RAPTOR NEST OCCUPANCY AND PRODUCTIVITY REPORT FOR PICEANCE BASIN, COLORADO

2011 ANNUAL REPORT

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ABSTRACT

A total of 306 nest structures (286 visited by BLM staff and 20 visited by contractors), representing approximately 298 known nesting territories, were visited during the 2011 field season. Of these nest, 34% (*N* = 105) were classified as being occupied during spring surveys, and 65% (*N* = 198) of these nests were confirmed as being unoccupied during the 2011 breeding season. Of the occupied nests where the outcome of the nesting attempt (e.g., failed or successful) was recorded (*N* = 89 nests), we reported a success rate of 58% (*N* = 52 successful nests), and a nest failure rate of 42% (*N* = 37 failed nests). A total of 118 fledglings ($\bar{x}$ = 2.4 ± 0.14 fledglings produced per successful nest) were recorded during the 2011 breeding season , which represents a 62% decline in the total number of fledglings recorded per successful nest in 2010 (*N* = 310). When considering all 2011 Cooper's hawk and Long-eared owl nesting attempts, fledging rates were equal to 1.3 (± 0.23) and 1.6 (± 0.36) fledglings produced per nesting attempt, respectively. We documented a significant decline from 2010 to 2011in the number of fledglings produced per nesting attempt among occupied Cooper's hawk (*W* = 1782.5, *P* = 0.00005) and Long-eared owl (*W* = 460, *P* = 0.034); however, we found no statistical difference among occupied Cooper's hawk nests when examining differences in fledging rates at successful nests (*W* = 594, *P* = 0.194). We did however note a significant decline in number of fledglings produced per successful Long-eared owl nest (*W* = 280, α = 0.1, *P* = 0.097). We noted that nest structure re-occupancy during the 2011 breeding season was low, with only 29% (*N* = 40) of those nest structures that were occupied in 2010, and consequently visited in 2011 (*N* = 136), also being reoccupied in 2011. Fifty-nine percent (*N* = 96) of the nests that were active in 2010 (*N* = 162) were determined to be inactive in 2011. Fourteen nests that failed in 2010 (*N* = 15) were visited in 2011. Fourteen of these nests were occupied in 2011; however, only 14 percent (*N* = 2 nests) successfully produced young during the 2011 breeding season. We noted that nesting area re-occupancy was high for Cooper's hawk with 11 pairs returning to the nest structure that was used in 2010, and an additional 20 pairs returning to the same nest stand to either construct a new nest or occupy an alternate nest, for a total of 31 pairs (or 74% of all known 2011 Cooper's hawk territories) reoccupying 31 known nesting territories during the 2011 breeding season. We found that occupied Cooper's hawk nests were generally located closer to road corridors, when compared to occupied Long-eared owl nests, which were located farther from a road corridor ($F_{1,56}$ = 3.645, α = 0.10, *P* = 0.061). Information collected as a result of this project will contribute to long-term, cumulative efforts to monitor reproductive success, nest site fidelity, better describe important nesting habitat features, and document possible changes in nest distribution and abundance of breeding raptors within the project area that may be impacted by natural gas exploration and extraction activities on BLM-managed lands.

INTRODUCTION

In April, 2008 the Bureau of Land Management (BLM), White River Field Office (WRFO) initiated a project designed to collect breeding season information for woodland raptors in the Piceance Basin, Colorado. The purpose of this project was to collect information that would allow for an assessment of nest distribution and territory occupancy over time in areas heavily influenced by natural gas exploration and extraction activities. The target species were Red-tailed hawk (*Buteo jamaicensis*), Cooper's hawk (*Accipiter cooperii*), Sharp-shinned hawk (*Accipiter striatus*), Northern goshawk (*Accipiter gentilis*), Golden eagle (*Aquila chrysaetos*), and Long-eared owl (*Asio otus*).

Project objectives included the following: (1) collect breeding season productivity information for selected raptor species to allow for a robust comparison of differences that may exist, and provide both a descriptive and statistical summary of differences in nesting productivity and occupancy among Cooper's hawk and Long-eared owl in areas where natural gas exploration and extraction activities are prevalent across the landscape.

The purpose and focus of this document is to provide a descriptive summary of results pertaining to nest occupancy and productivity of various raptor species that occupy the project area during the breeding season for nesting purposes. In addition, the purpose of this document is to provide a statistical comparison, using exploratory, and both parametric and nonparametric statistical tests to describe observed patterns in nest success and changes in productivity when juxtaposed within a landscape where natural gas exploration and extraction is a dominant feature. For this purpose, and because it was possible to identify discrete features associated with oil and gas activities (e.g., producing wells, well pads, and road infrastructure) we chose to focus our efforts on describing observed distance relationships among Cooper's hawk and Long-eared owl as they pertain to natural gas exploration and extraction, rather than also including possible effects that other land uses, such as grazing, may have on these species and their prey. A descriptive summary was provided for all species with regard to each response variable; however, because of inadequate sample size, only Long-eared owl and Cooper's hawk were chosen as the two species in which mean difference between response variables were examined statistically.

Assuming adequate funding is available for this project in 2012, the following topics will be included in the project objectives: (1) the continuation of an assessment of possible behavioral effects of oil and gas activities on prey delivery rates, prey diversity and prey equitability, parental behavior, and productivity of Cooper's hawk using video monitoring systems; and, (2) the development of a sampling scheme that allows for the assessment of energy-related effects on nest occupancy and productivity using Principle Components Analysis (PCA) and multiple logistic regression.

STUDY AREA

The study area is located in northwestern Colorado in the Piceance Basin (T. 1-3 S., R. 96-98 W., 6th Principle Meridian) (Figure 1), an area ranging from 1,737 to 2,590 m in elevation (Sedgwick 1987). The dominant overstory vegetation in the area is pinyon pine (*Pinus edulis*) and Utah juniper (*Juniperus osteosperma*). Low elevation woodlands on shales are dominated by juniper with an understory of scattered prairie junegrass (*Koleria cristata*), bluebunch wheatgrass (*Agropyron spicatum*), needle-and-thread (*Stipa comata*), bottlebrush squirreltail (*Sitanion hystrix*), Indian ricegrass (*Oryzopsis hymenoides*), and sometimes stunted antelope bitterbrush (*Purshia tridentata*) and true mountain mahogany (*Cercocarpus montanus*). Common forbs include groundsel (*Senecio* spp.), skyrocket gilia (*Gilia aggregata)*, penstemon (*Penstemon* spp.), Hood phlox (*Phlox hoodii*), and Nuttall golden weed (*Haplopappus nuttallii*). Pinyon pine, big sagebrush (*Artemisia tridentata*), and western wheatgrass (*A. smithii*) join on sandstone to form a more diverse plant community. Above 2,100 m, pinyon pine is the predominant tree species, and the shrub layer is composed of big sagebrush, rabbitbrush (*Chrysothamnus* spp.), antelope bitterbrush, and occasionally true mountain mahogany, chokecherry (*Prunus virginiana*), and Saskatoon service-berry (*Amelanchier alnifolia*). Gambel oak (*Quercus gambelii*) is prominent on steep slopes and frequently occurs in shady ravines. The grass-forb community above 2,100 m includes most species found at lower elevations, but percentage ground cover is higher; arrowleaf balsamroot (*Balsamorhiza sagittata*) and lupine (*Lupinus* spp.) are also frequently present.

METHODS

Nest Inventory and Monitoring:

Efforts to monitor known nesting territories for the 2011 breeding season began on 24 April and ended on 18 September 2011 within the study area. The start date was defined as the time when field work was conducted full-time by a person dedicated to nest inventory and monitoring tasks, and the end date was chosen as the date when it was confirmed that, of the nests that were being monitored, all accipiter juveniles had dispersed from the nest stand. For a list of raptor species codes used throughout this report, see Table 1.

Nest Inventory

During the 2008, 2009, 2010 and 2011 breeding seasons, potential nesting habitat was identified manually using one meter resolution National Aerial Imagery Program (NAIP) imagery and terrain information (e.g., Digital Elevation Model (DEM) data). Nesting habitat was identified qualitatively based on canopy closure, slope, elevation, dominant cover type, and tree stem density. The validity of using this method to identify potential nesting habitat was confirmed in 2008 and 2009. Qualitative methods used to assess how well this technique identified suitable accipiter nesting habitat were completed in 2009. In addition, canopy closure, slope, elevation, dominant cover type, and tree stem density for accipiter nests (N = 24) that were located by an independent third-party contractor, were compared qualitatively to known accipiter nests (N = 41) to verify that the topographic and nest stand information used to identify potential nesting habitat was reliable. This exercise was also completed in 2009.

In survey polygons, where tree density and canopy cover varied, and where discrete stands that exhibited higher tree density and canopy cover could be visually delineated, call-playback stations were plotted in the interior of these stands, in an effort to increase the observer's probability of detecting an occupied nest through defensive behavior of an adult, or locate unoccupied nests, by focusing the surveyors attention on suitable nesting habitat.

Nest Monitoring

Monitoring tasks included visiting known nest areas and assessing the breeding season status of known nests that occurred in these areas using established procedures. Known nest structures were relocated using a Garmin GPS76CSx unit. A Trimble GeoXT GPS unit, with sub-meter accuracy, was used to further refine position information for all nests used in this project. To help navigate to each nest, the UTM coordinates for each nest was uploaded into the GPS unit using the DNR Garmin version 5.4.1 software. Once at the nest, to help alleviate any discrepancies between the Nest ID number, UTM coordinates and the actual physical location of the nest, a photo was taken of the GPS screen where both the nest ID number and UTM coordinates were displayed. Next, a photo of the nest tree and nest were taken followed by a close-up photo of the nest, and a representative photo of the nest stand (Figure 2). Each series of photos were grouped by the Nest ID number and stored in separate folders using the Nest ID number as the folder name. In some cases, the datum was not recorded for a known nest or was unknown. For these nests, a procedure was developed that included converting UTM coordinates from NAD27 to NAD83 or vice versa while in the field using the Garmin GPS76CSx unit. For a detailed description of this process, see Smithers (2009). Information collected regarding raptor detections while conducting spring presence/absence surveys was recorded on the "Nest Monitoring and Raptor Detection Data Form", and ongoing monitoring information collected throughout the breeding season was recorded on the "WRFO Nest Monitoring Form" (Smithers 2009).

Determining nest occupancy status:

Evidence which would suggest a nest had been used during the 2011 breeding season included whitewash under the nest tree or at the roost site, prey remains in the nest stand, down present on the perimeter of the nest, castings under the nest tree, or fresh nesting material on the nest (Smithers 2009). The condition of individual nests was used as a general guide to assess the status of the nest prior to incubation. Occupied nests most often had fresh material (e.g., branches) and tended to appear less compressed or compacted than unoccupied nests. Unoccupied nests tended to have a flattened or compressed appearance, presumably from the effects of snow compacting nest material during the previous winter (Smithers 2009). Smithers (2009) also reported that in 2009 at 14 Cooper's hawk nests, regardless of the number of young present in the nest during the brooding, nestling or fledgling phase, because of the amount of residual whitewash that was present under occupied nests, the breeding season status of the nest (i.e., "Occupied" or "Unoccupied") could be confirmed through mid-September, 2009, and this pattern was also confirmed during the 2010 and 2011 breeding seasons.

For spring surveys and because of limitations in both time and funding for this project, it was decided that emphasis would be placed on documenting whether or not a nest stand was occupied, rather than evaluating whether the nesting territory was occupied. As such, an "occupied" nest stand, which was represented as an occupied nest structure within the nest stand, was defined as a nest where either the adult female was observed incubating eggs, as suggested by an adult being in an incubating posture on the nest, or by direct observation of eggs in the nest. A "successful" nest was defined as a nest that produced at least one fledgling. Nests that were determined to be occupied during the spring surveys, and where follow-up surveys indicated that the nest had failed for either known or unknown causes, was classified as a "failed" nest. For our purposes, we define a fledgling as young of the year capable of flying either short distances or capable of sustained flight to and from the nest structure or within the nest stand or post-fledgling area (PFA) prior to dispersal from the PFA.

All accipiter nests that were identified as being occupied during the 2011 spring nest monitoring surveys were visited throughout the breeding season to assess nest status. On average, monitored nests were visited approximately 17 times throughout the breeding season to assess nest occupancy, predation events, record presence/absence information for adults, and record fledgling dispersal information. The primary objective of the end-of-season (EOS) surveys was to determine if nests that were identified as being occupied during the spring surveys successfully produced young. It was determined that mid-June would be an appropriate period to assess nest success for those nests that remained occupied throughout the breeding season. The 2011 EOS nest status verification involved a two month period which started on 15 June and ended on 28 August, where all known nest areas that were identified as being occupied during the spring surveys were visited to access nest success. For those nest areas that remained occupied throughout the breeding season, information pertaining to fledging rates, and fledging and dispersal dates were recorded for each successful nest. The nest status verification start date was chosen to ensure that dispersal of LEOW, RTHA, CORA, and GOEA was also represented. A minimum of two visits to known active nest structures was required to assess the overall success of each occupied nest area.

Spatial Data Preparation and Analysis

Deriving raster data:

Density grids were generated using the Spatial Analyst extension in ArcMap (version 9.3.1), and the geographic extent of the analysis was confined to the analysis area (Figure 1). As such, prior to generating density grids, the Digital Elevation Model (DEM) dataset used to derive slope, aspect, and elevation was "clipped" or extracted to the analysis area using the extraction tool available in the Spatial Analyst extension. Moreover, prior to deriving density grids for road, well and producing well density, these datasets were clipped to the analysis area.

The kernel density tool was used to generate density grids for producing well density (PRW_DEN), road density (RD_DEN), and nest density (i.e., nest density using all nests, NEST_DEN, nest density using only active nests, AC_DEN, and nest density using only inactive nests, IA_DEN) (Table 2). Output grid cell values were set to units per square mile, the search radius was set at 1,609.34 m, and the grid cell size was set at 30 m.

To extract grid cell values to nest points, the "extract values to points" tool was used in the extraction toolbox under the Spatial Analyst Extension.

Pooling data for COHA and LEOW:

In order to examine all known nest locations for COHA and LEOW, I pooled data over years for these two species. The first step required that I review the dataset for occurrences of COHA. I first sorted by "SPP_08", which included the species code for the species occupying the nest during the 2008 breeding season, and selected all "COHA" (e.g., Cooper's hawk) values. I repeated this process for "SPP_09", "SPP_10" and "SPP_11". This process resulted in selecting all known COHA nests that have been identified since the 2008 breeding season. I then exported this dataset as a stand-alone file. I repeated this process for LEOW. Nesting density grids were generated for COHA (CH_DEN) and Long-eared owl (LE_DEN) separately.

After both datasets were created for both LEOW and COHA, I then merged these two datasets into one shapefile. Because this dataset resulted in nests being represented more than once, the next step involved removing all duplicate nests. To ensure there were no duplicate nests, I first calculated distance among nests for the merged dataset using the near tool (Figure 3). I then opened the resultant attribute table and sorted the "NEAR_DIST" field, which included the calculated distance values, in ascending order. I then selected all zero values and re-sorted the table in ascending order on "BLM_ID", which included unique nest identification numbers for each nest. This process resulted in nest pairs being selected in the attribute table. I then proceeded to deselect one of each nest pairs, leaving only those nests that would be deleted from the dataset. This process resulted in the removal of 25 duplicate nests from the dataset. After completing this process I used the near tool and generated a new table with new distance measures and confirmed that all duplicate nests had been removed from the dataset.

The next step included reviewing the resultant table and assigning a "SPP_FINAL" value for each unique nest. In most cases, nests were occupied by different species from 2008 to 2011, and for analysis purposes, it was necessary to assign a unique species code to each nest. In order to accomplish this task, I first sorted on "SPP_08" in Excel and color coded each cell based on species that occupied the nest during the 2008 breeding season. I repeated this procedure for each year. All nests that were occupied by Cooper's hawk during at least one breeding season were assigned a value of "COHA". All other nests were assigned a value of "LEOW". The process described above resulted in a total of 169 nests, 123 of these nests (72%) were designated as Cooper's hawk nests and 46 of these nests (27%) were designated as Long-eared owl nests.

<u>Comparative analysis at random nests versus known nest locations:</u>

In order to help determine whether known Cooper's hawk nest locations were randomly distributed within the project area and showed no association with producing well density, I generated random nest locations and compared producing well density at these locations to producing well density at known Cooper's hawk locations. The purpose of this analysis, as mentioned above, was to compare mean producing well density (PRW_DEN) values at random points to known nest locations and determine if known Cooper's hawk nests were distributed randomly or whether producing well density differed among random nests and known nest locations. This relationship could be used to help provide additional support for Cooper's hawk coexisting with natural gas development activities in the project area. I used the random point generator tool in Hawth's Tools (version 3.27) to generate random points within the analysis area. A total of 250 points were generated, and the minimum distance between points was set at 500 m. The analysis was limited to known nest data for Cooper's hawk, and these data were pooled among years.

<u>Distance analyses:</u>

For the 2011 distance analyses, I used the near tool in the Proximity toolbox in ArcToolbox (ArcGIS version 9.3.1) to calculate four distance measures (e.g., distance from each nest to the nearest producing well (DIST_PR_WELL), distance from each nest to the nearest known well location (DIST_WELL), distance from each nest to the nearest linear feature (DIST_RD), which included pipeline and road corridors, and fence lines, and distance from each nest to the closest neighboring nest (DIST_NEAR_NEST). Units are reported in meters.

<u>Nest re-occupancy analysis:</u>

To complete this analysis, I first selected all active 2009 COHA nests and exported these nests to a shapefile. I repeated this process for 2010 and 2011. I then used the near tool and used the active 2010 nests as the input file and the 2009 active nests as the near file. This tool calculated distance from the 2009 active COHA nests to the nearest 2010 active COHA nest, and I used a 500 m search radius. Nest structures that were reoccupied in 2010 using the 2009 occupied nests as the near feature, and nest structures that were reoccupied in 2011 using the 2010 occupied nests as the near feature resulted in a distance value of zero. The resultant distance values for the 2009/2010 nests were stored in the attribute table of the input file (i.e., the 2010 active COHA shapefile). I then exported this table to Excel, and added the distance values to the data table used for this analysis (Table 3). I repeated the steps above to generate distance values for 2010/2011 nests. Moreover, the process described above was used to derive distance estimates for reoccupied 2010 and 2011 LEOW nests.

