

Prepared in cooperation with San Diego Association of Governments, U.S. Fish and Wildlife Service, Bureau of Land Management, and California Department of Fish and Wildlife

## A Clarification on the Effects of Urbanization on Golden Eagle (*Aquila chrysaetos*) Habitat Selection



Open-File Report 2020–1110

**Cover Photo:** Photograph of a golden eagle (*Aquila chrysaetos*) being released by U.S. Geological Survey biologist, Melanie Madden, after being captured and fitted with a telemetry unit, March 6, 2018. Photograph by Peter H. Bloom, Bloom Biological, Inc. Used with permission.

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By Jeff A. Tracey, Melanie C. Madden, Peter H. Bloom, and Robert N. Fisher

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**U.S. Department of the Interior  
U.S. Geological Survey**

**U.S. Department of the Interior**  
DAVID BERNHARDT, Secretary

**U.S. Geological Survey**  
James F. Reilly II, Director

U.S. Geological Survey, Reston, Virginia: 2020

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## Conversion Factors

International System of Units to U.S. customary units

<b>Multiply</b>	<b>By</b>	<b>To obtain</b>
Length		
meter (m)	3.281	foot (ft)
meter (m)	1.094	yard (yd)
kilometer (km)	0.6214	mile (mi)
Area		
hectare (ha)	2.471	acre
hectare (ha)	0.003861	square mile (mi <sup>2</sup> )

## Abbreviations

GAMM	generalized additive mixed-effects model
ID	identification
TPI	topographic position index
USGS	U.S. Geological Survey
VRM	vector ruggedness measure

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## Introduction

In 2018, the U.S. Geological Survey (USGS) published an Open-File Report (Tracey and others, 2018) presenting a Bayesian habitat selection model for golden eagles (*Aquila chrysaetos*) in San Diego County, California. The model used telemetry data to examine the effects of urban development, exurban development, and topography (characterized by a topographic position index and a vector ruggedness measure, TPI and VRM respectively) on golden eagle habitat selection probability. Based on figures 3 and 6 of Tracey and others (2018), we received inquiries from cooperators (U.S. Fish and Wildlife Service and California Department of Fish and Wildlife) about how the probability of eagle use declines with decreasing distance to the urban edge. Here, we clarify our results by addressing that question.

## Methods

We considered telemetry data for 44 golden eagles tracked between November 22, 2014, and December 2, 2019 (Tracey and others 2016, 2017, 2020). Data from the telemetry devices were collected at a frequency of as little as 3 seconds between fixes. We identified move steps in these data that were separated by 15-minute time intervals ( $\pm 1$  minute). Each move step consisted of a starting point (a from-location) paired with an end point (a to-location). To ensure that each move step occurred between cells in our habitat predictor rasters, we removed any move steps that had a distance of less than 100 meters (m) between the from-location and to-location of the move step. Hence, when an eagle was stationary (for example, when perching, nesting, or roosting) the associated

move steps were removed, but the movements to and from the stationary location were included. In addition, any move steps with a from-location or to-location outside San Diego County were also excluded. The end points (to-locations) of each move step constituted the use data (distance to the urban edge at observed eagle locations) in the regression model.

Data were analyzed under a use-availability design (Design III, Manly and others, 2002) using a generalized additive mixed-effects model (GAMM; Wood, 2017) with distance to the nearest urban edge (distance to urban, for brevity) as the single fixed-effect predictor variable and the individual eagle identification (ID) as a random-effect variable. For each eagle with at least 2,000 observed use locations, we randomly sampled 2,000 availability (pseudo-absence) locations from a uniform distribution within San Diego County, excluding the desert climate zone. Any eagles that had less than 2,000 use locations were omitted from this analysis. Distance to urban was extracted at the use and availability locations for each eagle (using distance at the cell centroids using the land use raster described in Tracey and others, 2018). Finally, we omitted all data with locations more than 6,050 m from urban values, because 95 percent of our use data were within this distance (fig. 1). Distance to the urban edge was standardized (a common practice in regression modeling) by subtracting the mean distance to urban from each distance value and dividing by the standard deviation of the distances. In order to assess the effect of the resampling scheme on GAMM predictions, we repeated this process for 10 trials, thereby generating 10 randomly sampled datasets, fitting the GAMM to each dataset, and calculating a mean prediction across all 10 trials. More extensive assessment using a larger number of trials will be performed prior to publication in a peer-reviewed journal.

