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Predictive Modeling for Four Clark County Bird Species: Final Report

(Clark County # CBE 2011-GBBO-901A)

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Contents

Introduction

The project on predictive modeling for four Clark County bird species included three components, (1) creation of conceptual models that describe environmental stressors and responses by each of the four species, (3) preparation of predictive maps that project expected bird presence and/or densities of each of the species based on environmental data from occupied areas, and (3) preparation of statistical models for two species for which we have sufficient vegetation field data collected in occupied sites previously. In the first phase of the project, the Great Basin Bird Observatory (GBBO) developed conceptual models for the species Golden Eagle, Costa's Hummingbird, Loggerhead Shrike, and Gilded Flicker to help illustrate their conservation needs in Clark County. The models were based on published literature on these species, as well as our experience with these species in Clark County and elsewhere in Nevada. Three of the species, Golden Eagle, Costa's Hummingbird, and Gilded Flicker, are currently recognized by Partners in Flight as conservation priority species, and GBBO has provided earlier conservation assistance on these in its Nevada Comprehensive Bird Conservation Plan (GBBO 2010). Here we present the results of the predictive mapping and statistical models in the context of the conceptual models for each of the species. The primary difference between the predictive maps, which also represent habitat models, and the statistical model based on field data is that the predictive maps can only be based on remotely-sensed vegetation data that are available for the whole county and are therefore relatively course in their resolution for habitat selection by birds, while the statistical models are based on precise vegetation measurements in the field which, on the other hand, cannot be extrapolated out to unsurveyed areas. We therefore feel that the two modeling efforts together provide a more complete picture of a bird species' habitat selection than would either one by itself. The report is organized so that results for all three models for this the project are grouped together by species.

Methods

Conceptual Models

Conceptual models present a simplified schematic of intricate ecological processes and complicated cause-and-effect relationships. The conceptual models for the nine focal species are summarized below, and they focus on the major stressors (threats) present in Clark County today, how these are expected to affect the primary habitat of the bird species, and what responses are expected from the bird species with regard to nesting, survival, and population ecology. More details on the conservation issues of conservation priority bird species and the habitat types present in Clark County can be reviewed in GBBO (2010).

Bird Population Assessments

The primary method of bird density data collection used a network of randomly selected variable-distance point count transects, stratified by habitat, which allowed us to extend coverage over a large area and wide array of habitats (Figure 1). Point count transects typically contained 10 survey points and were, on average, 3 km in length. All survey points were georeferenced with a handheld GPS unit. Each point was surveyed for 10 minutes, recording all birds detected by sight or sound. The detections were recorded in three distance intervals (0-50 m, 50-100 m, and >100 m) that were measured with an electronic rangefinder from the survey point. All bird surveys were conducted between mid-April and

July 7, within the breeding season of most small landbirds in this region. Point count surveys were conducted according to GBBO's standard protocol (www.gbbo.org: Projects). Between 2007 and 2011, 129 transects were surveyed. In 2012 and 2013, 184 transects were surveyed. Sample sizes for all survey years and habitat types are listed in Table 1.