STATISTICAL ANALYSIS

Sampling units for this project consisted of nests, and nests were opportunistically selected from a sample of all occupied nests based on accessibility. Thus, nests used in this study were not randomly selected from the population of nests within the study area. All statistical tests were completed using the R statistical software package (R Development Core Team 2005). An alpha of 0.05 was used for all statistical tests (unless noted otherwise), and results are reported as the mean ± *SE*. For a list and brief description of predictor (i.e., independent or explanatory variables) and response (i.e., dependent) variables used in the analyses, see Table 4.

Data exploration began with examining the frequency distribution for each variable to visually assess whether or not the data was distributed normally. After visual inspection of the frequency distributions, it was apparent that most of the data were positively skewed to the right of the median. I used the Shapiro-Wilk test procedure to statistically examine which variables did not follow a normal distribution, and the variance of each response variable was tested using Levene's test (Zar 1999).

Because the data were not normally distributed, and because I intended to use both parametric and non-parametric test procedures to examine differences among independent variables, the response variables were transformed prior to analysis. The following transformations were used: Log_{10}, square root, cube root, fourth root and Box-Cox (Table 5). The first step included plotting each transformed variable using the R Commander interface. I then applied the Shapiro-Wilk test procedure to each variable to determine what transformation produced the largest *P-value* for the Shapiro-Wilk test statistic, *W*. The resultant transformed response variables were used for all subsequent analyses (Figure 3). Variable ELEV was the only response variable in which transformation of the dataset did not result in a smaller *P*-value for the Shapiro Wilk test procedure. As such, the untransformed values for this variable were used for purposes of statistical analysis.

Using Ecological Methodology 6.1 (Exeter Software, Setauket, NY, USA) and procedures described in Krebs (1999), I used the Box-Cox transformation (Box and Cox 1964) to transform response variables RD_DEN, DIST_WELL, DIST_PR_WELL and DIST_RD. The following equation was used to transform each variable:

$$X' = \frac{X^{\lambda} - 1}{\lambda} \qquad (\text{when } \lambda \neq 0)$$

The Box-Cox transformation uses the log-likelihood function (*L*) to determine the value of λ that maximizes *L* by calculating values of λ using an iterative process (Box and Cox 1964). Ecological Methodolgy 6.1 (Exeter Software, Setauket, NY, USA) was used to calculate the value of λ, *L*, and the 95% confidence interval for λ for each response variable. The following log-liklihood function was used to calculate values of λ that maximized the value of *L*:

$$L = -\frac{v}{2}\log_e s_T^2 + (\lambda - 1)\frac{v}{n}\sum(\log_e X)$$

where:

L = Value of log-likelihood
v = Number of degrees of freedom (*N* - 1)
s_T^2 = Variance of transformed *X* values
λ = Provisional estimate of power transformation parameter
X = Original data values

Using the R Commander GUI in R, I examined differences among response variable means that met parametric assumptions for all nests and the predictor variable STATUS_11, which included two levels ("ACTIVE" and "INACTIVE") using a one-way, single factor Analysis of Variance (ANOVA) test procedure (Zarr 1999). Moreover, I examined differences among response variables and the predictor variable END_11, which included two levels ("SUCCESSFUL" and "FAILED"), using a one-way, single factor ANOVA. Finally, I examined differences among response variables and the predictor variable SPP_11, which included two levels ("COHA", "LEOW") using a one-way, single factor ANOVA.

I used a two-way factorial ANOVA to determine if nest success (e.g., "END_11" which consisted of two levels: "FAILED" or "SUCCESSFUL") influenced observed patterns among COHA and LEOW when examining mean differences among response variables. A factorial design was selected to try and reduce the unexplained (or residual) variation in the response variable, and to examine possible interactions between main effects (e.g., factors) (Quinn and Keough 2002).

Because the re-occupancy data were not normally distributed, and because efforts to normalize the data failed, I used a two-sample, non-parametric Wilcoxian Rank Sum test (*W*) to examine differences in median distance values between 2009/2010 and 2010/2011 active COHA nests, and I repeated this procedure for 2009/2010 and 2010/2011 active LEOW nests. This test procedure was also used to examine differences in fledging rates between the 2010 and 2011 breeding season for Cooper's hawk. Similarly, I used a two sample Wilcoxian Rank Sum test to examine median differences among random nests and known Cooper's hawk nests using producing well density (PRW_DEN) as the response variable.

I used a one-way, single factor ANOVA to examine mean differences in transformed response variables among occupied COHA nests that fledged 1,2,3,4 or 0 fledglings during the 2011 breeding season and 1,2,3,4,5 or 0 during the 2010 breeding season. Where *F* tests produced a significant *P*-value, I used a Kruskal-Wallis one-way ANOVA (*K*) to confirm parametric results. The grouping factor was NF_11, which represented the number of young that fledge from the nest. Zero values indicate nests that failed during the 2011 or 2010 breeding season.

Because I was interested in examining differences among nests that successfully fledged young and those nests that failed, in addition to examining relationships among response variables and predictors using ordinary least squares (OLS) estimation techniques (e.g., ANOVA), maximum likelihood (ML) estimation techniques (e.g., logistic regression) using a Generalized Linear Model (GLM) was used to model the outcome of the binary response variable END_11, which consisted of two levels: SUCCESSFUL, FAILED against three transformed predictor variables. The primary question of interest pertained to whether distance to a producing well (BC_DIST_PRW), distance to a travel corridor (BC_DIST_RD) or producing well density (FOURTH_PRWD) could be used to model (i.e., predict) the outcome of a nesting attempt. Because the response variable END_11 was binary, and because the frequency distribution was under dispersed (i.e., the variance was smaller than the mean), I used a quasi-binomial model with a quasi-binomial error term. Moreover, I used the *logit* transformation link function to model the predictors against the response variable. In addition to providing regression coefficients (β_i), or slope, for each predictor variable, for purposes of model comparison, Akaike Information Criterion (AIC) estimates are also provided. The following null hypotheses were tested:

H_o: β_1(BC_DIST_PR_WELL) = 0, or there is no relationship between the outcome of a nesting attempt among occupied Cooper's hawk nests and distance to a producing well (BC_DIST_PR_WELL).

H_o: β_1(BC_DIST_RD) = 0, or there is no relationship between the outcome of a nesting attempt among occupied Cooper's hawk nests and distance to a travel corridor (BC_DIST_RD).

H_o: β_1(FOURTH_PRWD) = 0, or there is no relationship between the outcome of a nesting attempt among occupied Cooper's hawk nests and producing natural gas well density (FOURTH_PRWD).

Because I was also interested in modeling fledging rates (e.g., number of young fledged per successful nest) against distance to producing wells, distance to travel corridors and natural gas well density, I used logistic regression to model the outcome of response variable NF_11, which represented the number of young that fledged from successful nests against the three predictor variables. The primary question pertained to whether fledging rates were influenced by the predictor variables mentioned above. Because the response variable represented counts, I assumed the data followed a *poisson* distribution. Moreover, because these data were over dispersed (i.e., the variance was larger than the mean), I used a quasi-poisson likelihood model with a quasi-poisson error term, and I used the *log* transformation link function. The following hypotheses were tested:

H_o: β_1(BC_DIST_PR_WELL) = 0, or there is no relationship between the number of young that fledge from a nest among occupied Cooper's hawk nests and distance to a producing well (BC_DIST_PR_WELL).

H_o: β_1(DIST_RD) = 0, or there is no relationship between the number of young that fledge from a nest among occupied Cooper's hawk nests and distance to travel corridors (BC_DIST_RD).

H_o: β_1(FOURTH_PRWD) = 0, or there is no relationship between the number of young that fledge from a nest among occupied Cooper's hawk nests and producing natural gas well density (FOURTH_PRWD).

RESULTS

Nest Monitoring

A total of 306 nest structures (286 visited by BLM staff and 20 visited by contractors), representing approximately 298 known nesting territories, were visited during the 2011 field season. Of these nests 34% (*N* = 105) were classified as being occupied during the spring surveys, and 65% (*N* = 198) of these nests were confirmed as being unoccupied during the 2011 breeding season. Of the occupied nests where the outcome of the nesting attempt (e.g., failed or successful) was recorded (*N* = 89 nests), we reported a success rate of 58% (*N* = 52 successful nests), and a nest failure rate of 42% (*N* = 37 failed nests). Compared to 2010 findings, nest failure rates in 2011 represented a 146% increase (15 of 124 nests, 12%, failed in 2010 vs. 37 of 89 nests, 42%, failed in 2011) in the number of nests that failed from 2010 to 2011. The outcome of sixteen nesting attempts (*N* = 16 nests or 15% of all occupied nests) was not recorded during the 2011 breeding season.

Fledging rate information was collected at all nests that successfully fledged young (*N* = 50 successful nests). These nests produced a total of 118 fledglings ($\bar{x}$ = 2.4 ± 0.14 fledglings produced per successful nest), which represents a 62% decline in number of fledglings produced per successful nest in 2010 (*N* = 310). When considering all occupied nests for all species, fledging rates within the project area were 1.3 fledglings produced per nesting attempt (*N* = 89 occupied nests). Compared to 2010 findings, as mentioned above, only 38% of the total number of fledglings produced in 2010 were produced in 2011.

We found that productivity was similar among Cooper's hawk and Long-eared owl in our study area during the 2011 breeding season. When considering only successful (i.e., excluding failed nesting attempts) Cooper's hawk nests (20 of 42 possible 2011 occupied nests), we found that Cooper's hawk produced on average 2.7 (± 0.20 fledglings) per successful nest (Table 6), and this finding was statistically similar to what was recorded in 2010, with 3.0 (± 0.14) fledglings produced per successful Cooper's hawk nest (*W* = 594.5, *P* = 0.194). When considering only successful Long-eared owl nests, (*N* = 10) of 17 possible 2011 occupied nests, Long-eared owl produced on average 2.3 (± 0.30 fledglings) per breeding pair, and unlike Cooper's hawk, this finding represented a statistically significant decline from 2010 findings in number of young that fledged from successful Long-eared owl nests (*W* = 280, α = 0.1, *P* = 0.097). During the 2010 breeding season Long-eared owl produced, on average, 3.0 fledglings per successful nest.

When considering all Cooper's hawk and Long-eared owl nesting attempts (i.e., including both successful and failed nesting attempts), fledging rates were equal to 1.3 (± 0.23) and 1.6 (± 0.36) fledglings produced per nesting attempt, respectively, in the project area (Table 6). We documented a significant decline in the number of fledglings produced per nesting attempt among occupied Cooper's hawk (*W* = 1782.5, *P* = 0.00005) and Long-eared owl (*W* = 460, *P* = 0.034) during the 2010 and 2011 breeding seasons.

A total of 129 nest structures, representing 70% of all nest structures visited in 2010 (*N* = 183), were visited in 2011. Moreover, 136 (84%) of the 2010 nest structures that were occupied in 2010 (*N* = 162) were visited in 2011. We noted that nest structure re-occupancy during the 2011 breeding season was low, with only 29% (*N* = 40) of those nest structures that were occupied in 2010, and consequently visited in 2011 (*N* = 136), also being reoccupied in 2011 (Table 6).

Fifty-nine percent (*N* = 96) of the nests that were active in 2010 were determined to be inactive in 2011. Fourteen nests that failed in 2010 (*N* = 15) were visited in 2011. Fourteen of these nests were occupied in 2011; however, only 14 percent (*N* = 2 nests) successfully produced young during the 2011 breeding season. In order to examine mean differences between response variables at nests that failed in 2010 and remained inactive in 2011, we described the overall proximity to roads, producing well density, distance to producing wells, etc., for these failed nests and compared these values to all other 2011 failed nests and found no response variable that differed statistically among the two. Twenty-six nests (16%) that were active in 2010 (*N* = 162) were not revisited in 2011.

During the 2011 breeding season, occupancy information was collected at an additional 114 nest territories compared to 2010, representing a 162% increase in the number of known nesting territories in the project area from 2010 to 2011 where monitoring information has been collected.

Correlation Analysis

When considering data for all nests and all species, there were no unexplained or unanticipated statistically significant correlations between the response variable combinations (Figure 5, Table 7). Statistically significant correlations that could be explained fairly easily included the relationship between distance to a known well location (BC_DIST_WELL) and distance to producing wells (BC_DIST_PRW). Nests that were located at greater distances from known well locations were also located at greater distances from producing wells (r_s = 0.66). Moreover, as producing well density increased, distance to a producing well decreased (r_s = -0.75). Similarly, as known well density increased, distance to a producing well decreased (r_s = -0.65). Nests that were located in areas where well density was high were also located closer to a producing well.

Similar to correlation results when all nests were examined, we found no unexplained or unanticipated statistically significant correlations between response variable combinations (Tables 8 and 9, Figures 6 and 7) for "Active" and "Inactive" nests, and for COHA and LEOW.

Nest Stand Re-occupancy Analysis

We noted that nesting area re-occupancy was high for Cooper's hawk with 11 pairs (*N*= 31 of the 2010 territories reoccupied in 2011, 26% of all known 2011 COHA territories, *N* = 42) returning to the nest structure that was used in 2010, and an additional 20 pairs returning to the same nest stand to either construct a new nest or occupy an alternate nest, for a total of 31 pairs (or 74% of all known 2011 Cooper's hawk territories) reoccupying 31 known nesting territories (i.e., nesting areas) during the 2011 breeding season.

The mean distance from 2011 active COHA nests to the nearest active 2010 COHA nests was 177 (± 18.94 m, *N* = 20 nest pairs, range = 33.84 to 340.21) (Table 3). The mean distance from 2010 active COHA nests to the nearest active 2009 COHA nest was 186 (± 43.24 m, *N* = 7, range = 115.43 to 436.22). We found that mean distance between 2009/2010 COHA nests and 2010/2011 COHA nests did not differ (*W* = 66.5, *P* = 0.8681). Though no statistical difference was recorded, COHA tended to reoccupy or construct nests during the 2011 breeding season that were closer to 2010 occupied nests when compared to those nests that were reoccupied or constructed in 2010 from the 2009 occupied nests (Table 3).

When comparing mean distance between active 2009 LEOW nests and active 2010 LEOW nests ($\bar{x}$ = 132 ± 47.70 m, *N* = 5, range = 23.71 to 291.53) to mean distance between active 2010 LEOW nests and active 2011 nests ($\bar{x}$ = 327 ± 29.90 m, *N* = 7, range = 240.35 to 436.22) , we found that, contrary to what was observed for COHA, LEOW tended to reoccupy or construct nests during the 2011 breeding season that were farther from occupied 2010 LEOW nests, when compared to the distance between occupied 2009 and 2010 nests (*W* = 31.5, *P* = 0.02807, Table 3).

One-way ANOVA, and Non-parametric Results

We found no statistical difference among ACTIVE (*N* = 105) and INACTIVE nests (*N* = 194) when comparing their proximity to linear features (BC_DIST_RD) ($F_{1,299}$ = 1.6, *P* = 0.0.195, Table 10). On average, active nests were 198 (± 16.49 m) and inactive nests were 224 (± 13.61 m) from a linear feature (Table 11).

When comparing response variable means among FAILED (*N* = 37) and SUCCESSFUL nests (*N* = 52), at an alpha of 0.10, we found that successful nests tended to be located in areas where producing well density was low when compared to failed nests, which were located in areas where producing well density was generally high (*W* = 760, α = 0.1, *P* = 0.092) (Table 10), though the biological significance of a difference of 0.16 producing wells/mi^2 among failed and successful nests is less certain. On average, successful nests were located in areas where producing well density was equal to 2.3 (± 0.36 producing wells/mi^2, range = 0.01 to 10.41), while failed nests were located in areas where producing well density was equal to 2.4 (± 0.96 producing wells/mi^2, range = 0.03 to 26.26) (Table 11). When comparing known Cooper's hawk nest locations with 250 randomly generated nest locations, we noted that random locations were generally located in areas where producing well density was low, with a mean value of 1.2 producing wells per square mile, while, when using pooled Cooper's hawk nest locations, known Cooper's hawk nest locations were found in areas where mean producing well density equaled 2.8 producing wells per square mile (*W* = 10,500, *P* = 0.000013). We also found that successful nests were generally located closer to travel corridors when compared to failed nests ($F_{1,86}$ = 6.00, *P* = 0.016) (Table 10). On average, successful nests were located 158 (± 17.51 m, range = 7.68 to 591) m from a travel corridor, while failed nests were located 255 (± 36.15 m, range = 12.34 to 1,078) m from a travel corridor (Table 11).

When comparing response variable means among COHA (*N* = 42) and LEOW (*N* = 17), using an alpha of 0.10, we found that occupied COHA nests were generally located closer to road corridors, when compared to occupied LEOW nests, which were located farther from a road corridor ($F_{1,56}$ = 3.645, α = 0.10, P = 0.061) (Table 10, Figure 8 and 9). On average, occupied COHA nests were located 187 (± 24.17, range = 12.34 to 655.13) m from a road corridor, while occupied LEOW nests were located 249 (± 33.51, range = 53.38 to 530.01) m from a road corridor (Table 11). We also found that COHA nests were generally located in areas where active nest density was low, when compared to LEOW nests, which were located in areas where active nest density values were generally larger (W = 242, P = 0.045) (Table 10), though these results are most likely misleading because the interaction term between "SPP_11" and "END_11" was significant (α = 0.1, $F_{1,57}$ = 3.57, P = 0.064). On average, occupied COHA nests were located in areas where mean active nest density was equal to 3.5 (± 0.20 active nests/mi^2, range = 2.47 to 7.36), while occupied LEOW nests were located in areas where mean active nest density was equal to 4.2 (± 0.33 active nests/mi^2, range = 2.47 to 7.34) (Table 11).

When examining mean differences in transformed response variables among 2011 occupied COHA nests that produced 1,2,3,4 or 0 fledglings, we found no statistical difference among these nests. However, we observed a general pattern of increasing nest productivity with decreasing producing well density, though as mentioned above, this relationship was not statistically significant ($F_{4,37}$ = 1.36, P = 0.27) (Table 15).