Using these data, we used a generalized additive mixed-effects model (GAMM) to regress use ( $y=1$ ) versus availability ( $y=0$ ) on standardized distance to urban as a fixed-effect predictor with individual eagle as a random effect (Wood, 2017). Analysis was performed in R (R Core Team, 2018) using the `gamm4` package (Wood and Scheipl, 2020).

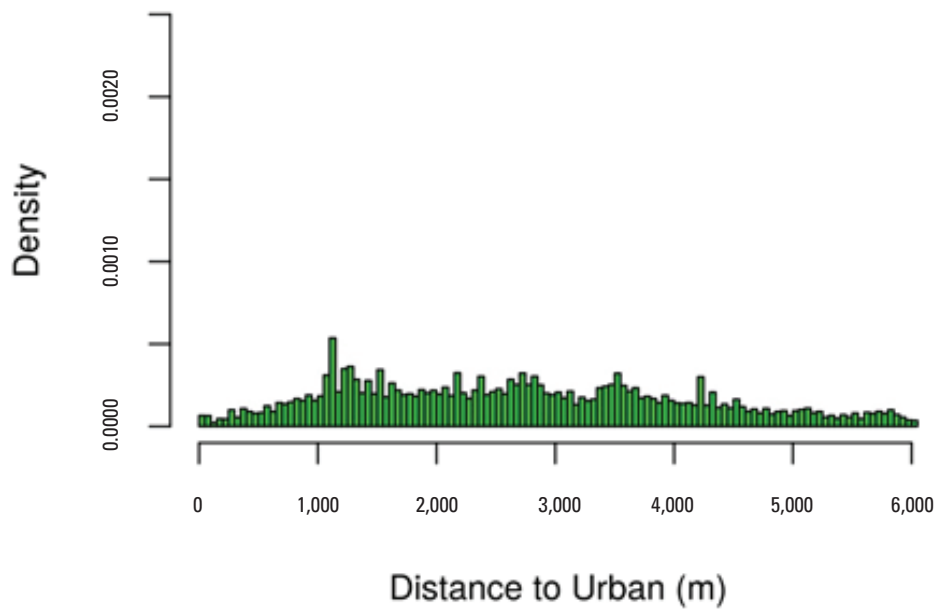
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<sup>1</sup>U.S. Geological Survey, Western Ecological Research Center, San Diego, California

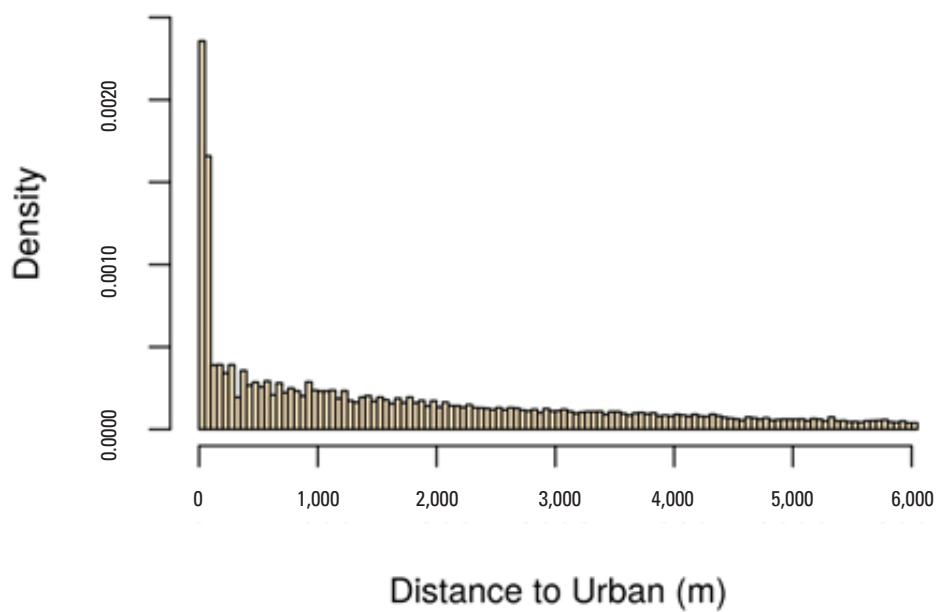
<sup>2</sup>Bloom Biological Inc., Santa Ana, California