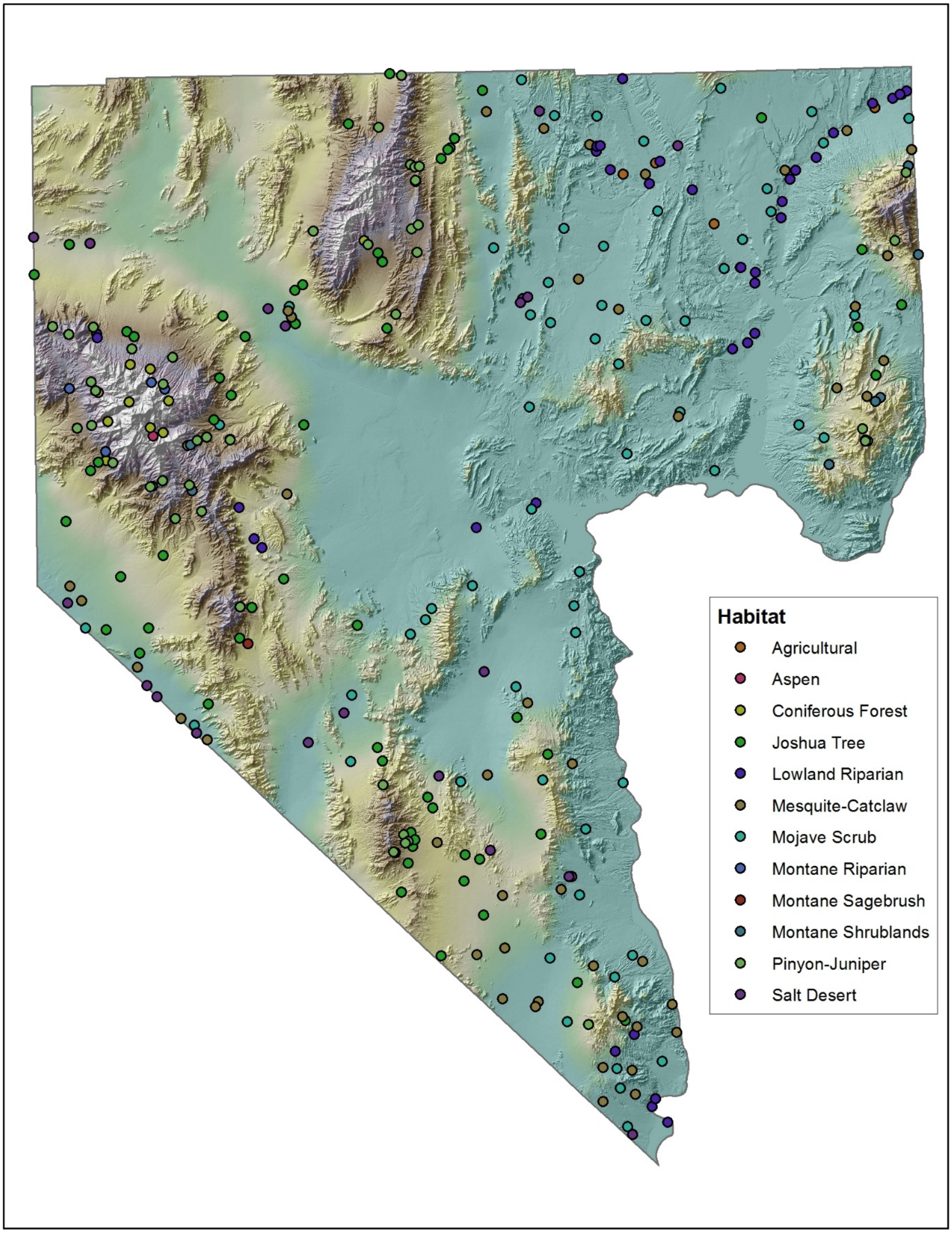

Figure 1. Locations of all point count transects surveyed within Clark County, by habitat.

Table 1. Total number of transects surveyed per year in Clark County, by habitat, 2008-2013.

Habitat	2008	2009	2010	2011	2012	2013	Total (2003-2013)
Agricultural	4	4	4	3	1	1	6
Aspen	1	1	1	1			1
Coniferous Forest	4	4	4	6	4	1	12
Joshua Tree	20	19	19	20	17	24	64
Lowland Riparian	20	18	17	14	11	13	47
Mesquite-Catclaw	9	10	9	9	14	20	44
Mojave Scrub	12	13	10	17	16	23	62
Montane Riparian	4	4	4	5	1		6
Montane Sagebrush	1	1	1	1			1
Montane Shrublands	5	3	3	3		3	9
Pinyon-Juniper	9	9	8	9	13	19	44
Salt Desert	8	7	7	9	9	2	21
Total	**97**	**93**	**87**	**97**	**86**	**106**	**317**

While Golden Eagles were also recorded on the point count transects, we used nest data collected in a statewide Golden Eagle nest inventory conducted in 2013 by GBBO and the Nevada Department of Wildlife. Funding for this effort was provided by the U.S. Bureau of Land Management, who also made the data available for this project.

Field Vegetation Assessments

We conducted vegetation assessments in the field at over 2000 data points along the surveyed bird transects over the course of the project. These vegetation data were used for modeling the relationships of focal bird species to local habitat features that are not measurable through remote sensing (for specific variables measured, see Table 2, below). We collected three types of vegetation data in the field sites. First, observers recorded the presence or absence of a series of landscape features such as roads, development, water, dry washes, tall cholla, mesquite-mistletoe, or trees (including Joshua trees and Mojave yuccas) at different distance categories. Abundance classes of tall cholla and mistletoe were also collected when present. The observers also recorded a list of all identifiable dominant plant species within 100 m. Finally, they collected angle-order data, a plotless density estimation method, which we analyzed using the point-centered quarter method (Engeman et al. 1994); this method can also be used to estimate occurrence frequency for focal plants. Distances from the bird survey point to the nearest woody plants within five height classes were recorded using this method, and these could then be transformed into density estimates for each height class together, or for individual plant species. The height classes considered here were 0 to 0.5 m, 0.5 to 1.5 m, 1.5 to 4 m, 4 to 10 m, and greater than 10 m height. Woody plants were assigned to height classes by their maximum height, and they were not double-counted among height classes.

Observed Actual Distribution

To create the actual-distribution maps, we included all Nevada Bird Count point locations where each focal species was recorded between 2003 and 2013, including incidental observations. In addition, we included species locations from the Nevada Breeding Bird Atlas data collection, 1998-2000 (Floyd et al. 2007), including incidental records denoted by a triangle to visually separate them from the point count records. It should be noted, however, that survey records from the atlas period were mapped with a UTM coordinate from the corner of the atlas block, rather than from the actual location of the bird, which introduces a slight mapping error for these records.

Map Products and Use of Spatial Data

A new vegetation classification based on LandFire that includes vegetation condition classes and was developed by The Nature Conservancy for the Nevada Wildlife Action Plan (Provencher and Anderson 2011). The Nature Conservancy's Nevada habitat map has the advantages over the original GAP classifications of (1) having a finer mapping resolution based on smaller mapping units, (2) indicating stand condition classes that represent different degrees of habitat degradation, and (3) having LandFire's improved remote sensing methods. These factors contributed to more realistic portraits of bird habitats, but even this mapping effort had disadvantages. For instance, as with other remotely-generated maps, *Yucca* landscapes still could not be delineated without ground-mapping, and many small habitat patches, such as spring outflows, mesquite-acacia washes, and small aspen stands may still be missed despite the finer resolution of the new maps. Also, the irregular and linear habitat patches of riparian areas may be poorly represented, which affects our ability to use the map for habitat suitability estimates of riparian birds.

Spatial Habitat Models

Predictive distribution maps based on habitat models can be very useful for county planning because they combine actual species distribution with each species' basic habitat preference. We created this spatial map using Provencher and Anderson's (2011) statewide vegetation classifications based on LandFire that include condition classes within vegetation types, and were developed by The Nature Conservancy for the Nevada Wildlife Action Plan.

In the predictive models, we used the frequency of bird detection locations in different habitat classes to predict average expected densities in areas with similar habitat cover types. For this, we calculated detections within each habitat cover type and within 100 m of each survey location. The resulting habitat-specific densities were then projected across the region to create the maps. The Costa's Hummingbird and Loggerhead Shrike maps use the same color scheme and density metrics for comparison, but because of the rarity of Gilded Flickers across the landscape, a different density metric was used to illustrate Gilded Flicker probabilities.

