection probabilities and as the basis for population estimation (Nichols et al. 2000, Buckland et al. 2007). Such surveys provide an initial assessment of winter habitat relationships and density and will be the foundation for future management, research and monitoring programs.

We surveyed along transects distributed throughout BLM's California Desert District. Transects were randomly distributed from the Mexico border to Death Valley and included land use and vegetation communities in accordance to their occurrence on BLM land. Two expert observers surveyed for raptors at five 10-minute point counts that were connected by 6.4 km road surveys.

Surveys in January 2012 occurred on 155 km of road in the California Desert District spread over 24 transects. A map showing our transects is provided (Fig. 4), as is a table showing the species encountered and the number of individuals of each species counted during surveys (Table 4).

These surveys showed that density of golden eagles wintering in the desert is low and not effectively estimated by surveys such as these. However, these surveys are providing us with a series of additional information on density and distribution of other wintering raptors, shrikes, and Corvids. After the second season of data collection, we will compile our survey results with MARK-based population estimation to understand habitat relationships of these species.

Table 3. Mean, variation and range in flight altitude above ground level of territorial, breeding season, golden eagles in the California Desert. Data are stratified by sex and were collected from January to June, 2012.

Sex	n	Mean flight altitude (AGL) in meters	Median flight altitude in meters [range]
Full season average (SD)			
Male	3	180.7 (59.27)	183.5 [120.0, 238.5]
Female	4	249.9 (104.07)	236.8 [139.5, 386.6]
Daily average (SE)			
Male	3	183.1 (80.2)	152.0 [17.7, 1292.2]
Female	4	268.5 (359.2)	165.2 [1.7, 2648.1]

Table 4. Raptors, shrikes, and Corvids observed along transects and numbers of individuals of each species counted in BLM's California Desert District (routes shown in Fig. 2). Species are presented in standard taxonomic order (American Ornithologists Union 2003).

	Species observed	Scientific Name	Number counted
1	Turkey Vulture	*Cathartes aura*	164
2	Osprey	*Pandion haliaetus*	2
3	White-tailed Kite	*Elanus leucurus*	3
4	Northern Harrier	*Circus cyaneus*	10
5	Cooper's Hawk	*Accipiter cooperii*	2
6	Red-tailed Hawk	*Buteo jamaicensis*	98
7	Unknown hawks		7
8	Golden Eagle	*Aquila chrysaetos*	3
9	American Kestrel	*Falco sparverius*	24
10	Peregrine Falcon	*Falco peregrinus*	1
11	Prairie Falcon	*Falco mexicanus*	4
12	Loggerhead Shrike	*Lanius ludovicianus*	47
13	Common Raven	*Corvus corax*	559

Table 5. Range of distances moved and the range of flight altitudes covered over the first 30 days after fledging by three golden eagles in the Mojave Desert of California.

Eagle Nestling	Estimated fledging date	Maximum distance moved from nest (m)	Average flight altitude (SD)
Calico	22 June 2012	1885	68.1 (89.0)
Margaritaville	29 May 2012	4351	50.1 (61.6)
Paradise	23 May 2012	1996	31.0 (50.7)