When examining mean differences in transformed response variables among 2010 occupied COHA nests that produced 1,2,3,4,5 or 0 fledglings, we recorded a significant difference in mean values for BC_DIST_RD (e.g., distance to the nearest linear feature) ($F_{5,51}$ = 2.27, α = 0.1, P = 0.061), and these findings were confirmed using non-parametric test procedures ($K_{5,51}$ = 10.68, α = 0.1, P = 0.058) (Figure 10). We noted that nests that were located farther from a linear feature, in presumably less fragmented areas, tended to produce more young per successful nest; however, interestingly, these nests also exhibited higher nest failure rates. The mean value for failed nests was 381 m (N = 8) from a linear feature. As mentioned above, nests that produced at least one fledgling were generally closer to linear features and located in areas that were presumably more fragmented. The mean value for these nests was 81 m (N = 4). All other nests that produced 2 to 5 fledlings exhibited similar distance values, with a mean distance of 242 m (N = 45) from a linear feature (Figure 10). These findings suggest that occupied nests that are located close to linear features, which are a heavily represented by road and pipeline corridors, and occur in areas that exhibit increased landscape fragmentation, may produce less young than nests that are located in less fragmented landscapes, at greater distances from linear features. During the 2010 breeding season nests that produced three fledglings per occupied nest tended to be the most common, with a total of 23 nests in this category, producing 69 fledglings. The mean distance for these nests from a linear feature was 181 m.

Two-way Factorial ANOVA

Similar to the results for the single-factor ANOVA, two-way factorial ANOVA results indicated that producing well density (FOURTH_PRWD) varied among failed and successful nests (END_11) (,$F_{1,57}$ = 2.54, α = 0.1, P = 0.09, Figure 12), though the biological significance of a difference of 0.16 producing wells/mi^2 among failed and successful nests is less certain. On average, producing well density was equal to 2.3 (± 0.36 producing wells/mi^2) at successful nests and 2.4 (± 0.96 producing wells/mi^2) at failed nests.

Logistic Regression Results

When modeling the outcome of a nesting attempt (e.g., successful vs. failed) to the three predictor variables (BC_DIST_PRW , FOURTH_PRWD, BC_DIST_RD), we found that the only statistically significant relationship among these variables existed when distance to roads (BC_DIST_RD) was used as the predictor variable (β_1(BC_DIST_RD) = -.006, P = 0.04, AIC = 54.63). However, adding this predictor variable to the model only explained 8% of the variability in the model. Moreover, one unit change in the odds of a nest successfully producing young or failing resulted in <1% change in distance to the nearest road, suggesting that, though statistically significant, distance from an occupied nest to the nearest road, by itself, did not explain enough variability in the model to make it useful. Similarly, when modeling fledging rates against the three predictor variables, we found that the best fit model included distance to roads as the predictor variable (β_1(BC_DIST_RD) = -0.003, P = 0.01, AIC = 133.79), but similar to what was found when this predictor variable was added to the nesting attempt outcome model above, adding this predictor to the fledging rate model accounted for <1% of the variation in the model.

Looking forward, the addition of other predictors, such as producing well density, percent suitable nesting habitat within one mile of the nest, road corridor density, mean precipitation and recorded daily low temperatures during the month of May and June, and mean prey deliveries per hour, analyzed using multiple logistic regression, which allows for multiple predictor variables in the model, may result in a more appropriately fit model, and thus provide a better tool to help describe both nesting success and fledging rates for Cooper's hawk in the project area.

DISCUSSION

A total of 306 nest structures, representing approximately 298 known nesting territories, were visited during the 2011 field season. Of these nest, 34% (*N* = 105) were classified as being occupied during the spring surveys, and 65% (*N* = 198) of these nests were confirmed as being unoccupied during the 2011 breeding season. Of the occupied nests where the outcome of the nesting attempt (e.g., failed or successful) was recorded (*N* = 89 nests), we reported a success rate of 58% (*N* = 52 successful nests), and a nest failure rate of 42% (*N* = 37 failed nests). Compared to the 2010 findings, nest failure rates in 2011 represented a 146% increase (15 of 124 nests, 12%, failed in 2010 vs. 37 of 89 nests, 42%, failed in 2011) in the number of nests that failed in 2011 compared to the number of nests that failed in 2010.

During the 2011 breeding season, the increase in nest failures from 2010 to 2011 were most likely attributed to stochastic spring weather events (e.g., rain and snow showers) and cold temperatures. Estimated nest failure dates showed that most failures occurred during the months of April and May, which also coincided with early spring rain and snow showers and cold temperatures. Using data collected at the Pinto Mesa RAWS weather station, when comparing 2010 and 2011 weather data for the months of April, May and June, the only piece of information that stood out was the number of days in which a measureable amount of precipitation was recorded during the month of April. In April 2010, there were a total of 8 days where a measurable amount of precipitation was recorded, while in April of 2011 there were a total of 17 days where a measurable amount of precipitation was recorded; however, total precipitation in April (recorded in inches) did not differ among 2010 and 2011 breeding seasons ($F_{1,57} = 0.21$, $P = 0.65$), nor did mean values for minimum temperatures recorded in April 2010 and April 2011 ($F_{1,58} = 0.46$, $P = 0.50$). In addition to precipitation events being more numerous, the distribution of days where a measurable amount of precipitation was recorded in 2011 during the month of April was generally more equitably distributed (i.e., precipitation events were distributed equally throughout the month), while precipitation events in April 2010 were less equitably distributed (Figures 13, 14 and 15). In addition to more numerous precipitation events, precipitation events were smaller in magnitude compared to 2010 precipitation events, which were generally less numerous but produced more precipitation per event. These findings may indicate that the distribution of precipitation events may influence productivity more than total volume of precipitation produced per event. Mean value for minimum temperatures during the month of April 2010 and 2011 were 32 and 30 ºF, respectively, while total precipitation estimates during the month of April 2010 and 2011 were 0.87 and 1.13 in, respectively. As noted above, we found no statistical difference among mean precipitation estimates during the month of April in 2010 or 2011. However, our findings suggest that the distribution of precipitation events may influence Cooper's hawk nest productivity more than the total volume of precipitation produced per event.

Unfortunately, we did not assess prey delivery rates during the 2011 breeding season, though based on anecdotal evidence, using the same observer in 2011 as 2010, we noted a decline in the overall presence of either adult in the nest stand during routine monitoring visits. In addition, unlike observations recorded during the 2010 breeding season at occupied nests, during the 2011 breeding season, we noted a decline in the number of occurrences where prey items were observed on the rim of the nest, in the nesting area, or on the ground directly below the nest. In addition, based on point-count surveys that were conducted by BLM staff during the 2011 breeding season in the project area, breeding bird abundance was consistently lower than average in 2011 (Ed Hollowed, personal communication). Moreover, we noted that, when compared to 2010 observations, fledglings tended to disperse from the nest stand, and presumably from the Post Fledging Area (PFA), sooner in 2011 vs. 2010, in which they tended to remain in the nest stand for longer periods prior to dispersal. These anecdotal observations provide support that prey abundance and possibly prey availability may have been reduced during the 2011 breeding season, which may have also influenced nest occupancy and productivity results.

Fledging rate information was collected at all nests that successfully fledged young (N = 50). These nests produced a total of 118 fledglings ($\bar{x}$ = 2.4 ± 0.14 fledglings produced per successful nest), which represents a 62% decline in number of fledglings produced per successful nest in 2010 (N = 310). When considering all occupied nests for all species, fledging rates within the project area were 1.3 fledglings produced per nesting attempt (N = 89 occupied nests). Compared to 2010 findings, only 38% of the total number of fledglings produced in 2010 were produced in 2011. Because the same observer was used in both 2010 and 2011, and because survey effort was similar during the 2010 and 2011 breeding seasons, we are led to believe that there was both a numerical and biological difference (i.e., decline) in number of fledglings produced per successful nest in 2011 compared to 2010 findings, and as mentioned above, both seasonal weather patterns and prey abundance and prey availability most likely led to the observed pattern.

Similar to 2010 findings, we found that productivity was similar among Cooper's hawk and Long-eared owl in our study area during the 2011 breeding season. When considering only successful Cooper's hawk nests (20 of 42 possible 2011 occupied nests), we found that Cooper's hawk produced on average 2.7 (± 0.20 fledglings) per successful nest, and this finding was statistically similar to what was recorded in 2010, with 3.0 (± 0.14) fledglings produced per successful nest (W = 594.5, P = 0.194). This finding contradicts our supposition that prey abundance and availability was a key factor influencing nest occupancy and productivity results. If prey availability and abundance was a primary factor influencing nest occupancy and productivity results, then one would expect a noticeable decline in the number of fledglings produced per successful nest when looking at all successful Cooper's hawk nests. However, this finding provides support for the clustered distribution of occupied Cooper's hawk nests as it relates to prey abundance and availability, which is most likely also clustered and patchy during years when prey density is low. Cooper's hawk nest occupancy and productivity may be more heavily influenced by the distribution, abundance and availability of small mammals in our study area.

Findings recorded in 2010, which, based on nest occupancy and productivity information, most likely represent an exceptional year for Cooper's hawk nest occupancy and productivity, and findings recorded in 2011, which, based on the same information, most likely represent a low year for Cooper's hawk. When comparing 2010 findings to 2011 results, 2011 findings provide support for the theory that even though nest occupancy may be low in years when prey densities are low, because of the patchy distribution of prey (both avian and mammalian) within a territory, nest productivity can still be high at the local scale, though nest occupancy and productivity estimates based on number of fledgling produced per *nesting attempt* will be low at the regional scale. Additional support for this concept includes the fact that we documented a significant decline in the number of fledglings produced per nesting attempt among occupied Cooper's hawk (W = 1782.5, P = 0.00005) and Long-eared owl (W = 460, P = 0.034) during the 2010 and 2011 breeding seasons.

Regarding additional proximate factors that may have indirectly influenced nest success, we found that successful nests tended to be located in areas where producing well density was low, when compared to failed nests, which were located in areas where producing well density was generally high (W = 760, α = 0.1, P = 0.092). However, we also found that successful nests were generally located closer to road and pipeline corridors when compared to failed nests ($F_{1,86}$ = 6.00, P = 0.016), which were generally located at greater distances from these features. Lastly, we observed a general pattern of increasing nest productivity with decreasing producing well density and increasing distance from road and pipeline corridors. The mean value for failed nests was 381 m (N = 8) from a linear feature. Nests that produced at least one fledgling were generally closer to linear features and located in areas that were presumably more fragamented. The mean value for these nests was 81 m (N = 4). All other nests that produced 2 to 5 fledlings during the 2010 breeding season exhibited similar distance values, with a mean distance of 242 m (N = 45) from a linear feature (Figure 10). We noted that nests that were located farther from a linear feature, in presumably less fragmented areas, tended to produce more young per successful nest; however, interestingly, these nests also exhibited higher nest failure rates. These findings suggest that occupied nests that are located close to linear features, which are a heavily represented by road and pipeline corridors, and occurr in areas that exhibit increased landscape fragmentation, may produce less young, than nests that are located in less fragmented landscapes, at greater distances from linear features. However, these nests are generally more likely to be successful in these areas where fragmenation of woodlands and sagebrush parks by these features is prevalent. These features may increase both prey availability and enhance local populations of small mammals and ground foraging birds by the addition of grass, forb, and shrub seed from both small and large-scale reclamation projects associated with oil and gas activities in the project area. Natural seed production by pinion pine in the project area durring the 2010 breeding season may have also influenced small mammal and ground foraging bird abundance.

A total of 129 nest structures representing 70% of all nest structures visited in 2010 (*N* = 183) were visited in 2011. Moreover, 136 (84%) of the 2010 nest structures that were occupied in 2010 (*N* = 162) were visited in 2011. We noted that nest structure re-occupancy during the 2011 breeding season was low, with only 29% (*N* = 40) of those nest structures that were occupied in 2010, and consequently visited in 2011 (*N* = 136), also being reoccupied in 2011 (Table 6). As mentioned above and below, this finding does not necessarily mean that raptors in our study area were selecting alternate territories based on prey availability; rather, territories that exhibited low prey density and availability were most likely either not occupied by breeding pairs or did not produce young. Coupled with the fact that nest stand fidelity for Cooper's hawk appears to be high, with 74% of the monitored Cooper's hawk nests that were occupied with breeding pairs during the 2011 breeding season returning to the same nest stand that was used during the 2010 breeding season.

During the 2011 breeding season, occupancy information was collected at an additional 114 nest territories compared to 2010, representing a 162% increase in the number of known nesting territories in the project area from 2010 to 2011 where monitoring information has been collected. This finding can best be explained by the fact that the individual responsible for monitoring nests had more time to visit additional known nest locations and confirm occupancy status because of low nest occupancy rates and high nest failure rates in the project area, which would have required more time to conduct routine visits to these territories to confirm occupancy status if the later had been true (i.e., higher occupancy rates and lower nest failure rates). As such, we do not believe these findings represent a statistical increase in the number of new territories in the project area, rather, these findings illustrate the level of effort that is possible to confirm occupancy status when overall nest occupancy is low and nest failure rates are high in our study area.

Assuming funding is available for this project in 2012, the following topics will be included in the project objectives for 2012: (1) the continuation of an assessment of possible behavioral effects of oil and gas activities on prey delivery rates, prey diversity and prey equitability, parental behavior, and productivity of Cooper's hawk using video monitoring systems; and, (2) the development of a sampling scheme that allows for the assessment of energy-related effects on nest occupancy and productivity using Principle Components Analysis (PCA) and multiple logistic regression.

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Table 1. The following table includes a list of species' codes used throughout this document.

Species	Code
American kestrel	AMKE
Bald eagle	BAEA
Cooper's hawk	COHA
Common raven	CORA
Great-horned owl	GHOW
Golden eagle	GOEA
Long-eared owl	LEOW
Northern goshawk	NOGH
Peregrine Falcon	PEFA
Prairie falcon	PRFA
Red-tailed hawk	RTHA
Sharp-shinned hawk	SSHA
Northern saw-whet owl	SWOW
Osprey	OSPR
Unknown species	UNK

Table 2. The following table shows the grid datasets that were used to analyze density and derive topography datasets. For a brief description of each variable, see Table 5.

Grid Name (untransformed)	Grid Name (transformed)	Source
ASP	LOG_ASPECT	DEM (10 m)
ELEV[1]		DEM (10 m)
SLOPE	LOG_SLP	DEM (10 m)
PRW_DEN	FOURTH_PRWD	COGCC[2] Well Data
WDEN	FOURTH_WDEN	COGCC Well Data
RD_DEN	BC_RD_DEN	WRFO Road and Trail Layer
NEST_DEN	SQRT_NEST_DEN	WRFO Raptor Inventory Layer
AC_DEN	CUBE_AC_DEN	WRFO Raptor Inventory Layer
IA_DEN	LOG_IA_DEN	WRFO Raptor Inventory Layer

[1] Because the transformed dataset for this variable produced larger Shapiro-Wilk *P*-values, the untransformed dataset was used for all analyses.
[2] Colorado Oil and Gas Conservation Commission

Table 3. The following table shows the data that was used to compare nest re-occupancy information for Cooper's hawk and Long-eared owl in the project area. Cooper's hawk tended to reoccupy or construct nests during the 2011 breeding season that were closer to 2010 occupied nests when compared to those nests that were reoccupied or constructed in 2010 from the 2009 occupied nests, though this relationship was not statistically significant (W = 66.5, P = 0.8681). Long-eared owl tended to reoccupy or construct nests during the 2011 breeding season that were farther from occupied 2010 nests, when compared to the distance between occupied 2009 and 2010 nests (W = 31.5, P = 0.02807). Distance measures are reported in units of meters.

	DIST_09_10_COHA	DIST_10_11_COHA	09_10_DIST_LEOW	10_11_DIST_LEOW
	436.22	113.07	23.71	240.35
	115.43	185.65	61.72	262.55
	115.68	317.41	101.24	290.11
	117.59	252.87	181.39	291.53
	150.22	223.45	291.53	333.67
	181.60	38.47		433.28
	181.95	230.42		436.22
		33.84		
		129.56		
		178.94		
		108.19		
		138.96		
		93.56		
		340.21		
		124.33		
		234.13		
		224.72		
		150.22		
		276.15		
		145.17		
Mean =	185.53	176.97	131.92	326.82
SD =	114.40	84.68	106.66	79.11
SE =	43.24	18.94	47.70	29.90
CV =	0.62	0.48	0.81	0.24
N =	7	20	5	7

Table 4. The following table includes variable codes and variable descriptions for the independent (i.e., explanatory or predictor) categorical variables (above), and the dependent (i.e., response) variables (below).

Variable Name	Description
SPP_11	Species documented using the nest during the 2011 breeding season.
STATUS_11	The 2011 breeding season status of the nest (e.g., "ACTIVE", "INACTIVE", "UNKNOWN")
END_11	The 2011 end status of the nest (e.g., "SUCCESSFUL", "FAILED", UNKNOWN")
NF_11	The number of young that fledged from the nest during the 2011 breeding season.

Variable Name	Description
PRW_DEN	Producing well density. Producing well density grid cell values were extracted to each nest.
RD_DEN	Road density. Road density grid cell values were extracted to each nest.
NEST_DEN	Nest density. Using all nests (i.e., Active, Inactive, Unknown), nest density values were extracted to each nest.
AC_DEN	Active nest density. Using only "Active" nests to create the nest density grid, density grid cell values were extracted to each nest.
IA_DEN	Inactive nest density. Using only "Inactive" nests to create the nest density grid, density grid cell values were extracted to each nest.
ASP	Gird cell values for apsect at each nest.
SLOPE	Grid cell values for slope at each nest.
ELEV	Grid cell values for elevation at each nest.
DIST_NEAR_NEST	Distance between nests. This variable was created to examine patterns in clustering of nests. The values represent the nearest distance to another nest and units were recorded in meters.
DIST_PR_WELL	Distance to the nearest producing well. This variable was created to examine patterns proximity of nest to active (e.g., producing) natural gas wells. The values represent the distance (in meters) from the nest to the nearest surface hole location (represented as a point).
DIST_RD	Distance to the nearest road. This variable was created to examine patterns of proximity of nest to roads. The values represent the straight-line distance (in meters) from the nest to the nearest linear feature (represented as a line).

Table 5. The following table shows the type of transformation that was performed on each variable. See Figure 3 for resultant frequency distribution curves using the transformation identified below. Data used in this project was collected throughout the study area during the 2011 breeding season in Piceance Basin, Colorado.