To project expected distribution and abundance of three species, Costa's Hummingbird, Loggerhead Shrike, and Gilded Flicker, we created maps using available spatial data sets that mapped vegetation of Clark County and the surrounding Mojave Desert areas of Nevada. Specifically, we used spatial data from the statewide vegetation classifications based on LandFire that include condition classes within vegetation types, and were developed by The Nature Conservancy for the Nevada Wildlife Action Plan (Provencher and Anderson 2011). For these three species' predictive models, we used the frequency of bird detection locations in different habitat classes to predict average expected densities in areas with similar habitat cover. For this, habitat cover at detection locations was summarized for each survey point, rather than for the entire transect, and prevalence of vegetation cover within 100 m of the survey point was used to determine the dominant vegetation for each point at which a species was detected. These habitat-specific densities were then projected across the region to create the map (for comparison with published bird densities, the densities per count reported here can be converted to densities per 40 ha by multiplying by 12.73). More details on the mapping procedures used can be reviewed in GBBO (2013). For the Golden Eagle predictive map, we had to use a different approach because their large home ranges prevent us from detecting fine-scale habitat associations at occupied point count locations that are commonly found in landbirds with smaller territories. We therefore used Golden Eagle nest locations that were detected in Clark County during GBBO's and the Nevada Department of Wildlife's statewide inventory of Golden Eagle nest sites in 2013 to map predicted nest areas throughout the county based on cliffs, aspect, and elevation attributes of known nest locations. We also added slope, distance to water, and distance to urban areas to the model, but these variables added nothing to the model. Therefore, we present the predictive map for Golden Eagle based only on the environmental variables cliffs, aspect, and elevation.

Statistical Habitat Models

For statistical bird-habitat models, we only included two of the four species, Costa's Hummingbird and Loggerhead Shrike, as these were the only two species for which there was a sufficient sample size available from our previous field data collection. Gilded Flicker was only found in four locations during our random sampling for monitoring, and while this is insufficient for statistical analysis, we present a summary of vegetation attributes of these locations here. No vegetation assessment data were available for Golden Eagle, and furthermore, vegetation attributes around Golden Eagle nest sites are not likely to explain their nest site selection.

Field vegetation data were available for 2,000 points on 246 transects. The plotless plant density estimation was used for logistic regression analysis testing the difference between plots occupied and unoccupied by a focal species. The point-centered quarter method (Cottam and Curtis 1956) estimated the density of woody plants in five height classes by converting distances to the first plant in each quarter to plants/ha according to Mitchell (2007).

We also recorded the species of each of 23,025 plants, and these data were used to calculate the proportion of the overall density, in different height classes, represented by plant species that were common enough for analyses (Table 2). For overall species proportions, all height classes were lumped together to form an index of frequency.

Simple logistic regression was used to relate presence of focal species to overall densities at the different height classes, and to the frequency of species occurrence. Categorical data on the presence or absence of key habitat and landscape elements at different distances (Table 3) lend themselves well to the non-parametric Kruskal-Wallis analyses, relating those elements to the abundance of the focal species. The presence or absence of key plant species were also derived using the field-generated plant species lists and analyzed in the same way using Kruskal-Wallis analyses.

Variables determined to be significant (alpha = 0.05) for each species were then included in an overall logistic regression analysis for that species. Stepwise logistic regression, both forward and backward, was used, with a p = 0.15 criterion used for adding and removing variables. This analysis included data from all habitats combined. Logistic regression for Costa's Hummingbirds was run on 1911 survey points, on which 53 contained Costa's Hummingbirds. Logistic regression for Loggerhead Shrikes was run on 1976 survey points, of which 238 contained the focal species. The difference in the number of survey points is attributed to missing data for the variables included.

Gilded Flickers were not found on sufficient points to allow for data analysis; however, a description was included of the points on which individuals were found.

Table 2. Plant species used in the statistical habitat models for the two focal species, with total number sampled in each height class of the plotless distance sampling (point-centered quarter).

SPECIES	Common Name	0 to 0.5 m height	0.5 to 1.5 m height	1.5 to 4 m height	4 to 10 m height	> 10 m height	Total
Acacia greggii	Acacia	18	125	662	32	0	837
Artemisia sp.	Sagebrush	449	212	8	0	0	669
Atriplex sp.	Saltbush	315	309	25	0	0	649
Coleogyne ramosissima	Blackbrush	524	385	34	0	0	943
Cylindropuntia	Cholla	64	108	61	1	0	234
Juniperus sp.	Juniper	12	47	408	242	11	720
Larrea tridentata	Creosote	243	2,000	2,180	3	0	4,426
Pinus monophylla	Pinyon pine	71	127	365	715	221	1,499
Pinus longaeva	Bristlecone pine	0	1	3	4	2	10
Populus fremontii	Fremont cottonwood	0	0	6	31	21	58
Prosopis sp.	Mesquite	12	37	205	85	1	340
Purshia stansburiana	Cliffrose	40	89	134	3	0	266
Salix sp.	Willow	8	22	57	45	2	137
Tamarix ramosissima	Saltcedar	112	136	399	159	0	806
Yucca brevifolia	Joshua tree	11	45	880	531	0	1,467
Yucca schidigera	Mojave Yucca	9	162	525	9	0	705
Total		**6,630**	**7,205**	**6,766**	**2,014**	**410**	**23,025**

Table 3. Variables included within initial analyses for both species. Significantly contributing variables included within stepwise logistic regression modeling are noted where applicable.

Variable	Costa's Hummingbird	Loggerhead Shrike
Woody Plant Density, height 0 to 0.5m	Included	