## 2 A Clarification on the Effects of Urbanization on Golden Eagle Habitat Selection

**A**



**B**

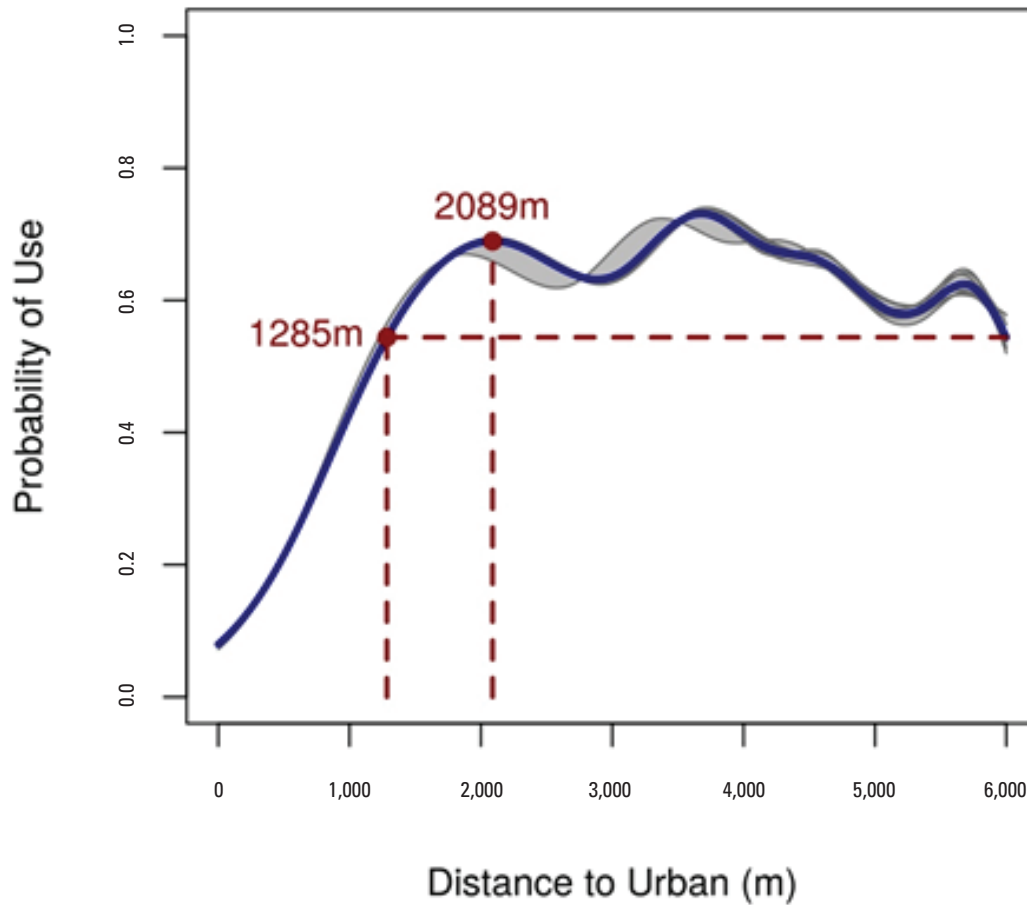


**Figure 1.** Distance to urban in meters at *A*, use locations (lime green) and at *B*, availability locations (tan) used in the generalized additive mixed-effects model (GAMM) regression. These data are for a single trial.