Variable	Description	Shapiro-Wilk *P*-value	Type of Transformation	Transformed Variable	Shapiro-Wilk *P*-value	Test
ASP	Aspect at nest (deg.)	3.855E-16	Log transformation using the Log_{10} of each observation and adding 1	LOG_ASPECT	2.2E-16	Non-parametric
ELEV	Elevation at nest (meters)	0.00002	Log transformation using the Log_{10} of each observation and adding 1	LOG_ELEV	1.01E-09	Non-parametric
SLOPE	Slope at nest (%)	2.2E-16	Log transformation using the Log_{10} of each observation and adding 1	LOG_SLP	0.01506	Parametric
PRW_DEN	Producing well density (No. producing wells/mi^2)	2.20E-16	Power transformation using the fourth root of each observation (i.e., $x^{0.25}$)	FOURTH_PRWD	1.63E-10	Non-parametric
WDEN	Well density (wells/mi^2)	2.20E-16	Power transformation using the fourth root of each observation (i.e., $x^{0.25}$)	FOURTH_WDEN	0.00004	Non-parametric
RD_DEN	Road density (miles of road/mi^2)	0.001045	Box-Cox transformation using a lambda of 0.687	BC_RD_DEN	0.01291	Parametric
NEST_DEN	Nest density (nests/mi^2)	5.711E-07	Power transformation using the square root of each observation (i.e., $x^{0.5}$)	SQRT_NEST_DEN	1.69E-06	Non-parametric
DIST_NEAR_NEST	Distance to nearest nest (meters)	6.114E-13	Log transformation using the Log_{10} of each observation and adding 1	LOG_DIST_NEST	0.02927	Parametric
DIST_WELL	Distance to nearest well (meters)	2.2E-16	Box-Cox transformation using a lambda of 0.109	BC_DIST_WELL	0.1402	Parametric
DIST_PR_WELL	Distance to nearest producing well (meters)	2.20E-16	Box-Cox transformation using a lambda of 0.109	BC_DIST_PRW	0.3909	Parametric
DIST_RD	Distance to nearest road (meters)	2.20E-16	Box-Cox transformation using a lambda of 0.229	BC_DIST_RD	0.02387	Parametric
AC_DEN	Active nest density (nests/mi^2)	2.78E-16	Power transformation using the cube root of each observation (i.e., $x^{0.33}$)	CUBE_AC_DEN	2.2E-16	Non-parametric
IA_DEN	Inactive nest density (nests/mi^2)	1.15E-10	Log transformation using the Log_{10} of each observation and adding 1	LOG_IA_DEN	5.22E-13	Non-parametric

Table 6. The following tables summarize nest occupancy information by year and nest status (above), and productivity information by species (below). For productivity information, parentheses indicate 2010 values.

	2010				2011			
	N	Successful	Failed	Unknown	*N*	Successful	Failed	Unknown
Active	162(89%)	109 (88%, *N* = 124)	15 (12%, *N* = 124)	38 (23%, *N* = 38)	105 (34%)	52 (58%, *N* = 89)	37 (42%, *N* = 89)	16 (15%, *N* = 16)
Inactive	21(11%)				198 (65%)			
Unknown	0				3 (<1%)			
Total	183				306			

Species	Failed	Successful	Unknown	Total Active Nests	No. Fledged (NF)	Mean NF/Successful Nest	Mean NF/Nesting Attempt
AMKE			1(2)	1(2)			
BAEA	1 (NA)	0 (1)	1(NA)	1(1)	0(1)		
COHA	22 (8)	20 (49)	NA(5)	42(62)	53(147)	2.65(3.0)	1.3(3.0)
CORA	5 (1)	6 (2)	7(7)	18(10)	15(7)	3.0(3.5)	1.5(2.0)
GHOW		NA (1)	1(2)	1(3)	NA(1)	NA(1)	
GOEA	2 (NA)	2 (1)		4(1)	2(1)	1(NA)	0.5(NA)
LEOW	4 (6)	10 (43)	3(10)	17(59)	23(126)	2.3(2.93)	1.6(3.0)
NOGH		3 (3)		3(3)	3(7)	1.33(2.33)	1.3(2.0)
PRFA		2 (2)	NA(1)	2(3)	3(2)	1.5(NA)	1.5(NA)
RTHA	1 (NA)	8 (6)	4(10)	13(16)	18(15)	2.3(2.5)	2.0(3.0)
SSHA		NA (1)		NA(1)	NA(3)		
SWOW			NA(1)	NA(1)			
OSPR		1 (NA)		1(NA)	2		
Total	35(15)	52(108)	17(38)	103(162)	117(310)		

Table 7. The following table includes Spearman correlation values (r_s) for the transformed variable combinations when data for *all nests* were used for correlation analyses. Values highlighted in bold exhibited a modest to high correlation. The following codes apply: LOG_ASPECT (aspect), SQRT_NEST_DEN (nest density), BC_RD_DEN (road density), BC_DIST_RD (distance to roads), ELEV (elevation), LOG_SLP (slope), LOG_DIST_NEST (distance between nests), BC_DIST_PRW (distance to a producing well), FOURTH_PRWD (producing well density), BC_DIST_WELL (distance to the nearest well), FOURTH_WDEN (well density), LOG_IA_DEN (inactive nest density), CUBE_AC_DEN (active nest density). Values ranging from 0.00 to 0.19 represent no correlation to very weak, 0.20 to 0.39 (weak correlation), 0.40 to 0.69 (modest correlation), 0.70 to 0.89 (strong correlation), and 0.90 to 1.00 (very strong correlation) (Fowler et al. 1998).

Variable	BC_DIST_PRW	BC_DIST_RD	BC_DIST_WELL	BC_RD_DEN	CUBE_AC_DEN	ELEV	FOURTH_PRWD	FOURTH_WDEN	LOG_ASPECT	LOG_DIST_NEST	LOG_IA_DEN	LOG_SLP	SQRT_NEST_DEN
BC_DIST_PRW	1.00	0.23	**0.66**	-0.17	-0.15	-0.08	**-0.75**	**-0.65**	-0.03	0.06	0.00	0.16	-0.28
BC_DIST_RD		1.00	0.29	-0.34	-0.07	-0.07	-0.18	-0.19	-0.04	-0.15	0.19	0.03	0.13
BC_DIST_WELL			1.00	-0.08	-0.17	-0.10	-0.39	-0.46	-0.01	0.10	-0.04	0.07	-0.26
BC_RD_DEN				1.00	0.06	0.11	0.31	0.39	-0.06	0.16	-0.08	0.04	-0.11
CUBE_AC_DEN					1.00	-0.11	0.08	0.13	-0.09	-0.33	0.09	-0.14	0.38
ELEV						1.00	-0.05	-0.08	0.14	-0.02	0.20	-0.26	0.05
FOURTH_PRWD							1.00	**0.84**	0.03	-0.09	0.09	-0.09	0.29
FOURTH_WDEN								1.00	-0.05	-0.06	-0.02	-0.07	0.23
LOG_ASPECT									1.00	-0.02	0.06	-0.06	0.10
LOG_DIST_NEST										1.00	-0.46	0.12	-0.42
LOG_IA_DEN											1.00	-0.09	**0.67**
LOG_SLP												1.00	-0.08
SQRT_NEST_DEN													1.00

Table 8. The following tables include Spearman correlation values (r_s) for the transformed variable combinations when data for *active* (above) and *inactive* (below) were used for correlation analyses. Values highlighted in bold exhibited a modest to high correlation. The following codes apply: LOG_ASPECT (aspect), SQRT_NEST_DEN (nest density), BC_RD_DEN (road density), BC_DIST_RD (distance to roads), ELEV (elevation), LOG_SLP (slope), LOG_DIST_NEST (distance between nests), BC_DIST_PRW (distance to a producing well), FOURTH_PRWD (producing well density), BC_DIST_WELL (distance to the nearest well), FOURTH_WDEN (well density), LOG_IA_DEN (inactive nest density), CUBE_AC_DEN (active nest density). Values ranging from 0.00 to 0.19 represent no correlation to very weak, 0.20 to 0.39 (weak correlation), 0.40 to 0.69 (modest correlation), 0.70 to 0.89 (strong correlation), and 0.90 to 1.00 (very strong correlation) (Fowler et al. 1998).

Variable	BC_DIST_PRW	BC_DIST_RD	BC_DIST_WELL	BC_RD_DEN	CUBE_AC_DEN	ELEV	FOURTH_PRWD	FOURTH_WDEN	LOG_ASPECT	LOG_DIST_NEST	LOG_IA_DEN	LOG_SLP	SQRT_NEST_DEN
BC_DIST_PRW	1.00	0.15	**0.77**	-0.07	-0.08	0.06	**-0.80**	**-0.71**	-0.08	-0.01	0.01	0.14	-0.29
BC_DIST_RD		1.00	0.24	-0.33	0.16	0.08	-0.20	-0.22	-0.14	-0.13	0.16	-0.20	0.07
BC_DIST_WELL			1.00	-0.04	-0.20	0.11	-0.56	-0.55	0.04	0.12	-0.16	-0.05	-0.33
BC_RD_DEN					-0.03	0.17	0.30	0.32	0.03	0.05	0.02	0.04	0.02
CUBE_AC_DEN					1.00	-0.09	-0.03	0.08	-0.17	-0.30	0.33	-0.12	0.48
ELEV						1.00	-0.13	-0.14	0.05	-0.02	0.25	-0.21	0.14
FOURTH_PRWD							1.00	**0.85**	0.03	0.05	0.05	-0.15	0.33
FOURTH_WDEN								1.00	-0.05	-0.11	0.05	-0.20	0.32
LOG_ASPECT									1.00	0.09	-0.08	-0.02	-0.07
LOG_DIST_NEST										1.00	-0.52	0.27	-0.26
LOG_IA_DEN											1.00	-0.17	**0.67**
LOG_SLP												1.00	-0.10
SQRT_NEST_DEN													1.00
BC_DIST_PRW	1.00	0.23	**0.60**	-0.26	-0.13	-0.18	**-0.75**	**-0.63**	-0.04	0.01	-0.07	0.20	-0.25
BC_DIST_RD		1.00	0.27	-0.34	-0.06	-0.12	-0.14	-0.16	-0.01	-0.19	0.28	0.11	0.19
BC_DIST_WELL			1.00	-0.16	-0.19	-0.17	-0.35	-0.43	-0.02	0.02	-0.06	0.11	-0.20
BC_RD_DEN				1.00	0.04	0.16	0.33	0.45	-0.07	0.21	-0.21	0.07	-0.12
CUBE_AC_DEN					1.00	-0.13	0.12	0.14	-0.07	-0.39	0.11	-0.19	0.42
ELEV						1.00	0.01	-0.01	0.19	0.05	0.09	-0.25	0.00
FOURTH_PRWD							1.00	**0.83**	0.05	-0.12	0.15	-0.09	0.31
FOURTH_WDEN								1.00	-0.08	-0.03	-0.01	-0.02	0.18
LOG_ASPECT									1.00	-0.09	0.14	-0.13	0.16
LOG_DIST_NEST										1.00	-0.53	0.05	-0.45
LOG_IA_DEN											1.00	-0.07	**0.81**
LOG_SLP												1.00	-0.11
SQRT_NEST_DEN													1.00

Table 9. The following tables include Spearman correlation values (r_s) for the transformed variable combinations when data for COHA (above) and LEOW (below) were used for correlation analyses. Values highlighted in bold exhibited a modest to high correlation. The following codes apply: LOG_ASPECT (aspect), SQRT_NEST_DEN (nest density), BC_RD_DEN (road density), BC_DIST_RD (distance to roads), ELEV (elevation), LOG_SLP (slope), LOG_DIST_NEST (distance between nests), BC_DIST_PRW (distance to a producing well), FOURTH_PRWD (producing well density), BC_DIST_WELL (distance to the nearest well), FOURTH_WDEN (well density), LOG_IA_DEN (inactive nest density), CUBE_AC_DEN (active nest density). Values ranging from 0.00 to 0.19 represent no correlation to very weak, 0.20 to 0.39 (weak correlation), 0.40 to 0.69 (modest correlation), 0.70 to 0.89 (strong correlation), and 0.90 to 1.00 (very strong correlation) (Fowler et al. 1998).

Variable	BC_DIST_PRW	BC_DIST_RD	BC_DIST_WELL	BC_RD_DEN	CUBE_AC_DEN	ELEV	FOURTH_PRWD	FOURTH_WDEN	LOG_ASPECT	LOG_DIST_NEST	LOG_IA_DEN	LOG_SLP	SQRT_NEST_DEN
BC_DIST_PRW	1.00	0.31	**0.71**	0.01	0.12	0.06	**-0.75**	**-0.66**	0.03	-0.22	0.23	0.17	-0.11
BC_DIST_RD		1.00	0.38	-0.30	0.11	-0.14	-0.34	-0.31	-0.28	-0.09	-0.10	0.08	-0.11
BC_DIST_WELL			1.00	-0.04	-0.09	0.19	-0.45	-0.43	0.14	-0.04	-0.05	-0.18	-0.18
BC_RD_DEN				1.00	-0.07	0.23	0.25	0.25	0.00	0.16	0.22	0.08	0.14
CUBE_AC_DEN					1.00	-0.20	-0.19	-0.09	-0.17	-0.13	0.30	0.13	0.46
ELEV						1.00	-0.12	-0.18	0.13	0.10	0.19	-0.24	-0.07
FOURTH_PRWD							1.00	**0.79**	0.02	0.24	-0.10	-0.13	0.28
FOURTH_WDEN								1.00	-0.04	0.06	-0.14	-0.18	0.26
LOG_ASPECT									1.00	0.01	-0.19	0.03	-0.17
LOG_DIST_NEST										1.00	-0.33	-0.08	-0.02
LOG_IA_DEN											1.00	0.15	0.45
LOG_SLP												1.00	0.14
SQRT_NEST_DEN													1.00
BC_DIST_PRW	1.00	0.33	**0.81**	-0.06	-0.31	0.34	**-0.81**	-0.54	**-0.64**	-0.19	0.05	-0.03	-0.32
BC_DIST_RD		1.00	0.45	-0.40	-0.32	0.12	-0.48	-0.46	-0.39	-0.14	0.12	-0.23	-0.17
BC_DIST_WELL			1.00	0.15	-0.14	0.27	**-0.64**	-0.35	-0.41	-0.17	0.01	-0.02	-0.22
BC_RD_DEN				1.00	0.28	-0.02	0.54	0.47	0.33	-0.14	0.07	0.00	0.23
CUBE_AC_DEN					1.00	-0.45	0.35	0.32	0.23	-0.46	0.21	-0.23	0.44
ELEV						1.00	-0.29	-0.43	-0.18	0.44	0.31	0.10	0.01
FOURTH_PRWD							1.00	**0.72**	0.50	0.07	0.02	-0.10	0.41
FOURTH_WDEN								1.00	0.41	0.09	-0.13	-0.20	0.33
LOG_ASPECT									1.00	0.05	-0.06	-0.02	0.06
LOG_DIST_NEST										1.00	-0.19	0.39	-0.02
LOG_IA_DEN											1.00	-0.33	**0.74**
LOG_SLP												1.00	-0.12
SQRT_NEST_DEN													1.00

Table 10. The following table includes results for the one-way, single factor ANOVA. To complete this analysis, the response variable was compared to factor STATUS_10, which included two levels ("ACTIVE" and "INACTIVE", **Table A**), factor END_11, which included two levels ("FAILED" and "SUCCESSFUL", **Table B**), and factor SPP_11, which included two levels ("COHA" and "LEOW", **Table C**) . We found that "ACTIVE" nests were generally located at lower elevations when compared to "INACTIVE" nests (W = 8862, P = 0.041). We also found that "SUCCESSFUL" nests tended to be located closer to existing road corridors when compared to "FAILED" nests ($F_{1,87}$ = 6.0, P = 0.016). At alpha of .1 or 10%, we found that "SUCCESSFUL" nests were generally located in steeper terrain when compared to "FAILED" nests, which were located in flatter terrain ($F_{1,87}$ = 2.832, P = 0.096). When examining differences among Cooper's hawk and Long-eared owl, we found that occupied Cooper's hawk nests were generally located in areas of low active nest density when compared to Long-eared owl, which were generally nesting in areas where active nest density was high (W = 242, P = 0.045). See Tables 11-14 for a summary of untransformed response variables.