Variable	**Costa's Hummingbird**	**Loggerhead Shrike**
Woody Plant Density, height -0.5 to 1.5m		
Woody Plant Density, height 1.5 to 4m		
Woody Plant Density, height 4 to 10m		
Woody Plant Density, height greater than 10m		
Relative Frequency of *Acacia*	Included	Included
Relative Frequency of *Artemisia*		
Relative Frequency of *Atriplex*		
Relative Frequency of *Coleogyne*		
Relative Frequency of *Larrea*	Included	
Relative Frequency of *Prosopis*		
Relative Frequency of *Pinus monophylla*		Included
Relative Frequency of *Juniperus*		
Relative Frequency of *Tamarix ramosissima*		
Relative Frequency of *Yucca brevifolia*		Included
Relative Frequency of *Yucca schidigera*		
Roads Within 400 m	Included	Included
Water Within 1000 m	Included	Included
Water Within 100 m	Included	
Dry Wash (> 5 ft wide)	Included	Included
Trees Within 100 m Present	Included	Included
Deciduous Trees Within 100 m	Included	Included
Coniferous Trees Within 100 m		
Joshua Trees/Mojave Yuccas Within 100 m		
Trees Within 1000 m Present	Included	Included
Large Riparian Shrubs Present		
California Mistletoe Present		
Tall Cholla (> 0.9 m) Present	Included	Included
Larrea Present		
Ambrosia Present		
Cylindropuntia Present		
Yucca brevifolia Present		
Yucca schidigera Present	Included	Included
Acacia Present		
Prosopis Present		
Juniperus Present	Included	
Pinus monophylla Present	Included	
Yucca baccata Present	Included	
Tamarix ramosissima Present		
Hymenoclea salsola Present	Included	Included
Ericameria/Chrysothamnus Present	Included	
Coleogyne Present		
Atriplex Present (not *Atriplex lentiformis*)		

Variable	**Costa's Hummingbird**	**Loggerhead Shrike**
Atriplex lentiformis Present		
Lycium Present		
Prunus fasciculatum Present		
Psorothamnus Present	Included	Included
Purshia stansburiana Present	Included	Included

Results and Discussion

Golden Eagle

Conceptual Model

The Golden Eagle is widespread and relatively common throughout Clark County and Nevada. It nests primarily in cliffs and rock outcroppings (ideally > 70 feet tall, GBBO 2010) and occupies home ranges that cover as much as 60,000 acres of desert lowlands, although these home ranges often overlap. The Golden Eagle's primary food source includes jackrabbits, cottontails, and ground squirrels, which it hunts during diurnal foraging flights over habitat types occupied by its primary prey (Kochert et al. 2002). We suspect that Golden Eagle densities in Clark County are primarily driven by prey densities, and thus, habitat management to preserve Golden Eagle populations is mostly as task of managing lagomorph and large rodent populations. Golden Eagles are facultative scavengers but, based on our experience, scavenging is a less preferred foraging method over hunting for live prey, and it is mainly done during times of low prey availability. Golden Eagles are also sensitive to disturbances of their nest sites, including human intrusions from recreational activities, but also construction of infrastructure and traffic associated with it. They are also prone to collisions and electrocutions from energy facilities, if these structures are not sufficiently equipped to prevent bird mortalities. Appendix 1 illustrates the stressors likely present in Clark County and predicted responses of Golden Eagles to them.

Predictive Model

Based on presence of cliffs, aspect, and elevation, we projected areas of high likelihood of Golden Eagle nest sites based on attributes of currently known nest sites. In Figure 2, we show the predictive model for Clark County based on these three variables overlaid with known nest locations. The model shows high probabilities of Golden Eagle nesting in most mid-elevation foothill locations that feature at least some cliffs in Clark County. The map also shows Golden Eagle sightings, which do not follow the pattern of nest locations, as is expected in a wide-ranging species such as the Golden Eagle. While this species nests primarily in cliffs in this region, its primary foraging habitat includes low-elevation scrub landscapes that are often many miles from their nest site.

While we feel this predictive model is likely a good rendition of high-probability areas for Golden Eagle nest locations, we also note that a more complex and more detailed predictive modeling effort for Golden Eagle nest sites throughout Nevada is currently underway by members of the western Golden Eagle working group, which is led by the regional U.S. Fish and Wildlife Service office and U.S. Geological Survey. Its results are expected to be published within the next year.