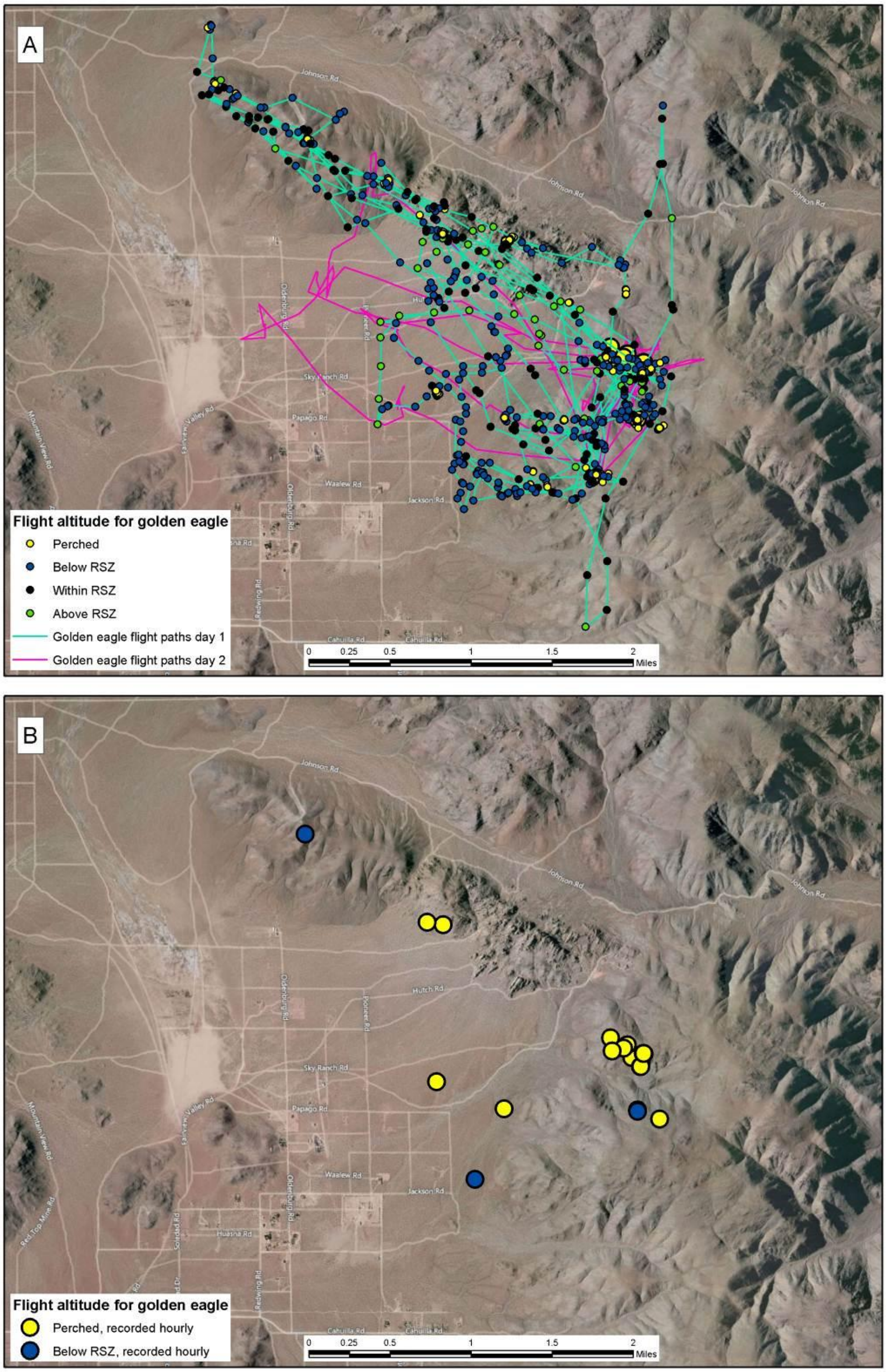

Figure 3. Movement tracks of one eagle for 2 days in the Mojave Desert of California, as recorded by A) 30-second GPS-GSM telemetry and B) hourly locations as would have been collected by GPS ARGOS telemetry.