Response Variable	*F*	*W*	*P-value*
BC_DIST_PRW	1.358		0.245
BC_DIST_RD	1.684		0.195
BC_DIST_WELL	1.214		0.272
BC_RD_DEN	0.277		0.599
CUBE_AC_DEN		16921	**2.20E-16**
ELEV		8862	**0.041**
FOURTH_PRWD		10471	0.859
FOURTH_WDEN		10938	0.410
LOG_ASPECT		9875	0.518
LOG_DIST_NEST	1.973		0.161
LOG_IA_DEN		5450	**2.93E-07**
LOG_SLP	0.006		0.936
SQRT_NEST_DEN		9420	0.202

A

Response Variable	*F*	*W*	*P-value*
BC_DIST_PRW	0.362		0.549
BC_DIST_RD	5.999		**0.016**
BC_DIST_WELL	1.354		0.248
BC_RD_DEN	0.350		0.556
CUBE_AC_DEN		1024	0.590
ELEV		945	0.891
FOURTH_PRWD		760	0.092
FOURTH_WDEN		878	0.484
LOG_ASPECT		1049	0.471
LOG_DIST_NEST	2.206		0.141
LOG_IA_DEN		714	0.823
LOG_SLP	2.832		**0.096**
SQRT_NEST_DEN		823	0.249

B

Response Variable	*F*	*W*	*P-value*
BC_DIST_PRW	0.242		0.625
BC_DIST_RD	3.645		0.061
BC_DIST_WELL	0.223		0.639
BC_RD_DEN	1.222		0.274
CUBE_AC_DEN		242	**0.045**
ELEV		403	0.450
FOURTH_PRWD		344	0.834
FOURTH_WDEN		344	0.834
LOG_ASPECT		473	**0.054**
LOG_DIST_NEST	0.123		0.727
LOG_IA_DEN		277	0.402
LOG_SLP	0.026		0.872
SQRT_NEST_DEN		251	0.077

C

Table 11. The following table summarizes the standard deviation (sd), coefficient of variation (cv), sample size (*N*), and non-numerical values in the sample (NA) for each response variable using untransformed data. The grouping factor was STATUS_11 (e.g., ACTIVE and INACTIVE). Distance and elevation measurements are reported in meters, and density estimates are reported in number of units (e.g., nests, producing wells, miles of linear features, etc.) per square mile. Aspect is reported in degrees, and slope is reported in units of percent slope. Data used for this analysis were collected during the 2011 breeding season in northwest Colorado, Picance Basin, Rio Blanco County

Variable:	**AC_DEN**				
	mean	sd	cv	*N*	NA
ACTIVE	3.46	1.25	0.36	105	0
INACTIVE	1.72	1.66	0.96	194	3

Variable:	**ASP**				
	mean	sd	cv	*N*	NA
ACTIVE	177.60	112.32	0.63	105	0
INACTIVE	186.68	119.88	0.64	197	0

Variable:	**DIST_NEAR_NEST**				
	mean	sd	cv	*N*	NA
ACTIVE	383.98	514.38	1.34	105	0
INACTIVE	336.45	610.56	1.81	197	0

Variable:	**DIST_PR_WELL**				
	mean	sd	cv	*N*	NA
ACTIVE	981.48	712.51	0.73	105	0
INACTIVE	1052.47	765.60	0.73	197	0

Variable:	**DIST_RD**				
	mean	sd	cv	*N*	NA
ACTIVE	198.03	168.18	0.85	104	1
INACTIVE	223.69	191.01	0.85	197	0

Variable:	**DIST_WELL**				
	mean	sd	cv	*N*	NA
ACTIVE	600.91	349.99	0.58	105	0
INACTIVE	666.34	460.30	0.69	197	0

Variable:	**ELEV**				
	mean	sd	cv	*N*	NA
ACTIVE	2030.93	85.92	0.04	105	0
INACTIVE	2051.63	72.78	0.04	197	0

Variable:	**IA_DEN**				
	mean	sd	cv	*N*	NA
ACTIVE	2.37	1.87	0.79	104	1
INACTIVE	3.89	1.91	0.49	197	0

Variable:	**NEST_DEN**				
	mean	sd	cv	*N*	NA
ACTIVE	3.32	1.50	0.45	105	0
INACTIVE	3.51	1.49	0.42	197	0

Variable:	**NF_11**				
	mean	sd	cv	*N*	NA
ACTIVE	1.36	1.37	1.01	88	17
INACTIVE	NaN	NA	NA	0	197

Variable:	**PRW_DEN**				
	mean	sd	cv	*N*	NA
ACTIVE	2.46	4.31	1.76	105	0
INACTIVE	2.81	5.36	1.91	197	0

Variable:	**RD_DEN**				
	mean	sd	cv	*N*	NA
ACTIVE	2.40	0.85	0.35	105	0
INACTIVE	2.35	0.85	0.36	197	0

Variable:	**SLOPE**				
	mean	sd	cv	*N*	NA
ACTIVE	21.76	21.74	1.00	105	0
INACTIVE	19.37	14.36	0.74	197	0

Variable:	**WDEN**				
	mean	sd	cv	*N*	NA
ACTIVE	6.42	7.53	1.17	105	0
INACTIVE	6.06	7.88	1.30	197	0

Table 12. The following table summarizes the standard deviation (sd), coefficient of variation (cv), sample size (*N*), and non-numerical values in the sample (NA) for each response variable using untransformed data. The grouping factor was END_11 (e.g., FAILED and SUCCESSFUL). Distance and elevation measurements are reported in meters, and density estimates are reported in number of units (e.g., nests, producing wells, miles of linear features, etc.) per square mile. Aspect is reported in degrees, and slope is reported in units of percent slope.

Variable: **AC_DEN**

	mean	sd	cv	*N*	NA
FAILED	3.64	1.30	0.36	37	0
SUCCESSFUL	3.45	1.29	0.37	52	0

Variable: **ASP**

	mean	sd	cv	*N*	NA
FAILED	190.81	122.13	0.64	37	0
SUCCESSFUL	170.17	107.18	0.63	52	0

Variable: **DIST_NEAR_NEST**

	mean	sd	cv	*N*	NA
FAILED	274.16	352.12	1.28	37	0
SUCCESSFUL	420.16	595.19	1.42	52	0

Variable: **DIST_PR_WELL**

	mean	sd	cv	*N*	NA
FAILED	1030.76	636.88	0.62	37	0
SUCCESSFUL	974.94	803.81	0.82	52	0

Variable: **DIST_RD**

	mean	sd	cv	*N*	NA
FAILED	255.38	216.87	0.85	36	1
SUCCESSFUL	158.29	126.26	0.80	52	0

Variable: **DIST_WELL**

	mean	sd	cv	*N*	NA
FAILED	650.48	373.41	0.57	37	0
SUCCESSFUL	551.28	331.07	0.60	52	0

Variable: **ELEV**

	mean	sd	cv	*N*	NA
FAILED	2035.41	73.31	0.04	37	0
SUCCESSFUL	2034.22	93.31	0.05	52	0

Variable: **IA_DEN**

	mean	sd	cv	*N*	NA
FAILED	2.39	1.92	0.80	37	0
SUCCESSFUL	2.43	1.81	0.74	52	0

Variable: **NEST_DEN**

	mean	sd	cv	*N*	NA
FAILED	3.16	1.27	0.40	37	0
SUCCESSFUL	3.49	1.55	0.45	52	0

Variable: **NF_11**

	mean	sd	cv	*N*	NA
FAILED	0.00	0.00	NA	37	0
SUCCESSFUL	2.35	0.96	0.41	51	1

Variable: **PRW_DEN**

	mean	sd	cv	*N*	NA
FAILED	2.43	5.84	2.40	37	0
SUCCESSFUL	2.27	2.63	1.16	52	0

Variable: **RD_DEN**

	mean	sd	cv	*N*	NA
FAILED	2.34	0.92	0.40	37	0
SUCCESSFUL	2.43	0.81	0.33	52	0

Variable: **SLOPE**

	mean	sd	cv	*N*	NA
FAILED	15.82	12.51	0.79	37	0
SUCCESSFUL	23.29	22.54	0.97	52	0

Variable: **WDEN**

	mean	sd	cv	*N*	NA
FAILED	5.67	8.01	1.41	37	0
SUCCESSFUL	6.43	6.75	1.05	52	0

Table 13. The following table summarizes the standard deviation (sd), coefficient of variation (cv), sample size (*N*), and non-numerical values in the sample (NA) for each response variable using untransformed data Cooper's hawk and Long-eared owl. The grouping factor was SPP_11 (e.g., COHA and LEOW). Distance and elevation measurements are reported in meters, and density estimates are reported in number of units (e.g., nests, producing wells, miles of linear features, etc.) per square mile. Aspect is reported in degrees, and slope is reported in units of percent slope. Data used for this analysis were collected during the 2011 breeding season in northwest Colorado, Picance Basin, Rio Blanco County

Variable: **AC_DEN**

	mean	sd	cv	*N*	NA
COHA	3.49	1.27	0.36	42	0.00
LEOW	4.23	1.35	0.32	17	0.00

Variable: **ASP**

	mean	sd	cv	*N*	NA
COHA	187.16	118.78	0.63	42	0.00
LEOW	118.92	112.99	0.95	17	0.00

Variable: **DIST_NEAR_NEST**

	mean	sd	cv	*N*	NA
COHA	225.23	303.19	1.35	42	0.00
LEOW	157.17	132.25	0.84	17	0.00

Variable: **DIST_PR_WELL**

	mean	sd	cv	*N*	NA
COHA	966.39	692.17	0.72	42	0.00
LEOW	794.25	491.85	0.62	17	0.00

Variable: **DIST_RD**

	mean	sd	cv	*N*	NA
COHA	187.31	154.77	0.83	41	1.00
LEOW	249.04	138.15	0.55	17	0.00

Variable: **DIST_WELL**

	mean	sd	cv	*N*	NA
COHA	609.07	369.01	0.61	42	0.00
LEOW	518.09	250.73	0.48	17	0.00

Variable: **ELEV**

	mean	sd	cv	*N*	NA
COHA	2053.27	71.02	0.03	42	0.00
LEOW	2034.57	51.21	0.03	17	0.00

Variable: **IA_DEN**

	mean	sd	cv	*N*	NA
COHA	2.39	1.61	0.67	42	0.00
LEOW	3.07	1.54	0.50	17	0.00

Variable: **NEST_DEN**

	mean	sd	cv	*N*	NA
COHA	3.29	1.16	0.35	42	0.00
LEOW	4.03	1.40	0.35	17	0.00

Variable: **PRW_DEN**

	mean	sd	cv	*N*	NA
COHA	2.12	3.99	1.88	42	0.00
LEOW	1.66	1.85	1.11	17	0.00

Variable: **RD_DEN**

	mean	sd	cv	*N*	NA
COHA	2.47	0.83	0.34	42	0.00
LEOW	2.20	0.67	0.31	17	0.00

Variable: **SLOPE**

	mean	sd	cv	*N*	NA
COHA	14.09	7.77	0.55	42	0.00
LEOW	13.68	7.83	0.57	17	0.00

Variable: **WDEN**

	mean	sd	cv	*N*	NA
COHA	6.46	7.74	1.20	42	0.00
LEOW	6.36	6.35	1.00	17	0.00

Table 14. The following table summarizes the standard deviation (sd), coefficient of variation (cv), sample size (*N*), and non-numerical values in the sample (NA) for each response variable using untransformed data. The grouping factor was SPP_11. Distance and elevation measurements are reported in meters, and density estimates are reported in number of units (e.g., nests, producing wells, miles of linear features, etc.) per square mile. Aspect is reported in degrees, and slope is reported in units of percent slope. Data used for this analysis were collected during the 2011 breeding season in northwest Colorado, Picance Basin, Rio Blanco County.

Variable: **AC_DEN**

	mean	sd	cv	*N*	NA
AMKE	2.47	NA	NA	1	0
BAEA	2.47	NA	NA	1	0
COHA	3.49	1.27	0.36	42	0
CORA	3.81	1.41	0.37	18	0
GHOW	3.13	NA	NA	1	0
GOEA	2.55	0.14	0.06	4	0
LEOW	4.23	1.35	0.32	17	0
NOGH	3.13	0.73	0.23	3	0
OSPR	2.47	NA	NA	1	0
PRFA	2.48	0.00	0.00	2	0
RTHA	2.72	0.45	0.16	13	0

Variable: **ASP**

	mean	sd	cv	*N*	NA
AMKE	130.09	NA	NA	1	0
BAEA	321.77	NA	NA	1	0
COHA	187.16	118.78	0.63	42	0
CORA	167.34	115.65	0.69	18	0
GHOW	154.37	NA	NA	1	0
GOEA	184.19	93.14	0.51	4	0
LEOW	118.92	112.99	0.95	17	0
NOGH	314.91	22.70	0.07	3	0
OSPR	223.99	NA	NA	1	0
PRFA	197.45	74.17	0.38	2	0
RTHA	167.54	76.65	0.46	13	0

Variable: **DIST_NEAR_NEST**

	mean	sd	cv	*N*	NA
AMKE	1185.28	NA	NA	1	0
BAEA	492.37	NA	NA	1	0
COHA	225.23	303.19	1.35	42	0
CORA	393.07	543.39	1.38	18	0
GHOW	777.82	NA	NA	1	0
GOEA	1341.11	714.64	0.53	4	0
LEOW	157.17	132.25	0.84	17	0
NOGH	106.73	61.15	0.57	3	0
OSPR	2424.71	NA	NA	1	0
PRFA	544.44	559.69	1.03	2	0
RTHA	677.28	611.60	0.90	13	0

Variable: **DIST_PR_WELL**

	mean	sd	cv	*N*	NA
AMKE	1488.89	NA	NA	1	0
BAEA	2555.61	NA	NA	1	0
COHA	966.39	692.17	0.72	42	0
CORA	934.42	637.32	0.68	18	0
GHOW	900.60	NA	NA	1	0
GOEA	1510.40	1300.06	0.86	4	0
LEOW	794.25	491.85	0.62	17	0
NOGH	1482.88	1071.19	0.72	3	0
OSPR	619.70	NA	NA	1	0
PRFA	2361.74	209.06	0.09	2	0
RTHA	788.19	634.14	0.80	13	0

Variable: **DIST_RD**

	mean	sd	cv	*N*	NA
AMKE	147.36	NA	NA	1	0
BAEA	319.69	NA	NA	1	0
COHA	187.31	154.77	0.83	41	1
CORA	209.24	158.44	0.76	18	0
GHOW	29.36	NA	NA	1	0
GOEA	188.25	46.87	0.25	4	0
LEOW	249.04	138.15	0.55	17	0
NOGH	164.96	141.64	0.86	3	0
OSPR	0.39	NA	NA	1	0
PRFA	89.07	119.73	1.34	2	0
RTHA	131.28	117.55	0.90	13	0

Variable: **DIST_WELL**

	mean	sd	cv	*N*	NA
AMKE	609.85	NA	NA	1	0
BAEA	1341.07	NA	NA	1	0
COHA	609.07	369.01	0.61	42	0
CORA	597.55	367.29	0.61	18	0
GHOW	607.97	NA	NA	1	0
GOEA	561.95	221.58	0.39	4	0
LEOW	518.09	250.73	0.48	17	0
NOGH	781.98	553.56	0.71	3	0
OSPR	33.62	NA	NA	1	0
PRFA	927.45	31.49	0.03	2	0
RTHA	599.19	374.46	0.62	13	0

Variable: **ELEV**

	mean	sd	cv	*N*	NA
AMKE	1747.35	NA	NA	1	0
BAEA	1985.71	NA	NA	1	0
COHA	2053.27	71.02	0.03	42	0
CORA	2030.96	62.40	0.03	18	0
GHOW	2051.47	NA	NA	1	0
GOEA	1976.12	49.57	0.03	4	0
LEOW	2034.57	51.21	0.03	17	0
NOGH	2037.73	62.83	0.03	3	0
OSPR	1763.47	NA	NA	1	0
PRFA	2150.91	143.54	0.07	2	0
RTHA	1988.88	120.47	0.06	13	0

Variable: **IA_DEN**

	mean	sd	cv	*N*	NA
AMKE	NaN	NA	NA	0	1
BAEA	1.95	NA	NA	1	0
COHA	2.39	1.61	0.67	42	0
CORA	2.81	2.22	0.79	18	0
GHOW	0.72	NA	NA	1	0
GOEA	0.41	0.65	1.59	4	0
LEOW	3.07	1.54	0.50	17	0
NOGH	6.01	2.33	0.39	3	0
OSPR	0.00	NA	NA	1	0
PRFA	0.90	0.82	0.91	2	0
RTHA	1.05	0.94	0.90	13	0

Variable: **NEST_DEN**

	mean	sd	cv	*N*	NA
AMKE	1.00	NA	NA	1	0
BAEA	2.08	NA	NA	1	0
COHA	3.29	1.16	0.35	42	0
CORA	3.70	1.70	0.46	18	0
GHOW	3.24	NA	NA	1	0
GOEA	1.31	0.69	0.53	4	0
LEOW	4.03	1.40	0.35	17	0
NOGH	5.42	1.22	0.23	3	0
OSPR	0.75	NA	NA	1	0
PRFA	1.51	0.03	0.02	2	0
RTHA	2.71	1.42	0.52	13	0

Table 14. Continued.

Variable: **NF_11**

	mean	sd	cv	*N*	NA
AMKE	NaN	NA	NA	0	1
BAEA	0.00	NA	NA	1	0
COHA	1.26	1.47	1.16	42	0
CORA	1.50	1.65	1.10	10	8
GHOW	NaN	NA	NA	0	1
GOEA	0.50	0.58	1.15	4	0
LEOW	1.64	1.34	0.81	14	3
NOGH	1.33	0.58	0.43	3	0
OSPR	2.00	NA	NA	1	0
PRFA	1.50	0.71	0.47	2	0
RTHA	2.00	1.22	0.61	9	4

Variable: **PRW_DEN**

	mean	sd	cv	*N*	NA
AMKE	0.08	NA	NA	1	0
BAEA	0.00	NA	NA	1	0
COHA	2.12	3.99	1.88	42	0
CORA	2.50	4.32	1.73	18	0
GHOW	0.50	NA	NA	1	0
GOEA	2.62	4.88	1.86	4	0
LEOW	1.66	1.85	1.11	17	0
NOGH	0.33	0.29	0.87	3	0
OSPR	1.43	NA	NA	1	0
PRFA	0.00	0.00	NA	2	0
RTHA	4.27	3.72	0.87	13	0

Variable: **RD_DEN**

	mean	sd	cv	*N*	NA
AMKE	3.77	NA	NA	1	0
BAEA	3.09	NA	NA	1	0
COHA	2.47	0.83	0.34	42	0
CORA	2.13	0.73	0.34	18	0
GHOW	3.74	NA	NA	1	0
GOEA	2.69	0.74	0.28	4	0
LEOW	2.20	0.67	0.31	17	0
NOGH	2.01	0.64	0.32	3	0
OSPR	4.76	NA	NA	1	0
PRFA	2.09	1.22	0.58	2	0
RTHA	2.53	0.95	0.37	13	0

Variable: **SLOPE**

	mean	sd	cv	*N*	NA
AMKE	77.50	NA	NA	1	0
BAEA	28.47	NA	NA	1	0
COHA	14.09	7.77	0.55	42	0
CORA	15.23	11.12	0.73	18	0
GHOW	75.57	NA	NA	1	0
GOEA	39.44	22.52	0.57	4	0
LEOW	13.68	7.83	0.57	17	0
NOGH	20.05	5.20	0.26	3	0
OSPR	2.32	NA	NA	1	0
PRFA	83.71	66.48	0.79	2	0
RTHA	45.85	28.98	0.63	13	0

Variable: **WDEN**

	mean	sd	cv	*N*	NA
AMKE	2.90	NA	NA	1	0
BAEA	0.18	NA	NA	1	0
COHA	6.46	7.74	1.20	42	0
CORA	5.84	6.69	1.15	18	0
GHOW	1.91	NA	NA	1	0
GOEA	4.69	7.44	1.59	4	0
LEOW	6.36	6.35	1.00	17	0
NOGH	0.85	0.64	0.75	3	0
OSPR	3.97	NA	NA	1	0
PRFA	0.61	0.30	0.50	2	0
RTHA	9.77	8.78	0.90	13	0

Table 15. The table below summarizes the standard deviation (sd), coefficient of variation (cv), sample size (*N*), and non-numerical values in the sample (NA) for response variables using untransformed data. The grouping factor was NF_11, which represented the number of young that fledged per nest (e.g., 0 to 4). Zero values indicate failed nests. Distance measurements are reported in meters, and density estimates are reported in number of units (e.g., nests, producing wells, miles of linear features, etc.) per square mile. Data used for this analysis were collected during the 2011 breeding season in northwest Colorado, Picance Basin, Rio Blanco County.