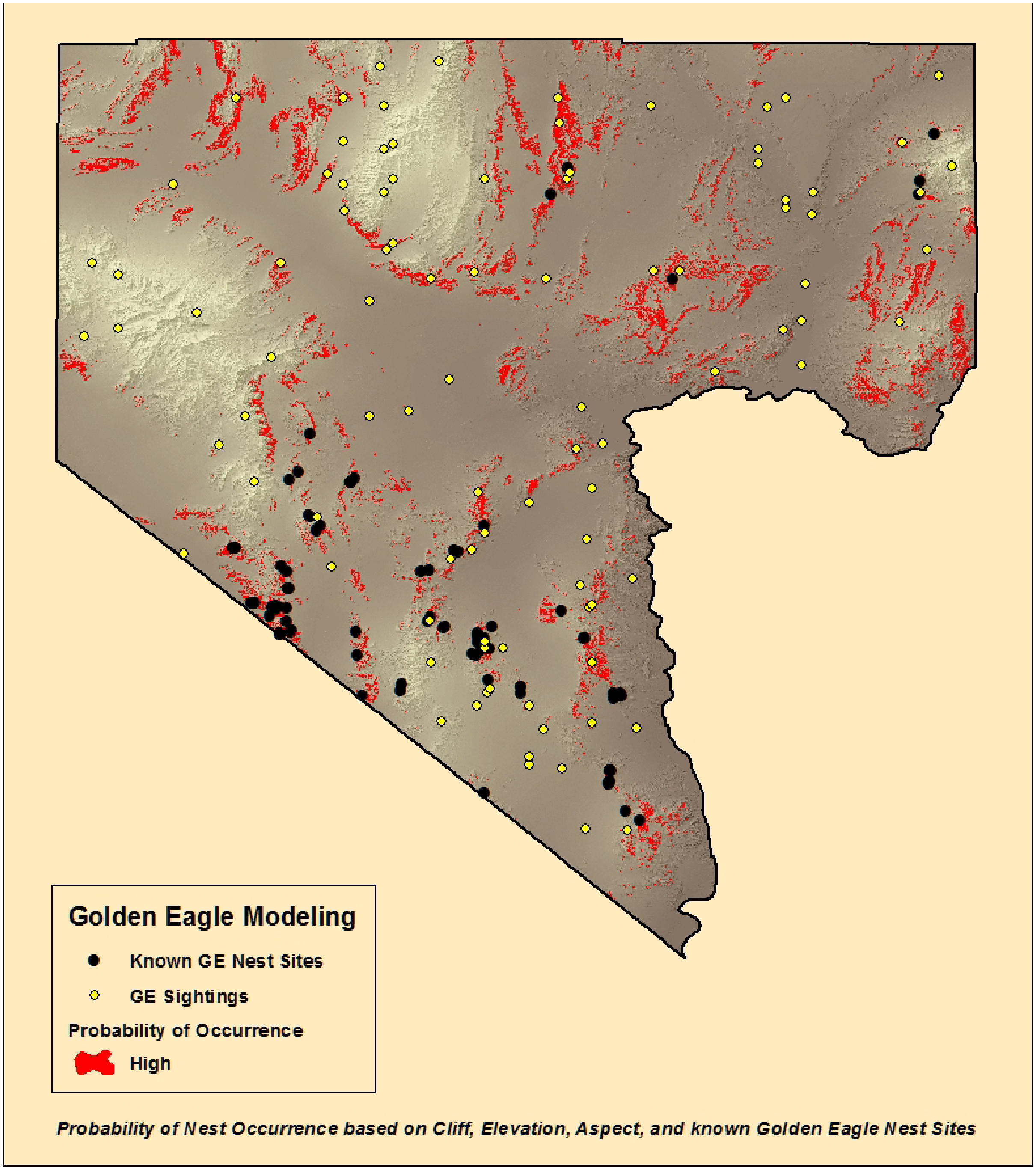

Figure 2. Predictive model map for Golden Eagle nest site locations in Clark County based on a nest inventory completed in 2013.

Costa's Hummingbird

Conceptual Model

Costa's Hummingbirds are associated with blooming shrubs and forbs of the Mojave Desert, and they may particularly rely on those associated with high groundwater tables that allow at least some of them to flower throughout the summer, such as bladderpot, penstemon, cactuses, squaw cabbage, desert willow (Baltosser and Scott 1996, GBBO 2010). While Costa's Hummingbirds are not considered strictly riparian in their habitat use, we find that they are more likely to occur near desert springs and vegetation that is typically associated with water and their highest breeding densities in Clark County were found on survey transects that had at least some lowland riparian vegetation (GBBO 2010). Unlike other hummingbirds, this species is not known to be reliably associated with artificial food sources, such as hummingbird feeders and urban landscaping (Baltosser and Scott 1996). Although average territory sizes are unknown, a typical nesting territory has 3-10 reliably blooming shrubs, but raising a brood also requires access to small invertebrates that are gleaned from shrub foliage or caught on the wing. Appendix 2 illustrates the stressors likely present in Clark County and predicted responses of Costa's Hummingbirds to them.

Predictive Model

Costa's Hummingbirds in Clark County are most often found in areas that have a dry wash or water, deciduous vegetation, or *Yucca* spp. The predictive map (Figure 3) shows moderate predicted densities throughout much of Clark County except urban areas, which is likely a result of Costa's Hummingbird selecting their territory locations at a finer spatial scale than the vegetation map used in the model can resolve. The spatial model therefore extrapolates throughout all areas where the finer-scale habitat selection variables are likely to occur at some frequency. However, the map also shows hotspots of high predicted densities of Costa's Hummingbird in the mountainous landscapes of the Sheep Range and the Spring Mountains (these can only be discerned when zooming into the map). We expect these to reflect riparian areas and dense deciduous vegetation associated with washes that are more predictably found at higher elevations in Clark County.