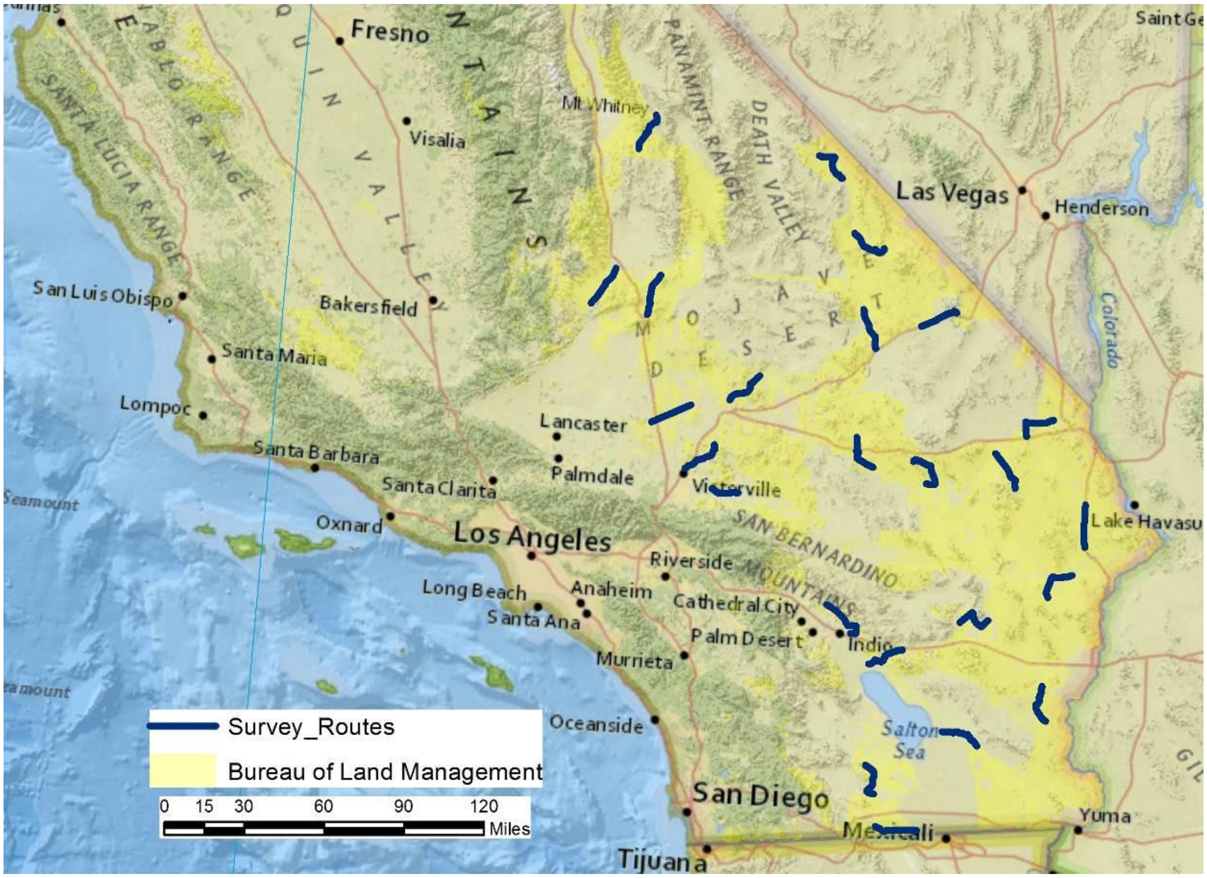

Figure 4. Map of the BLM's California Desert District, showing 24 road transects in the region. Raptors were surveyed along transects sin January 2012.

f) What is the nest productivity of eagles in the Mojave and Sonoran (Colorado) Deserts?

Nest productivity is assessed through nest visits following established regional and national protocols (Steenhof & Newton 2007) and analyzed in the context of spatial and temporal trends.

To date we have monitored productivity at 14 California nests (as reported in section I). Although this data set is small relative to that needed for statistical inference, the most useful information we gleaned from this data set is the large number of eagle chicks that died late in the nesting cycle or soon after fledging. If late-season mortality is a consistent characteristic of these desert eagles, this suggests that traditional monitoring protocols that call for nest visits late in the nestling stage to assess success may need to be adjusted for this population. These data may also highlight the importance of prey cycles to eagle productivity, as this is a period of especially high energetic requirements; certainly fluctuation in prey populations are known to be important to eagles in other arid environments (Steenhof & Kochert 1988).

g) What is the range/variance of natal dispersal distances, including movement patterns from sub-adult to adult?

Three telemetered eagle chicks have successfully fledged their nest sites. In the first 30 or so days in which eagle chicks left their nest, these three chicks moved approximately 406 - 753 meters from their hatch nest, on average (Table 5). Average flight altitude was slightly lower for chicks than for adults, indicative of generally lower flights as might be expected from an eagle "in training."

Dispersal by pre-adults will be addressed with telemetry of nestlings and genetic monitoring. To date, we have recorded dispersal events by two fledged chicks. The Margaritaville eaglet dispersed on 07 November 2012 and the Calico eaglet dispersed on 05 November 2012.

h) What are the trends in territory and nest occupancy?

Trends in territory and nest occupancy can be addressed at two basic scales. At a population level, we will address eagle use of territories and nest sites as they vary across time. However, the more compelling and useful statistics regarding territory and nest occupancy are addressed at an individual level. We are currently developing a framework whereby individual eagles at nests will be identified and tracked through time via non-invasive genetic monitoring within a mark-recapture framework. These tools allow us to estimate population size, mortality rates and a suite of other demographic parameters, including relatedness and immigration and emigration rates characteristic of the population.

i) What is the primary cause of eagle mortality?

Eagle mortality will be assessed primarily through tracking of telemetered birds, through reports of local downed birds, and through assessment of local rehabilitation centers. To date we have had no telemetered adult eagles die. One telemetry unit has not reported since July but we have yet to determine if this bird is dead or alive.

Next steps

Trapping of adult eagles for this project is largely complete. We may target one other eagle territory this winter or spring, should there be funding and interest. We do aim to telemeter an additional 5-8 eagle chicks this spring and follow them through their extended post-fledging and then dispersal periods. Nest visits this spring will also include feather collection and genetic sample collection. This winter a second expert field team will conduct winter road transect surveys, to build a distribution and abundance map of species occurrence through the region.