Variable: **AC_DEN**

	mean	sd	cv	*N*	NA
0	3.37	1.12	0.33	22	0
1	4.39	0.58	0.13	2	0
2	3.33	1.28	0.38	6	0
3	3.18	1.09	0.34	9	0
4	4.99	2.43	0.49	3	0

Variable: **DIST_NEAR_NEST**

	mean	sd	cv	*N*	NA
0	196.92	249.88	1.27	22	0
1	327.99	210.79	0.64	2	0
2	497.96	569.07	1.14	6	0
3	123.29	146.04	1.18	9	0
4	124.76	85.47	0.69	3	0

Variable: **DIST_PR_WELL**

	mean	sd	cv	*N*	NA
0	1013.09	548.09	0.54	22	0
1	579.37	27.61	0.05	2	0
2	803.91	715.00	0.89	6	0
3	1068.91	1075.56	1.01	9	0
4	899.37	674.19	0.75	3	0

Variable: **DIST_RD**

	mean	sd	cv	*N*	NA
0	241.87	188.52	0.78	21	1
1	84.34	29.66	0.35	2	0
2	153.98	118.22	0.77	6	0
3	116.86	54.76	0.47	9	0
4	152.11	82.99	0.55	3	0

Variable: **DIST_WELL**

	mean	sd	cv	n	NA
0	692.01	384.94	0.56	22	0
1	373.55	318.69	0.85	2	0
2	642.89	459.83	0.72	6	0
3	457.13	268.00	0.59	9	0
4	546.09	352.68	0.65	3	0

Variable: **IA_DEN**

	mean	sd	cv	*N*	NA
0	2.39	1.91	0.80	22	0
1	1.55	2.18	1.41	2	0
2	1.57	1.05	0.67	6	0
3	3.03	0.96	0.32	9	0
4	2.71	1.24	0.46	3	0

Variable: **NEST_DEN**

	mean	sd	cv	*N*	NA
0	3.13	1.19	0.38	22	0
1	3.47	1.68	0.48	2	0
2	3.69	1.69	0.46	6	0
3	3.33	0.70	0.21	9	0
4	3.44	1.18	0.34	3	0

Variable: **PRW_DEN**

	mean	sd	cv	n	NA
0	1.99	5.07	2.55	22	0
1	3.29	0.59	0.18	2	0
2	3.08	3.41	1.11	6	0
3	2.04	2.21	1.08	9	0
4	0.60	0.51	0.84	3	0

Variable: **RD_DEN**

	mean	sd	cv	*N*	NA
0	2.41	0.93	0.38	22	0
1	3.02	0.35	0.12	2	0
2	2.21	0.73	0.33	6	0
3	2.80	0.70	0.25	9	0
4	2.06	0.67	0.33	3	0

Variable: **WDEN**

	mean	sd	cv	*N*	NA
0	5.97	8.26	1.38	22	0
1	15.93	11.67	0.73	2	0
2	7.26	5.64	0.78	6	0
3	6.56	7.66	1.17	9	0
4	1.86	1.24	0.67	3	0

Figure 1. The figure above illustrates the geographic extent of the project area (symbolized as a red box) where raptor nest occupancy and productivity information was collected during the 2011 breeding season in Piceance Basin, Rio Blanco County, Colorado.

Figure 2. The image above shows a typical Cooper's hawk nest tree, nest structure, and nest stand in the study area. These photos were taken while visiting known nest structures to assess breeding season occupancy and productivity information.

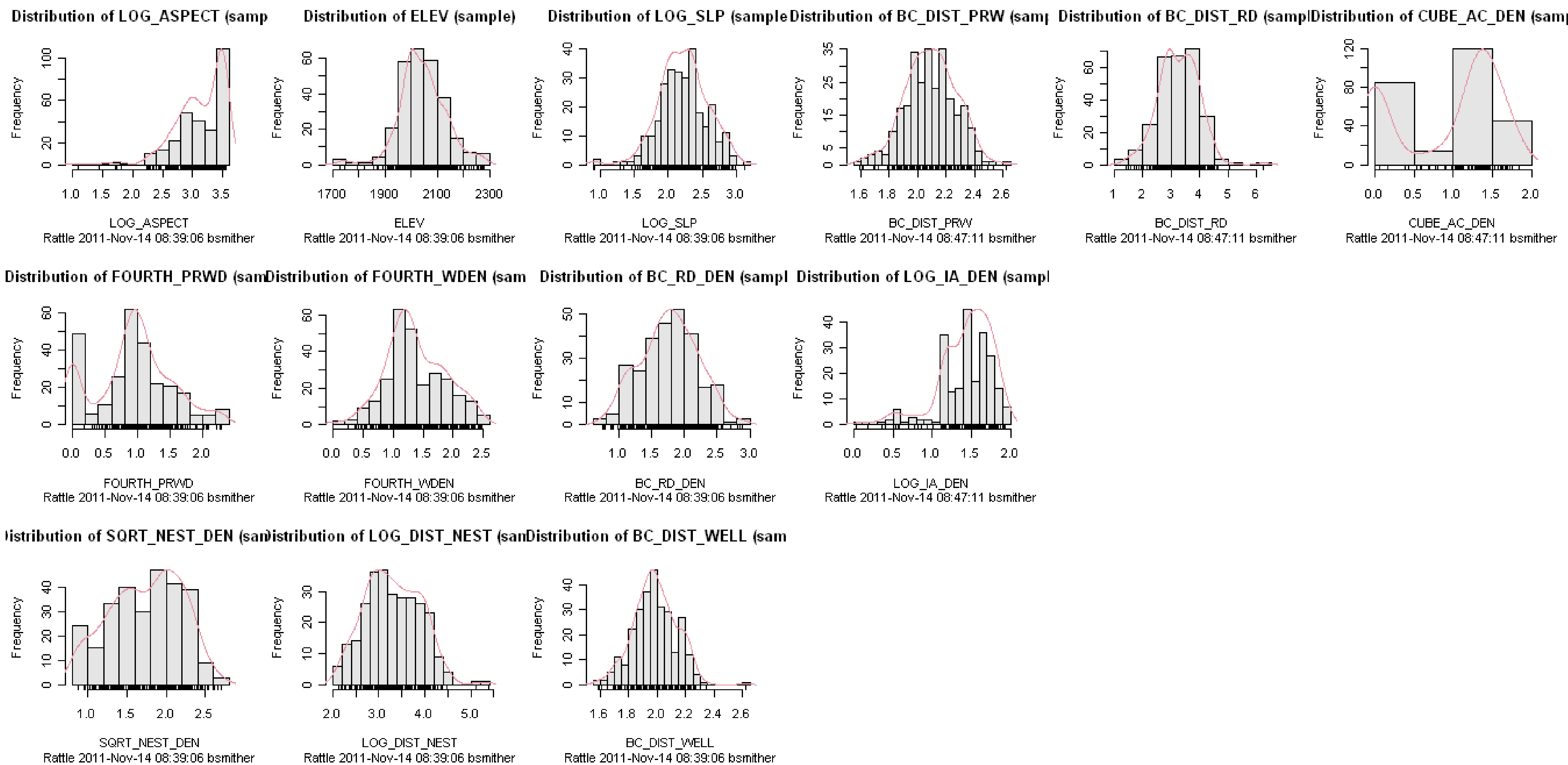


Figure 3. The figure above shows the frequency distributions of the transformed data for each response variable.

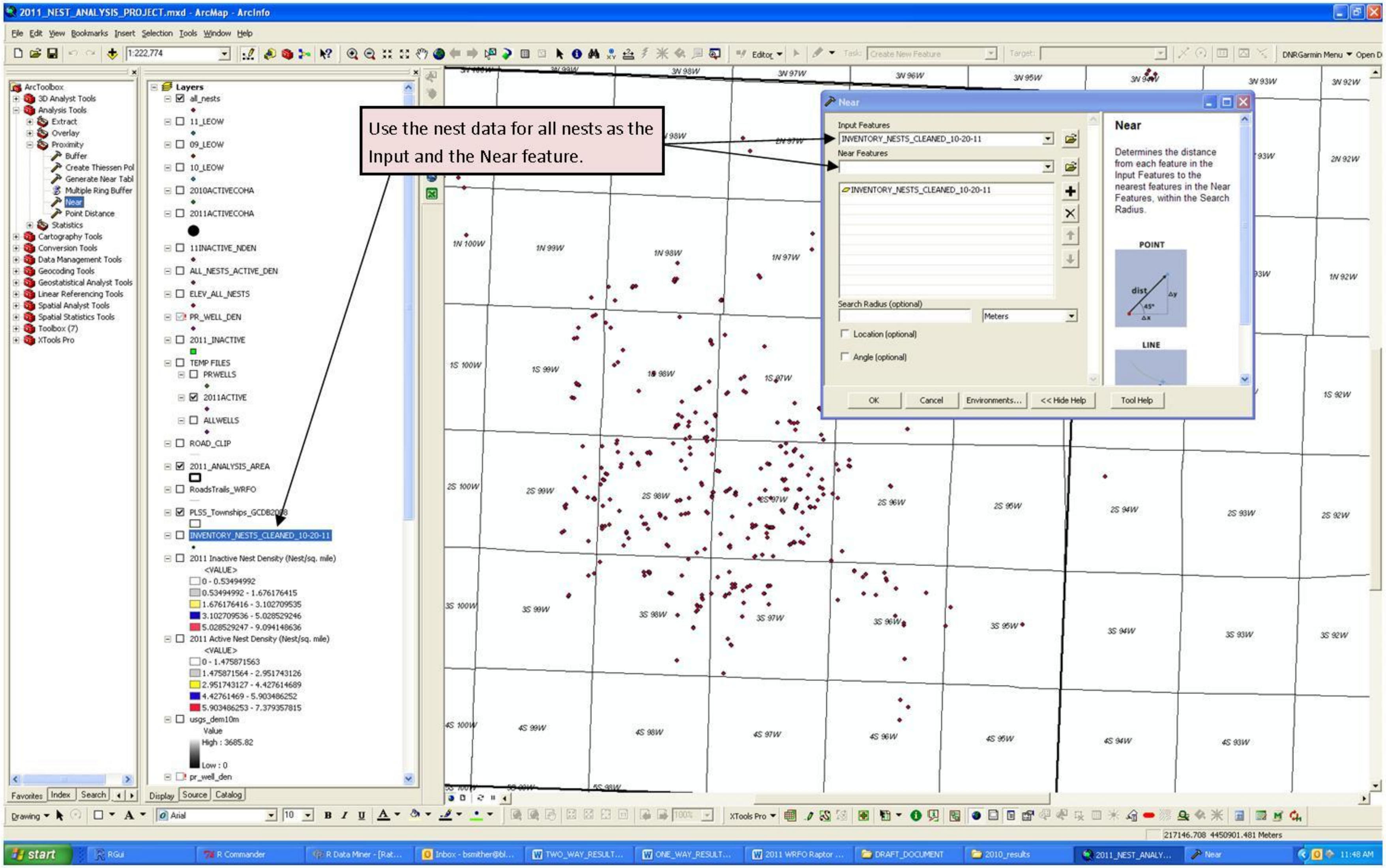


Figure 4. The figure above illustrates both the tool (e.g., near tool) and the input and near feature data that was used to calculate distance (in meters) from all known nests to the nearest nest. This tool was also used to derive distance estimates between occupied Cooper's hawk and Long-eared owl nests.

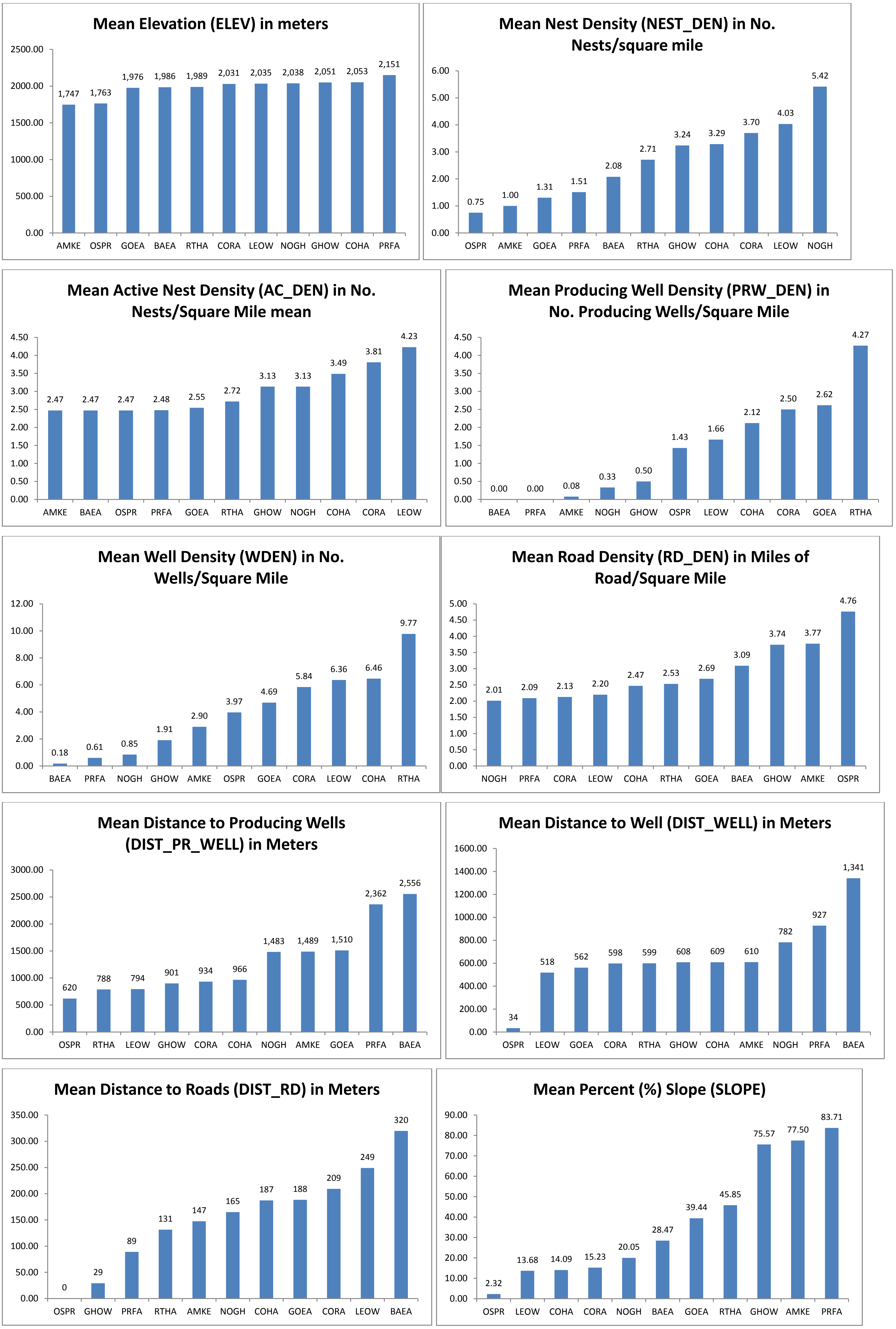


Figure 5. The figure above illustrates response variable values grouped by species and sorted in ascending order from left to right. We noted that there tended to be three clusters of species that exhibited similar distance values when examining distance from known nest structures to the nearest producing natural gas well. These groups were represented by Group 1 (PRFA and BAEA), Group 2 (NOGH, AMKE, GOEA), and Group 3 (OSPR, RTHA, LEOW, GHOW, CORA, COHA). We also noted that occupied RTHA nests were located in areas that exhibited the highest producing natural gas well and known well location density values of all species. In addition, occupied NOGH nests exhibited the highest known nest density values and the lowest road density values in the project area.

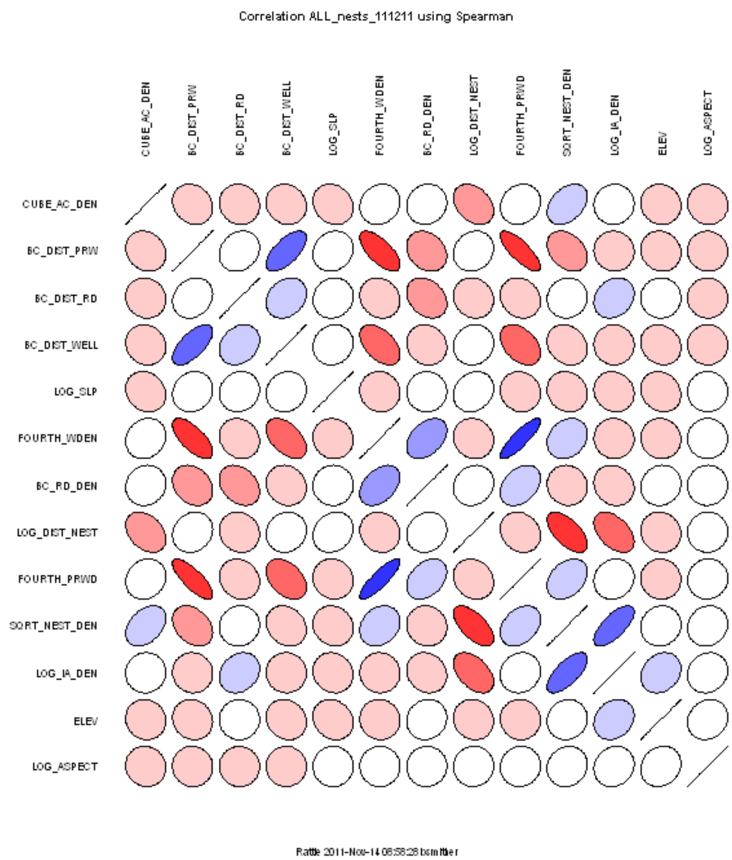


Figure 6. The above figure illustrates the degree of correlation between the response variables for all nests. The data used in this analysis were transformed. Moreover, because the data did not follow a normal frequency distribution, the Spearman correlation method was used. Stronger correlations are represented by darker colors and flatter circles.