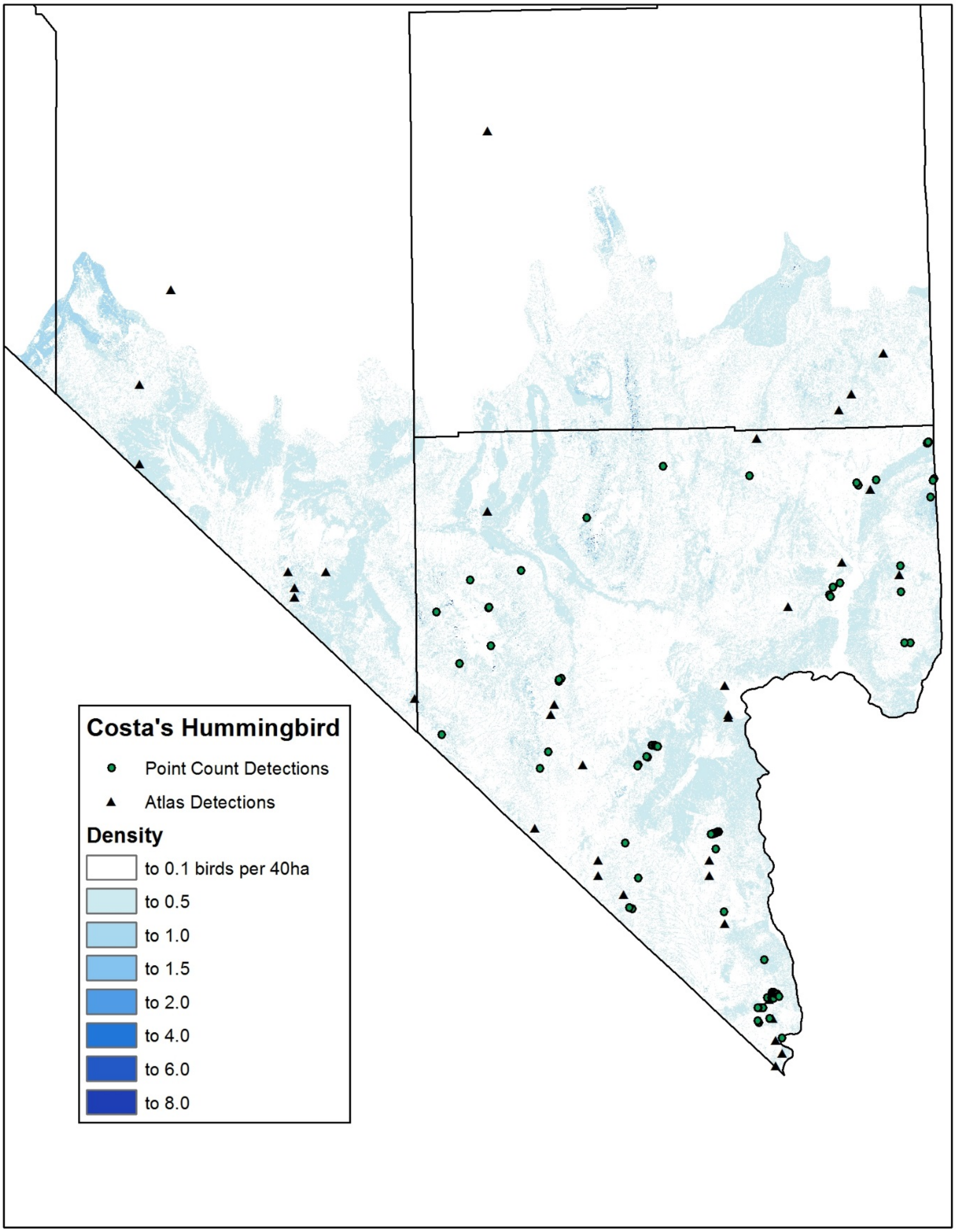

Figure 3. Predictive model map for Costa's Hummingbird's breeding distribution in Clark County and the greater Mojave region, overlaid with actual detections of the species within the past 10 years.

Statistical Model

A total of 64% of the sites where Costa's Hummingbirds were found had cheesebush (*Ambrosia salsola*) present, while only 25% of the sites were Costa's Hummingbird was absent had this plant species (Table 4). Similarly, a larger percentage of the sites occupied by Costa's Hummingbird (28%) had deciduous trees present than did sites where no hummingbirds were detected (10%). Following the same pattern, sites occupied by Costa's Hummingbird were more likely to have Mojave yucca (*Yucca schidigera*, 48%), dry washes (88%), and water within 1,000 m (29%) present than did sites where no hummingbirds were detected (29%, 69%, and 16% respectively, Table 2).

Table 4. Proportion of survey points in which Costa's Hummingbird was present and absent in which different habitat components were present.

	Costa's Hummingbird	
Habitat Feature	**Present**	**Absent**
Cheesebush Present	0.637931	0.248967
Deciduous Trees Present	0.275862	0.098131
Mojave Yucca Present	0.482759	0.290806
Dry Wash Present	0.87931	0.69039
Water within 1000 m	0.293103	0.16

Based on the logistic regression model, the odds of encountering Costa's Hummingbirds increased as densities of acacia increased (Table 5). The presence of water within 1000 m, dry washes, deciduous trees, Mojave yucca, and cheesebush were also associated with an increased likelihood of encountering Costa's Hummingbirds, though it is likely that cheesebush presence is correlated to the presence of dry washes. While the presence of indigo bush, rabbitbrush, and tall chollas were associated with increased odds of encountering Costa's Hummingbirds, the confidence intervals for these variables included 1 and the association is therefore not clear. Finally, the presence of deciduous trees within 100 m of the survey point also increased odds of encountering Costa's Hummingbirds. At a wider scale, however, the lack of trees within 1000 m of the survey point increased the odds of Costa's Hummingbird presence. Similarly, increased densities of creosote (*Larrea*) were associated with decreased odds of encountering Costa's Hummingbirds. Overall, the model for Costa's Hummingbird performed well, with a McFadden's Rho-Squared of 24.6%. For more details on the model, see Deliverable D05.

Table 7. Statistical model based on multiple logistic regression for sites where Loggerhead Shrike was present using vegetation variables in a stepwise selection.

Parameter Estimates for Costa's Hummingbird Model						
Parameter	**Estimate**	**Standard Error**	**Z**	**p-Value**	**95% Confidence Interval**	
					Lower	**Upper**
CONSTANT	2.204	0.725	3.040	0.002	0.783	3.624
D0_05	0.000	0.000	2.171	0.030	0.000	0.000
ACACIA(1)	2.948	1.279	2.304	0.021	0.441	5.455
LARREA	-2.661	1.106	-2.406	0.016	-4.828	-0.493
WATER1000$_No	-1.304	0.425	-3.064	0.002	-2.137	-0.470
DRYWASH$_No	-1.376	0.579	-2.376	0.017	-2.511	-0.241
DECIDUOUS$_No	-2.311	0.493	-4.691	0.000	-3.277	-1.346
TREES1000$_No	1.358	0.509	2.667	0.008	0.360	2.355
CYLINDROPUNTIA_$_No	-0.594	0.337	-1.763	0.078	-1.254	0.066
MOJ_YUCCA$_0.000000	-1.545	0.471	-3.280	0.001	-2.468	-0.622
CHEESE$_0.000000	-1.151	0.382	-3.013	0.003	-1.899	-0.402
INDIGO$_0.000000	-0.539	0.362	-1.491	0.136	-1.248	0.170
RABBIT$_0.000000	-0.619	0.317	-1.949	0.051	-1.241	0.003

Odds Ratio Estimates for Costa's Hummingbird Model				
Parameter	**Odds Ratio**	**Standard Error**	**95% Confidence Interval**	
			Lower	**Upper**
D0_05	1.000	0.000	1.000	1.000
ACACIA(1)	19.063	24.384	1.554	233.873
LARREA	0.070	0.077	0.008	0.611
WATER1000$_No	0.272	0.116	0.118	0.625
DRYWASH$_No	0.253	0.146	0.081	0.786
DECIDUOUS$_No	0.099	0.049	0.038	0.260
TREES1000$_No	3.887	1.978	1.433	10.541
CYLINDROPUNTIA_$_No	0.552	0.186	0.285	1.069
MOJ_YUCCA$_0.000000	0.213	0.100	0.085	0.537
CHEESE$_0.000000	0.316	0.121	0.150	0.669

Odds Ratio Estimates for Costa's Hummingbird Model				
Parameter	Odds Ratio	Standard Error	95% Confidence Interval	
			Lower	Upper
INDIGO$_0.000000	0.583	0.211	0.287	1.185
RABBIT$_0.000000	0.539	0.171	0.289	1.003