Our most important next steps will involve data interpretation and analysis. That effort will focus on the research questions above and those we highlighted in our timetable (below).

Time-table, looking backwards and moving forward

This project has a relatively short yet intensive field component (trapping, telemetry, nest visits), followed by an extensive period of remote telemetry data gathering and analysis. To date we have stuck closely to the projected timetable in our original proposal. Our original timetable is as follows (with an additional column evaluating performance):

Date	Activity	Performance
01 October 2011	Contract initiates.	on time
15 Oct.2011 – 15 Dec. 2011	Project planning and meetings with BLM biologists, site visits, scouting for trapping, testing GSM coverages, order telemetry.	on time
15 Dec. 2011 – 30 May 2012	Trapping & telemetry of adult eagles Telemetry of nestlings before they leave the nest. Blood lead-level analysis Nest site visits; meetings w/ BLM. Wintering eagle surveys, meetings w BLM.	on time
01 June 2012	Hire GIS biologist/postdoc to conduct home range & compositional analyses	on time (Duerr)
01 June 2012 – 01 June 2013	Home range, habitat use & change analyses; continued evaluation as data accumulate Meetings with BLM biologists.	ongoing
01 October 2012	Progress report due to BLM, meetings with BLM.	current report
01-20 Jan. 2013	Winter eagle surveys, meeting with BLM.	expected
15 April – 15 May 2013	Nest visits to monitor productivity & collect genetic samples.	expected
01 June 2013 – 31 Aug. 2013	Development of frameworks for follow-on monitoring and adaptive management, meetings with BLM.	expected, may delay for extra data collection
01 Sept. 2013 – 30 Sept. 2013	Creation and submission of final report. Meetings with BLM.	expected
30 Sept. 2013	Contract terminates	expected

Key Personnel

Key personnel on this project are:

Todd Katzner, Ph.D. is a Research Assistant Professor in the Division of Forestry and Natural Resources at West Virginia University, a co-founder of the wildlife telemetry company Cellular Tracking Technologies LLC, and is the lead investigator on this proposal. Katzner has 20+ years of experience as a biologist and has studied eagles and eagle ecology for the past 15 years, in the USA and abroad. For the past 5 years he has led research on interactions between golden eagles and energy development in the central Appalachian Mountains. This work is funded by state wildlife agencies in Pennsylvania, Virginia and West Virginia, as well as the U.S. Department of Energy.

Philip Turk, Ph.D. is an Assistant Professor of Statistics at West Virginia University and is the lead biometrician on this project. Turk has 25+ years of experience collecting and analyzing ecological field data. Turk has worked with golden eagles in the Bridger Mountains of Montana and also is currently the lead statistician on our US DoE project investigating interactions between golden eagles and energy development in the central Appalachian Mountains.

Adam Duerr, Ph.D. is a Wildlife Biologist in the Division of Forestry and Natural Resources at West Virginia University. Duerr has 18 years of experience studying avian ecology including 6 years of experience in the Sonoran Desert of Arizona and 6 years of experience with raptors. In addition, he has more than 10 years of experience studying and modeling drivers of population dynamics, including causes and consequences of changes in survival, fecundity, and dispersal. He develops population models that are applied to determine optimal management strategies to reduce conflicts with people, maximize population sizes of threatened and rare species, and form the basis of adaptive management of wildlife.

David Brandes, Ph.D. is an Associate Professor in the Department of Civil & Environmental Engineering at Lafayette College. Brandes' 15+ year interest in eagle movement has resulted in his development of spatially explicit models of eagle response to complex terrain and weather patterns that are a core feature of our research to understand eagle movements through the central Appalachian region.

Tricia Miller, Ph.D. is a Wildlife Biologist in the Division of Forestry and Natural Resources at West Virginia University. Miller has studied ecology and behavior of birds of prey for the past 15 years and is the lead spatial ecologist and database manager for our research on golden eagles and energy development in the central Appalachians. Miller has developed the models that describe home range and habitat use of golden eagles in eastern North America and she has developed the computer tools to automate many of the analyses we describe herein.

Michael Lanzone is CEO and co-founder of the wildlife telemetry company Cellular Tracking Technologies, LLC. Lanzone has studied ecology and behavior of birds of prey for the past 20+ years and is a highly experienced trapper who has captured many of the birds being followed in our current work in the central Appalachian Mountains.

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