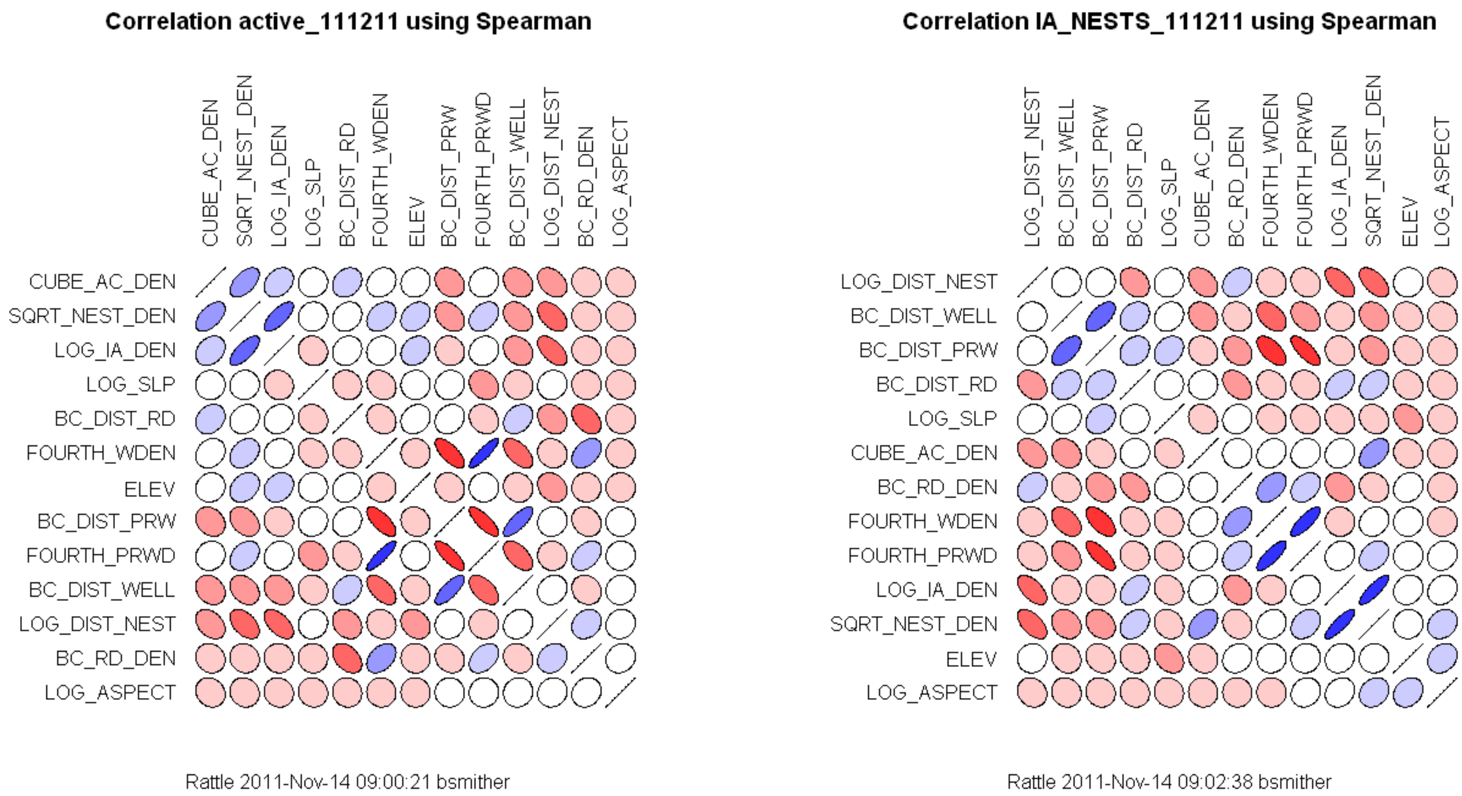
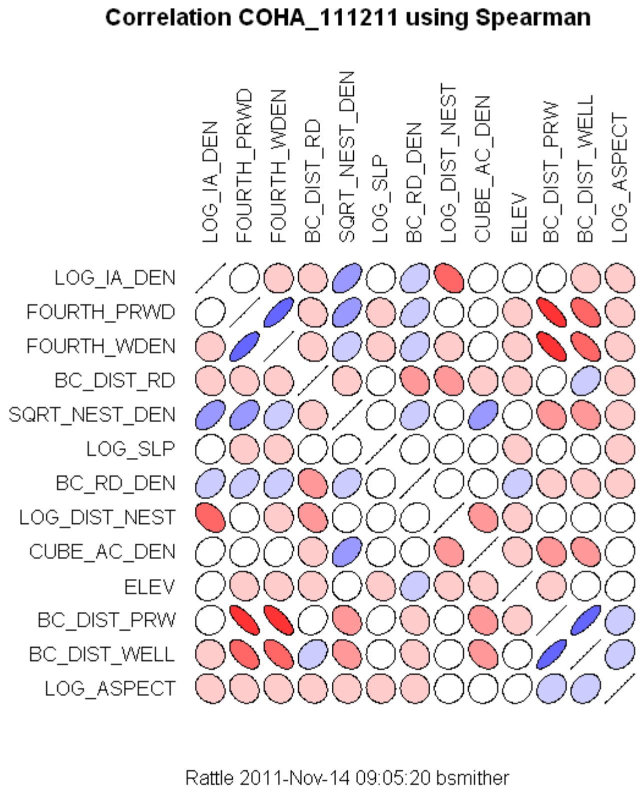


Figure 7. The above figure illustrates the degree of correlation between response variables when *active* (left) and *inactive* nests (right) were used for correlation analyses. The data used in this analysis were transformed. Moreover, because the data did not follow a normal frequency distribution, the Spearman correlation method was used. Stronger correlations are represented by darker colors and flatter circles.



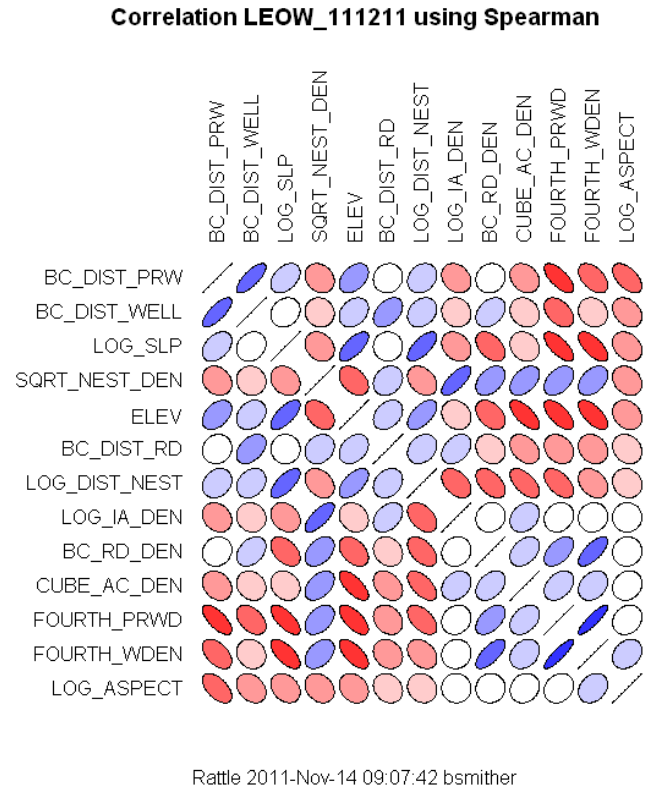


Figure 8. The above figure illustrates the degree of correlation between the response variables when *Cooper's hawk* (left) and *Long-eared owl* nests (right) were used for correlation analyses. The data used in this analysis were transformed. Moreover, because the data did not follow a normal frequency distribution, the Spearman correlation method was used. Stronger correlations are represented by darker colors and flatter circles.

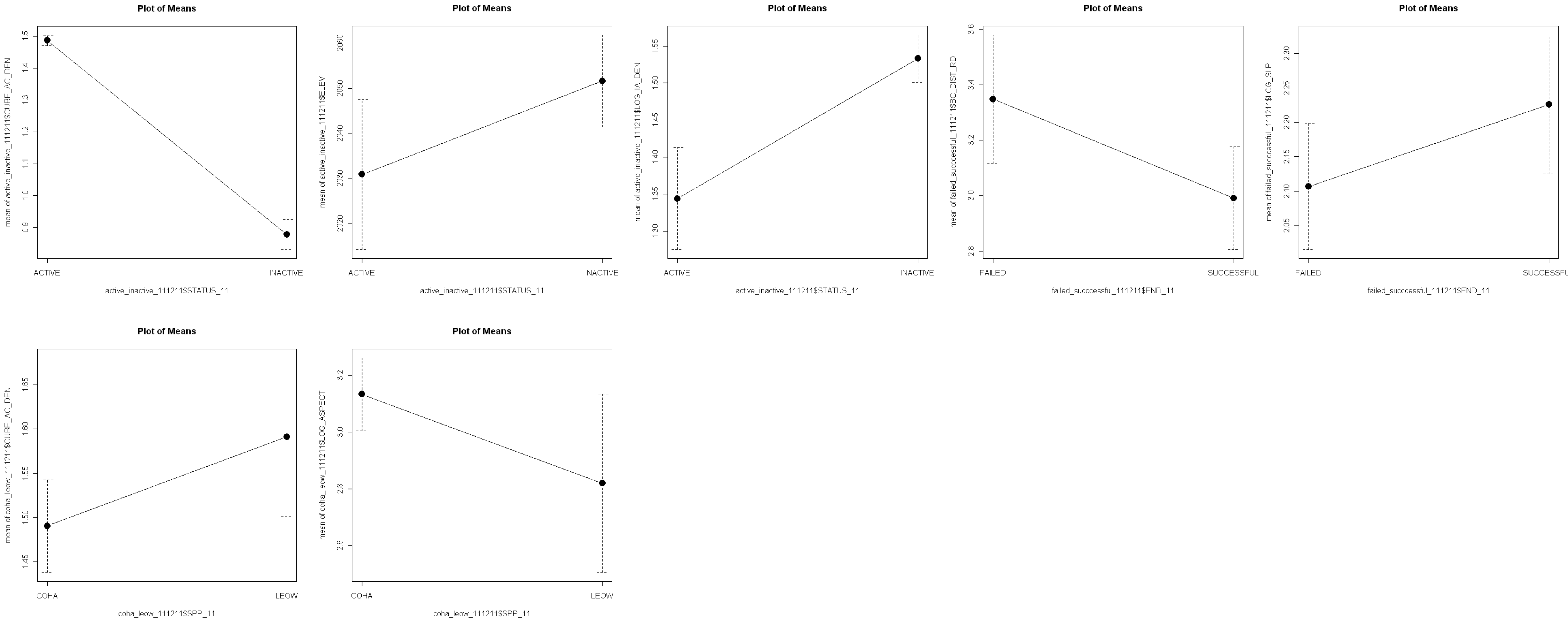


Figure 9. The graphs above illustrate response variables that exhibited statistically significant differences in mean (or median) values using either single-factor, one-way ANOVA or a two-sample, non-parametric Wilcoxian Rank Sum test (*W*). The top graphs show plots of statistically significant relationships between response variables CUBE_AC_DEN (active nest density), ELEV (elevation), and LOG_IA_DEN (inactive nest density) when using STATUS_11 (e.g., ACTIVE, INACTIVE) as the predictor variable, and variables BC_DIST_RD (distance to road), and LOG_SLP (slope) when using END_11 (e.g., FAILED, SUCCESSFUL) as the predictor variable. The bottom graphs show plots of statistically significant relationships between response variables CUBE_AC_DEN (active nest density), and LOG_ASPECT (aspect) when using SPP_11 (e.g., COHA, LEOW) as the predictor variable. For a list of applicable *P*-value scores, see Table 10, and for a descriptive summary of untransformed data, see Tables 11, 12, and 13. Error bars represent 95% confidence intervals.

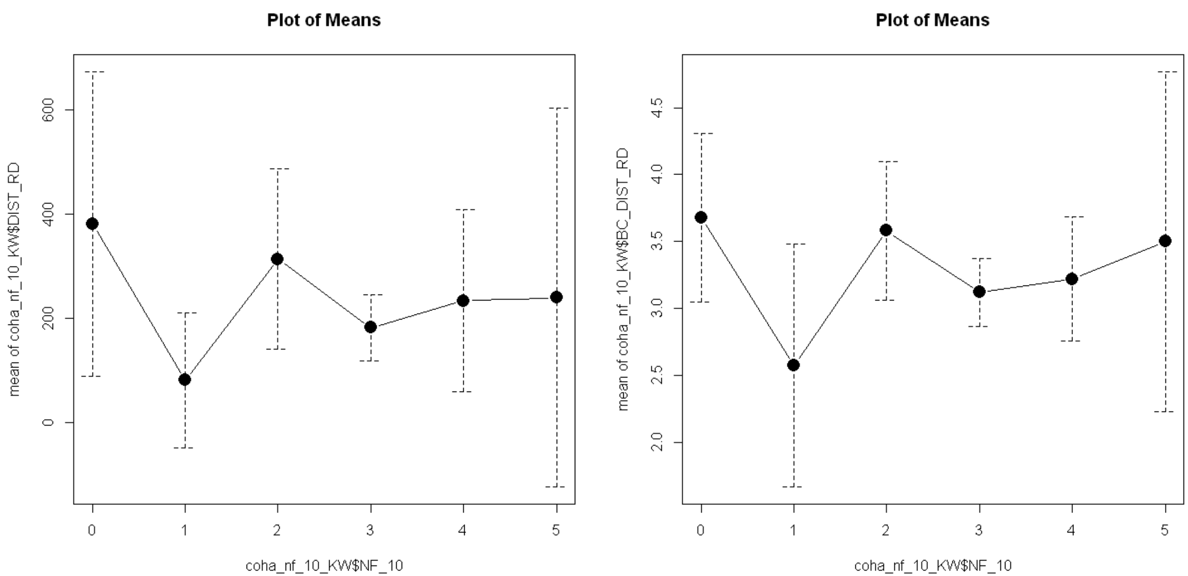
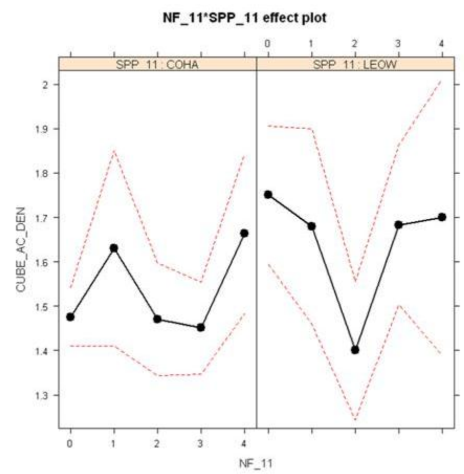
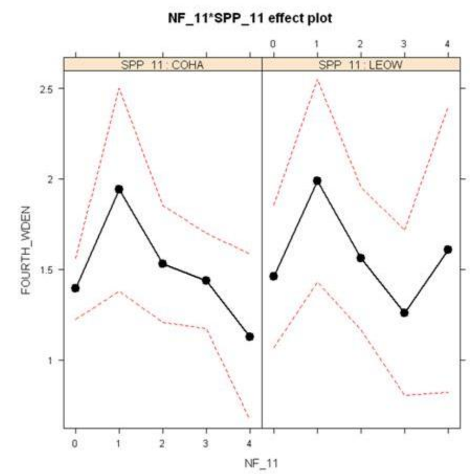


Figure 10. The graphs above show the mean values for distance to linear features (e.g., roads, trails, pipelines, fencelines, transmission lines, etc.) and the number of young that fledged from occupied Cooper's hawk nests durring the 2010 breeding season. Untransformed data were used to generate the graph on the left, while transformed data were used to generate the graph on the right. Fledging rate data for failed nests are represented as a "0". We documented a significant difference in mean values among nests that fledged 1,2,3,4,5, or 0 fledglings and distance from these nests to the nearest linear feature ($F_{5,51} = 2.27$, $\alpha = 0.1$, $P = 0.06$), and these findings were confirmed using non-parametric test procedures ($K_{5,51} = 10.68$, $\alpha = 0.1$, $P = 0.058$). Error bars are 95% confidence intervals.



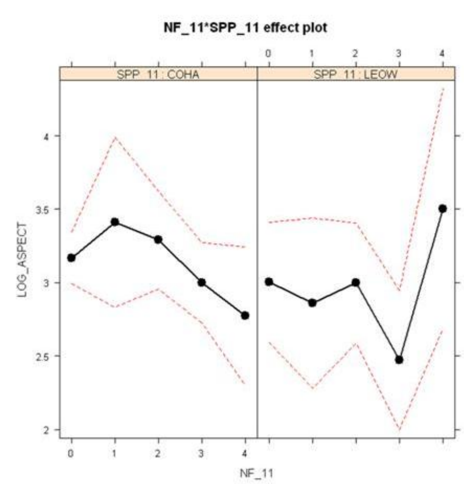

```
> Anova(AnovaModel.5)
Anova Table (Type II tests)

Response: CUBE_AC_DEN
          Sum Sq Df F value  Pr(>F)
NF_11       0.23454  4  2.4512 0.059222 .
SPP_11      0.18895  1  7.8988 0.007243 **
NF_11:SPP_11 0.20193  4  2.1104 0.094750 .
Residuals   1.10035 46
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```



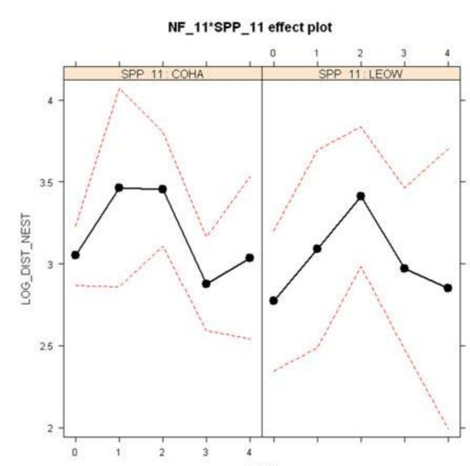

```
> Anova(AnovaModel.8)
Anova Table (Type II tests)

Response: FOURTH_WDEN
          Sum Sq Df F value  Pr(>F)
NF_11       1.3000  4  2.1064 0.09528 .
SPP_11      0.0105  1  0.0679 0.79564
NF_11:SPP_11 0.2557  4  0.4143 0.79747
Residuals   7.0977 46
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```



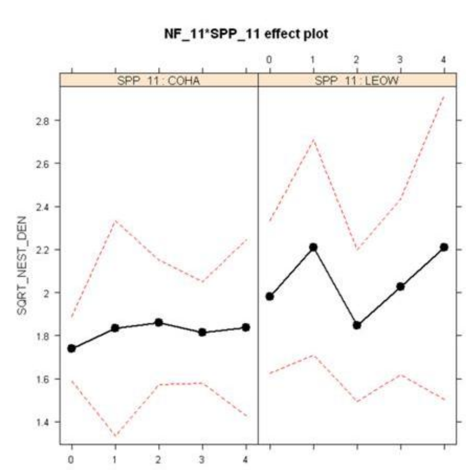

```
> Anova(AnovaModel.9)
Anova Table (Type II tests)

Response: LOG_ASPECT
          Sum Sq Df F value  Pr(>F)
NF_11       0.8551  4  1.2929 0.28675
SPP_11      0.6161  1  3.7262 0.05974 .
NF_11:SPP_11 1.0074  4  1.5232 0.21115
Residuals   7.6059 46
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```