Loggerhead Shrike

Conceptual Model

Loggerhead Shrikes are a species of the open desert and steppe environments, and they are found in most habitat types of Clark County except forests and the alpine zone. Loggerhead Shrikes tolerate dry shrub steppe and desert scrub, where they nest in tall, often thorny, shrubs and forage from tall perches on large insects, including grasshoppers, moths, and butterflies, as well as on lizards (Yosef 1996). They occupy large territories (20-60 acres, Yosef 1996), which may be relocated to more suitable areas from year to year, and they are known to follow recent fires that are thought to provide rich foraging opportunities during the nesting season (GBBO, unpubl.). The species' habitat preferences are otherwise difficult to characterize because almost all open habitat types, such as desert scrub, shrubsteppe, open pinyon-juniper, salt desert, and agricultural lands, are commonly used as long as suitable prey populations, tall perches, and tall nesting shrubs are available on the landscape. The species is reportedly often associated with spiny woody plants, and it is only known to avoid densely forested habitat types (Yosef 1996). Appendix 3 illustrates the stressors likely present in Clark County and predicted responses of Loggerhead Shrikes to them.

Predictive Model

Based on recent survey data from the breeding bird atlas project and the Nevada Bird Count program, Loggerhead Shrikes reach among their highest breeding densities in Clark County (Figure 4). Our spatial model predicts highest average abundances at the foot of the mountain ranges of Clark County that are likely preferred because they provide access to tall shrub vegetation for nesting and large open landscapes for foraging. The highest and lowest elevations of Clark County are largely avoided by this species, as are urban areas. However, as for Costa's Hummingbird, we observe predicted hotspots of high Loggerhead Shrike densities at mid to higher elevations around the skirts of the major mountain ranges of Clark County, including the Sheep Range and the Spring Mountains (these are best viewed by zooming into the map). It is possible that similar habitat features present in these hotspots predict the high likelihood of presence of both species, although we have not overlaid the two predictive maps to confirm this hypothesis.

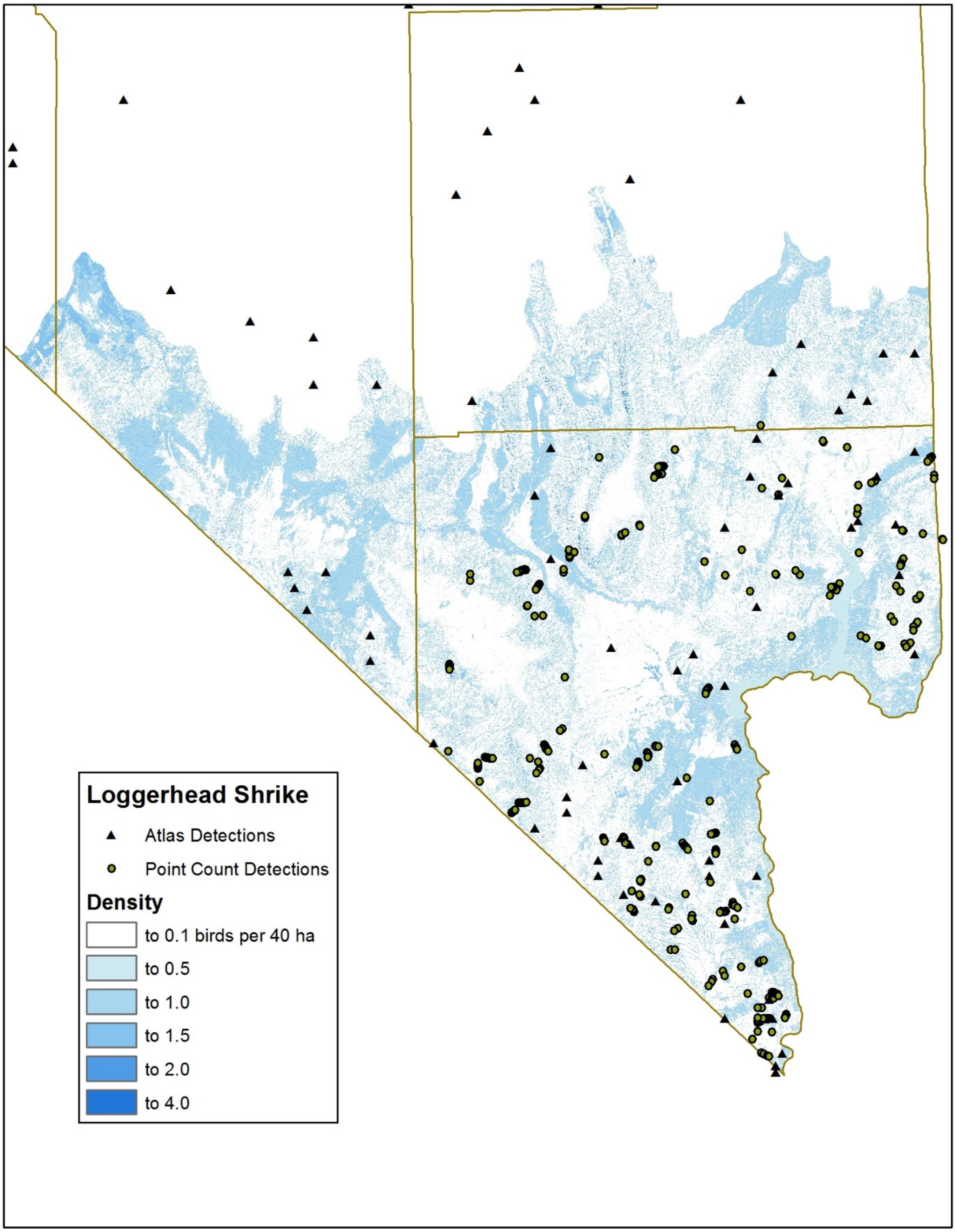

Figure 4. Predictive model map for Loggerhead Shrike's breeding distribution in Clark County and the greater Mojave region, overlaid with actual detections of the species within the past 10 years.