## Results and Discussion

The final datasets were generated based on data from 13 female and 5 male golden eagles. We used a mean of 66,667.3 observations per trial (range of 66,577–66,756). Our findings show that eagles used locations near the urban edge less than their availability within the study area based on histograms of distances to urban for the use and availability locations (fig. 1); this result is reinforced by the mean GAMM regression curve that shows a lower probability of use by eagles with decreasing distance to urban less than 2,089 m (fig. 2; table 1 numerical results at 50-m-distance intervals). Results were consistent across all 10 trials (fig. 2). At a distance of less than 1,285 m to the urban edge, predicted probability of eagle use falls below any probability predicted at greater distances and continually declines (to 0.0799) as distance to the urban edge goes to zero m. Hence, a deduction in predicted use by golden eagles

occurs not only in urban areas, but also extends beyond the urban edge into non-developed areas. The mean predicted probability of eagle use continues to increase with increasing distance from 1,285 to 2,089 m from the urban edge (reaching 0.6895); however, these probabilities fall within the range of predicted probability of use beyond 2,089 m (0.5540–0.7307). At distances greater than 1,285 m, predicted probability of eagle use levels off as distance to the urban edge increases, fluctuating between 0.5540 and 0.7307. These fluctuations in predicted use over this range are due to the adaptability of the GAMM function and variation in eagle habitat quality and use due to factors other than response to the urban edge. The spatial effect of the avoidance of urban areas is shown on figure 3. The mechanism behind this reduced use may be due to behavioral avoidance of urban areas by golden eagles or habitat impacts near the urban edge. The results in figures 2 and 3 and table 1 suggest that golden eagle use is reduced in non-urban areas within a kilometer or more of the urban edge.