```
> Anova(AnovaModel.10)
Anova Table (Type II tests)

Response: LOG_DIST_NEST
          Sum Sq Df F value  Pr(>F)
NF_11       2.1590  4  2.9928 0.02813 *
SPP_11      0.1900  1  1.0533 0.31012
NF_11:SPP_11 0.2644  4  0.3665 0.83125
Residuals   8.2961 46
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```




```
> Anova(AnovaModel.13)
Anova Table (Type II tests)

Response: SQRT_NEST_DEN
          Sum Sq Df F value  Pr(>F)
NF_11       0.1616  4  0.3276 0.85799
SPP_11      0.3722  1  3.0188 0.08899 .
NF_11:SPP_11 0.1687  4  0.3421 0.84814
Residuals   5.6712 46
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 11. The graphs above illustrate two-way factorial ANOVA results when comparing response variables among occupied nests for NF_11 (mean number of young that fledged per successful nest), SPP_11 (COHA, LEOW) and the interaction term (NF_11:SPP_11). Using an alpha of 0.1, we noted that aspect (LOG_ASPECT) and nest density (SQRT_NEST_DEN) values differed among Cooper's hawk and Long-eared owl. We also documented a statistical difference among response variable means for FOURTH_WDEN (well density) when using an alpha of 0.1, and LOG_DIST_NEST (distance to the nearest nest), using an alpha of 0.05, among Cooper's hawk and Long-eared owl.

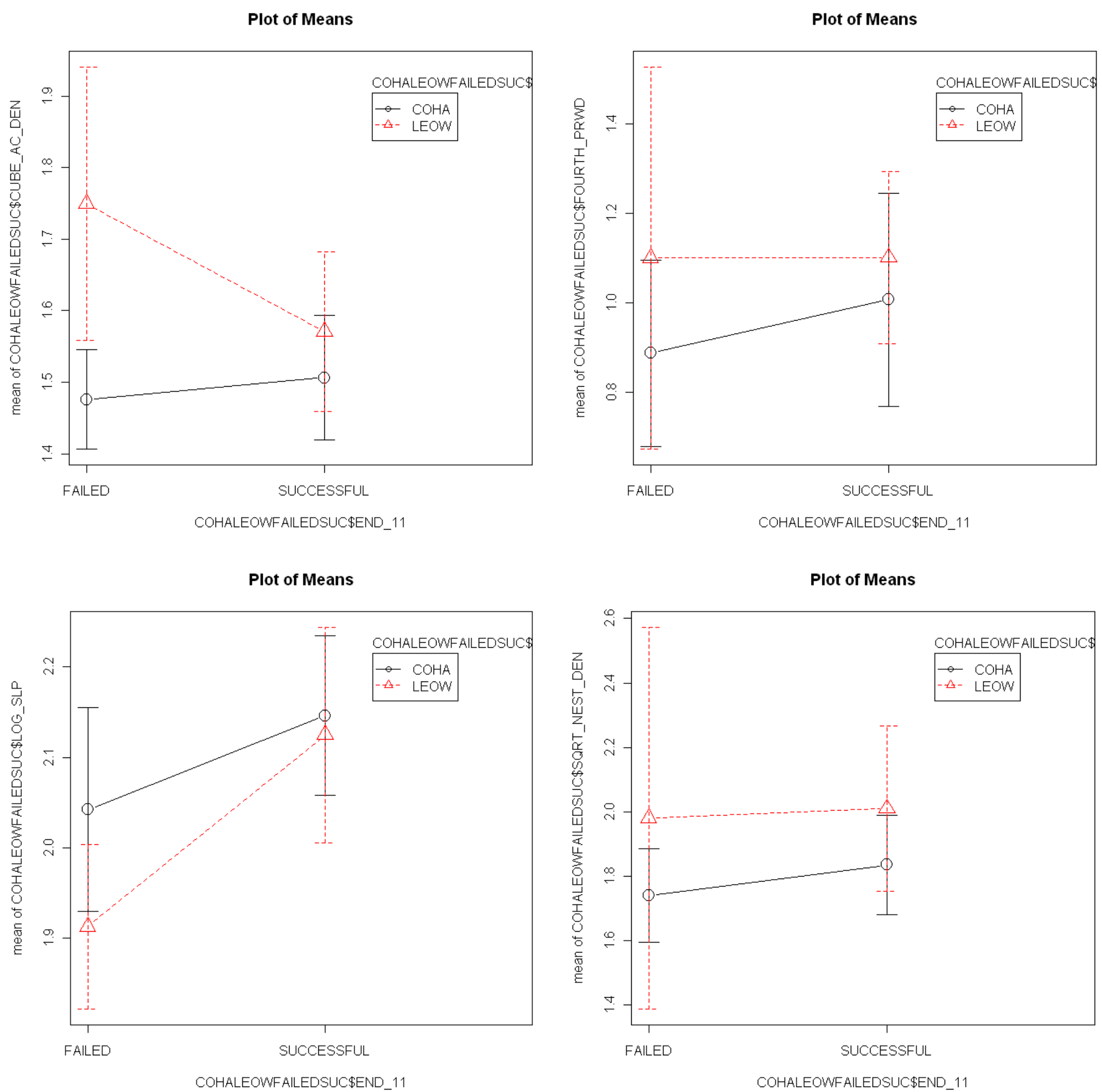


Figure 12. The figure above shows the two-way factorial ANOVA results comparing response variables to factor END_10 (two levels: successful and failed) and factor SPP_10 (i.e., raptor species, two levels: COHA and LEOW).

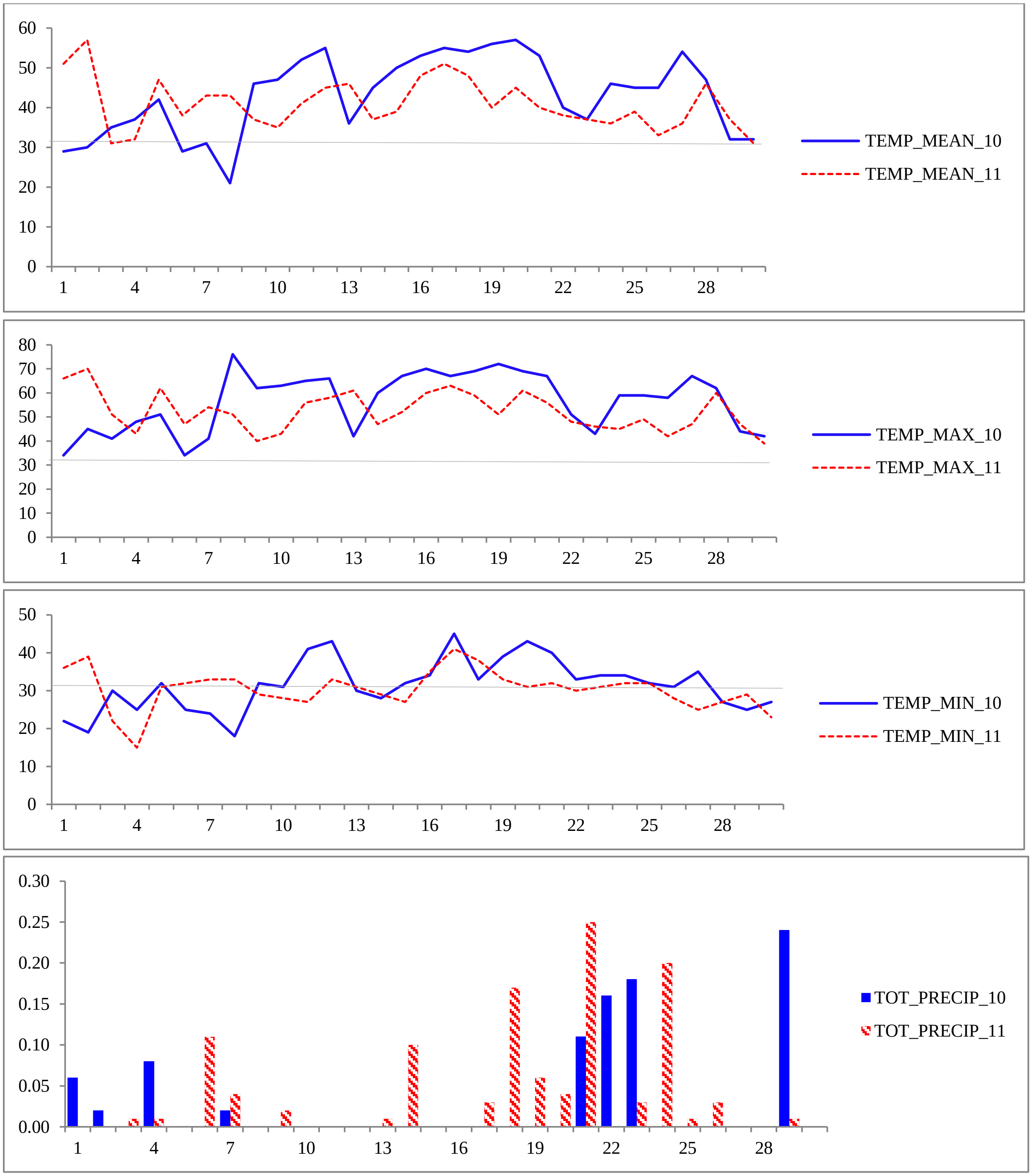


Figure 13. The figure above illustrates the mean, maximum and minimum temperatures (recorded in degrees Fahrenheit) for 2010 and 2011 for the month of April in the study area. Mean, maximum and minimum temperatures durring the month of April were generally lower in 2011 compared to 2010 temperatures. Morever, precipitation events tended to be more numerous, and more equitably distributed throughout the month of April 2011. April 2011 precipiation events generally resulted in less precipitation per event, when compared to April 2010 precipation events. Data used to develop this figure was obtained from the Pinto Ridge RAWS meterological station (http://www.raws.dri.edu/cgi-bin/rawMAIN.pl?coCPIN).

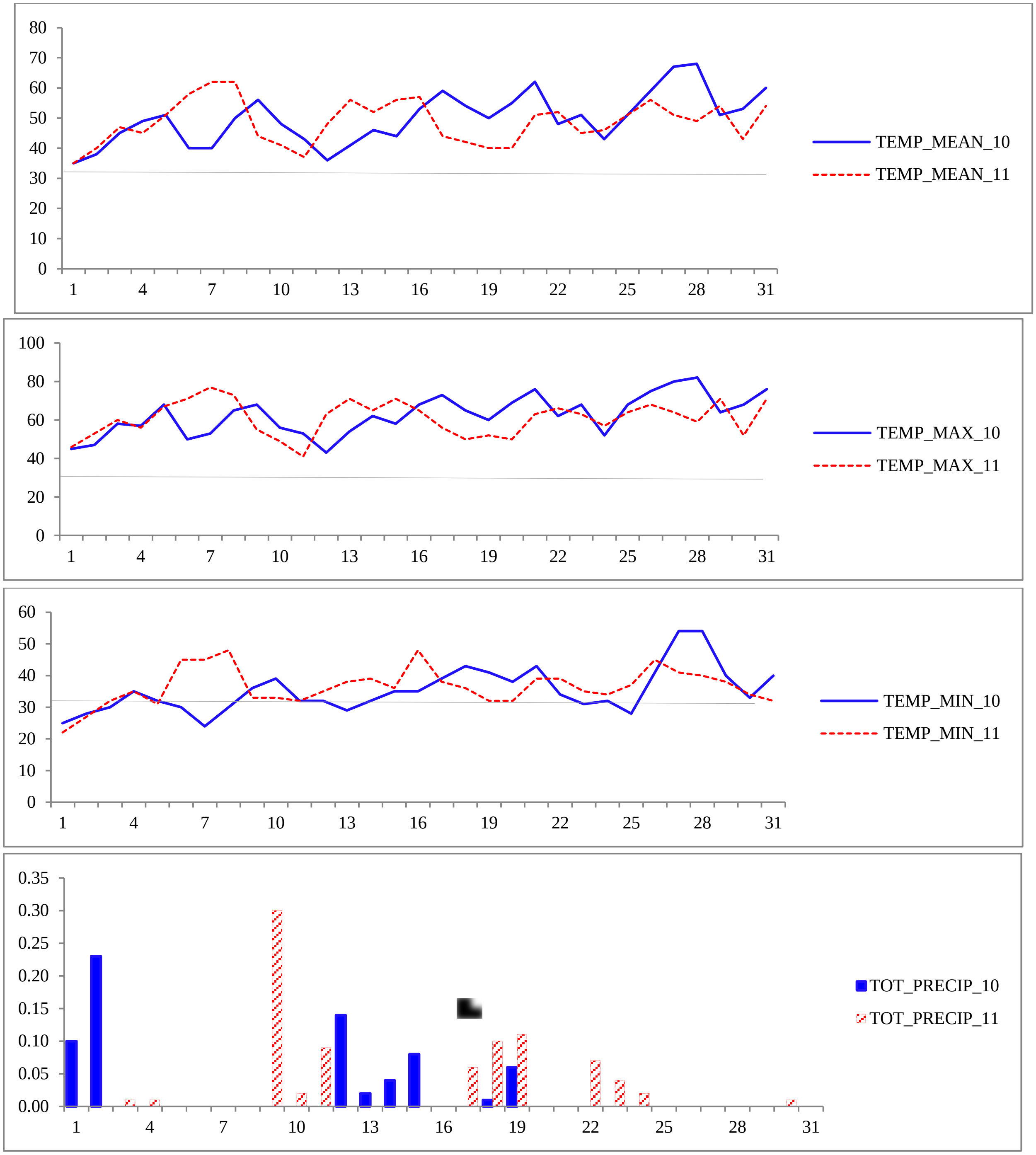


Figure 14. The figure above illustrates the mean, maximum and minimum temperatures (recorded in degrees Fahrenheit) for 2010 and 2011 for the month of May in the study area. Precipitation events during in 2011 during the month of May were generally more numerous when compared to 2010. Data used to develop this figure was obtained from the Pinto Ridge RAWS meterological station (http://www.raws.dri.edu/cgi-bin/rawMAIN.pl?coCPIN).

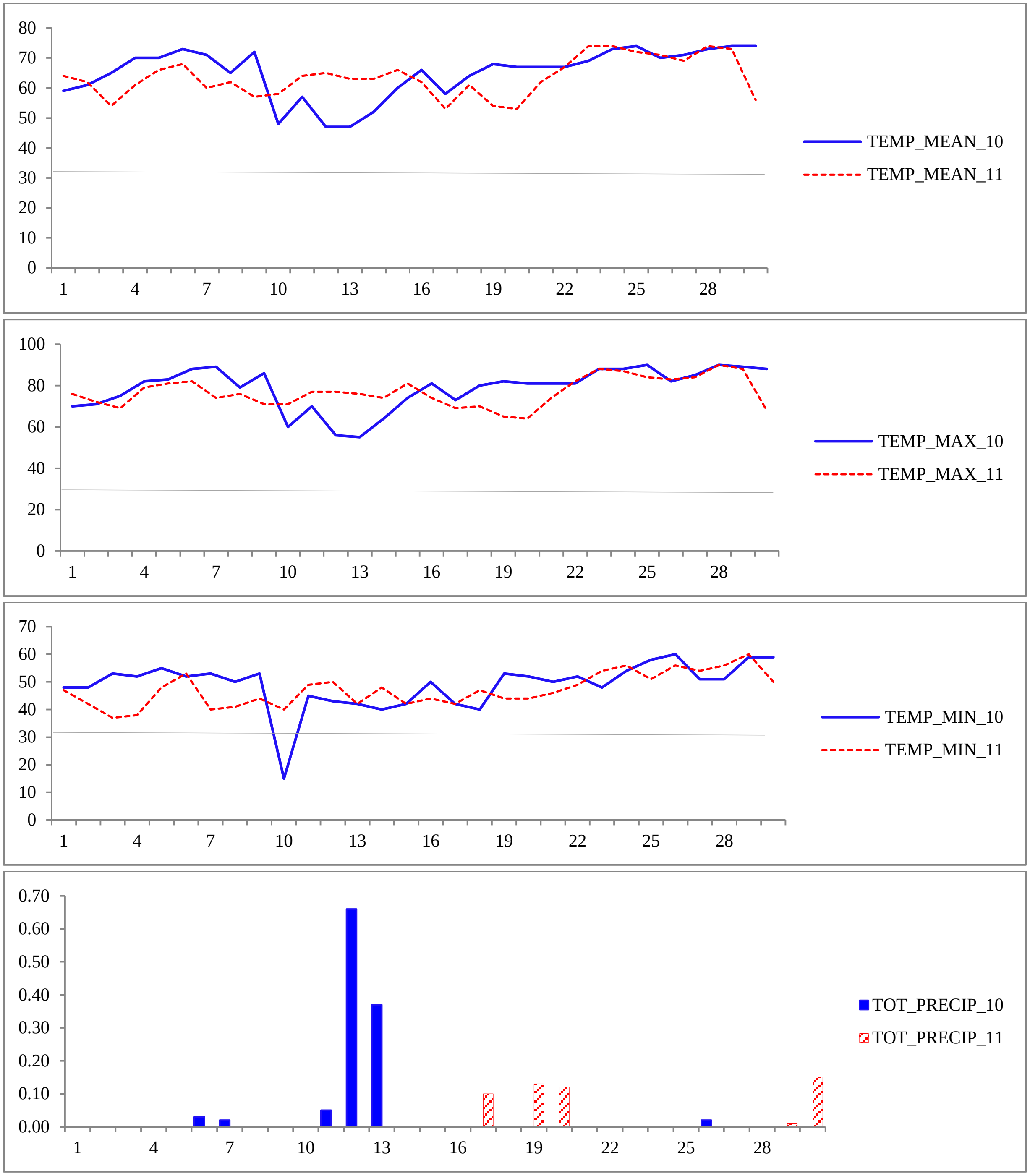


Figure 15. The figure above illustrates the mean, maximum and minimum temperatures (recorded in degrees Fahrenheit) for 2010 and 2011 for the month of June in the study area. Data used to develop this figure was obtained from the Pinto Ridge RAWS meterological station (http://www.raws.dri.edu/cgi-bin/rawMAIN.pl?coCPIN).