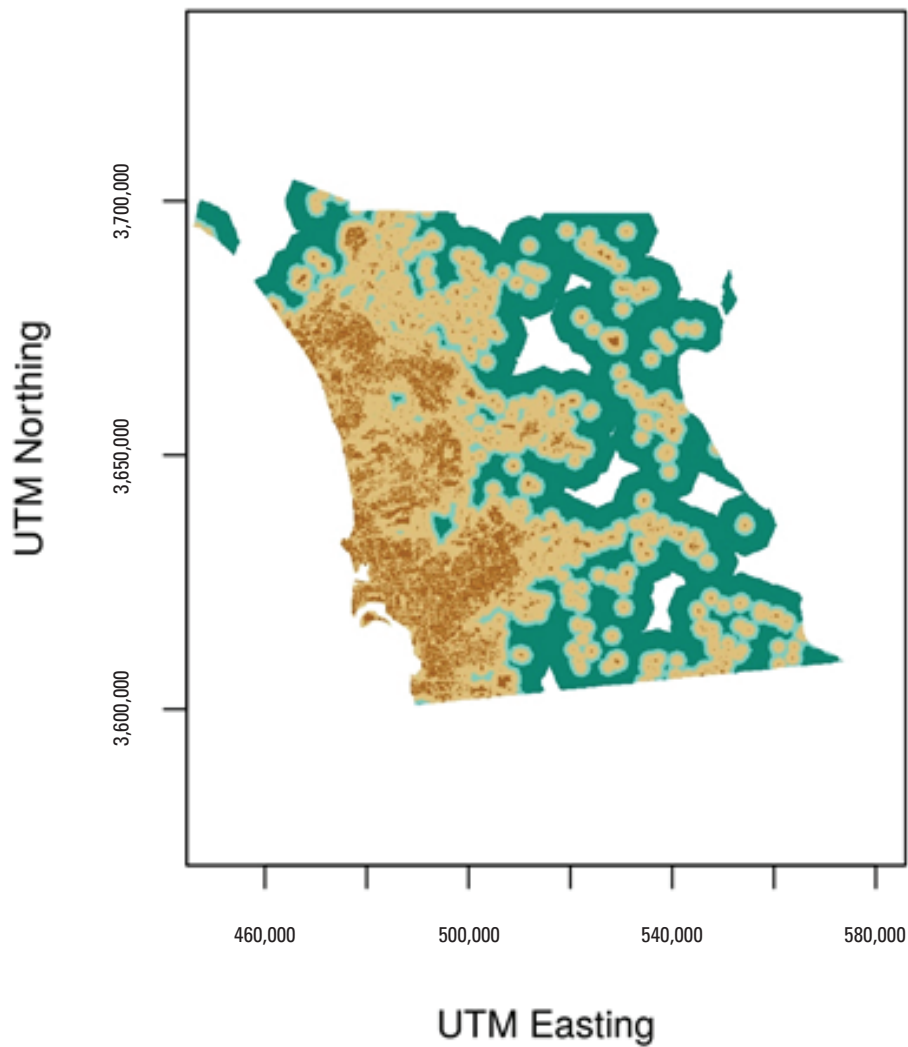


**Figure 2.** The mean generalized additive mixed-effects model (GAMM) population-level prediction for probability of use given availability as a function of distance to urban edge (in meters, m). The mean regression curve over 10 trials is shown in dark blue. Individual GAMM regression curves are shown in dark gray, and the range of predictions are shaded in light gray. The red-dashed lines show the distance at which predicted use declines below any level predicted at larger distances to urban (1,285 m) and the distance to the first local maximum of the predicted probability of the use regression curve (2,089 m).

**Table 1.** The probability of use at 50-meter (m) intervals for distances of 0–2,000 m from the urban edge based on predictions from the generalized additive mixed-effects model.

[For each distance, the mean predicted probability (Prediction) and the 95 percent confidence interval (95% CI) are given based on the 10 trials. **Abbreviation:** m, meter]

Distance (m)	Prediction	95% CI
0	0.0799	0.0735–0.0821
50	0.0889	0.0827–0.0911
100	0.0988	0.0928–0.1011
150	0.1096	0.104–0.1119
200	0.1214	0.1163–0.1237
250	0.1343	0.1298–0.1365
300	0.1481	0.1445–0.1504
350	0.1631	0.1604–0.1652
400	0.1791	0.1775–0.1811
450	0.1961	0.1946–0.1979
500	0.2141	0.2124–0.216
550	0.2331	0.2311–0.2365
600	0.2529	0.2506–0.258
650	0.2735	0.2709–0.2802
700	0.2947	0.2918–0.3031
750	0.3164	0.3132–0.3266
800	0.3386	0.335–0.3503
850	0.3609	0.357–0.3742
900	0.3834	0.3791–0.3981
950	0.4057	0.4012–0.4217
1,000	0.4279	0.4231–0.4448
1,050	0.4496	0.4447–0.4674
1,100	0.4709	0.4658–0.4892
1,150	0.4915	0.4864–0.5101
1,200	0.5114	0.5062–0.5299
1,250	0.5305	0.5253–0.5487
1,300	0.5486	0.5436–0.5662
1,350	0.5657	0.5608–0.5825
1,400	0.5818	0.5771–0.5975
1,450	0.5968	0.5924–0.6112
1,500	0.6108	0.6067–0.6235
1,550	0.6236	0.6198–0.6345
1,600	0.6352	0.6319–0.6441
1,650	0.6458	0.6428–0.6524
1,700	0.6552	0.6527–0.6593
1,750	0.6634	0.6613–0.6668
1,800	0.6705	0.6676–0.6741
1,850	0.6765	0.6704–0.6804
1,900	0.6813	0.6718–0.6855
1,950	0.685	0.6718–0.6895
2,000	0.6876	0.6706–0.6924



**Figure 3.** The spatial effect of golden eagle avoidance of urban areas. Urban areas (based on Tracey and others, 2018) shown in brown (estimated to be 82,548 hectares, ha); distance to urban less than 1–1,285 meters (m) shown in tan (estimated to be 273,574 ha); distance to the urban edge 1,285–2,089 m in light blue (estimated to be 109,011 ha); and distance to urban edge greater than or equal to 2,089–6,000 m in teal (estimated to be 324,307 ha). Note the modeled usage shown here does not consider the additional effects of exurban or other forms of development, small habitat patch size, or patch isolation. The map projection used is Universal Transverse Mercator (UTM) Zone 11, World Geodetic System (WGS) 84.

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