Statistical Model

Most of the survey plots (85%) where Loggerhead Shrikes were present also had cheesebush present, while only 23% of the survey plots where shrikes were absent had this plant (Table 6). However, shrikes appear to avoid areas with cliffrose (*Purshia glandulosa*) present with only 2% of the sites occupied by Loggerhead Shrike having this plant present while 12% of the sites where the bird was absent had the plant. Similar to our Costa's Hummingbird data, 88% of the sites occupied by Loggerhead Shrike had dry washes, while only 67% of those unoccupied by the shrike had dry washes. Finally, sites occupied by Loggerhead Shrike were more likely to have trees within 100 m (82%) and roads within 400 m (59%) compared with sites where the bird was not detected (63% and 49%, respectively; Table 6).

Table 6. Proportion of survey points in which Loggerhead Shrike was present and absent in which different habitat components were present.

	Loggerhead Shrike	
Habitat Feature	**Present**	**Absent**
Cheesebush Present	0.858156	0.227039
Cliffrose Present	0.024896	0.119224
Dry Wash Present	0.875	0.671256
Trees within 100 m	0.825	0.630161
Roads within 400 m	0.591667	0.493983

Based on the logistic regression model, the odds of encountering Loggerhead Shrikes occur as the densities of acacia and Joshua tree increase, and the density of pinyon pine decreases (Table7). The odds of encountering Loggerhead Shrikes also increase near roads and dry washes, where there are trees within 100 m (the above would imply primarily Joshua trees). Similarly, the odds of encountering the species increase where cheesebush is present. On the other hand, the odds of encountering Loggerhead Shrikes decreases where cliffrose is present (though cliffrose does tend to be associated with pinyon-juniper habitats). Trees within 1,000 m and the presence of tall chollas were not good predictors for the presence of Loggerhead Shrikes, and their confidence intervals included 1.

The model performed moderately well, with a McFadden's Rho-Squared of 14.9%. For more details, see also complete statistical outputs in Deliverable D05.

Table 7. Statistical model based on multiple logistic regression for sites where Loggerhead Shrike was present using vegetation variables in a stepwise selection.

Parameter Estimates for Loggerhead Shrike Model					
Parameter	Estimate	Standard Error	Z	p-Value	95% Confidence Interval

					Lower	Upper
CONSTANT	-2.440	0.482	-5.064	0.000	-3.384	-1.495
ACACIA(1)	1.933	0.746	2.591	0.010	0.471	3.395
PINYON(1)	-6.809	2.197	-3.099	0.002	-11.115	-2.502
JT(1)	2.722	0.572	4.757	0.000	1.601	3.844
ROADS400$_No	-0.393	0.154	-2.545	0.011	-0.695	-0.090
DRYWASH$_No	-0.895	0.218	-4.108	0.000	-1.323	-0.468
TREES100$_No	-0.930	0.318	-2.926	0.003	-1.552	-0.307
CHEESE$_0.000000	-0.634	0.163	-3.894	0.000	-0.954	-0.315
CLIFFROSE$_0.000000	1.302	0.450	2.896	0.004	0.421	2.183
TREES1000$_No	-0.037	0.342	-0.108	0.914	-0.706	0.633
CYLINDROPUNTIA_$_No	0.101	0.164	0.620	0.536	-0.219	0.422

Odds Ratio Estimates for Loggerhead Shrike Model

Parameter	Odds Ratio	Standard Error	95% Confidence Interval	
			Lower	Upper
ACACIA(1)	6.909	5.153	1.601	29.806
PINYON(1)	0.001	0.002	0.000	0.082
JT(1)	15.214	8.706	4.957	46.700
ROADS400$_No	0.675	0.104	0.499	0.914
DRYWASH$_No	0.408	0.089	0.266	0.626
TREES100$_No	0.395	0.125	0.212	0.736
CHEESE$_0.000000	0.530	0.086	0.385	0.730
CLIFFROSE$_0.000000	3.677	1.653	1.523	8.876
TREES1000$_No	0.964	0.329	0.493	1.883
CYLINDROPUNTIA_$_No	1.107	0.181	0.803	1.525

Gilded Flicker

Conceptual Model

Gilded Flickers were first recorded as nesting in Nevada by the breeding bird atlas project (Floyd et al. 2007), and they have since been observed during the breeding season in the same and nearby locations in southern Clark County. In Clark County, unlike in most of their global range where they are known to nest in saguaro cactuses and riparian forests, Gilded Flickers are currently exclusively found in mature Joshua tree landscapes of the southern half of the county. This may be a habitat type that they uniquely use in the Mojave Desert and little is known about specific habitat requirements, food habits, territory sizes, and stressors in this environment. Gilded Flickers require tree cavities (DBH 12-20 inches, GBBO 2010), which are provided by Joshua trees, and they forage primarily on the ground and in the desert vegetation for insects (Moore 1995). During the non-breeding season, they also consume fruits and seeds. Historically, Gilded Flickers may have been present in Clark County's lower Colorado River's riparian gallery forests, but since the loss of mature cottonwood and willow trees, no riparian populations have been reported from the lower Colorado River in at least 30 years. None of the other riparian areas in Clark County have ever had Gilded Flicker records. Gilded Flickers reach the northern edge of their global range in Clark County, and it is unknown how far north and west from Clark County their current population extends. In light of climate change models, this species should be monitored for northward movements and increased presence in Clark County. Appendix 4 illustrates the stressors likely present in Clark County and predicted responses of Gilded Flickers to them.

Predictive Model

The predictive model for Gilded Flicker predicts very low densities across the landscapes of Clark County, low enough that we selected a different color and shade pattern than for the other predictive maps to make the predicted distribution more visible (Figure 5). The Gilded Flicker is predicted to be present in a large swath of mid-elevation areas of Clark County, which describes the mid-elevation desert biome that features Joshua trees and other yuccas. While currently known records of the species are largely restricted to the McCullough Range and nearby mountains, this predictive map illustrates that based on remote vegetation data, the possibility exists that Gilded Flickers are found in other parts of the county. This is especially important in light of expected range shifts based on climate change.

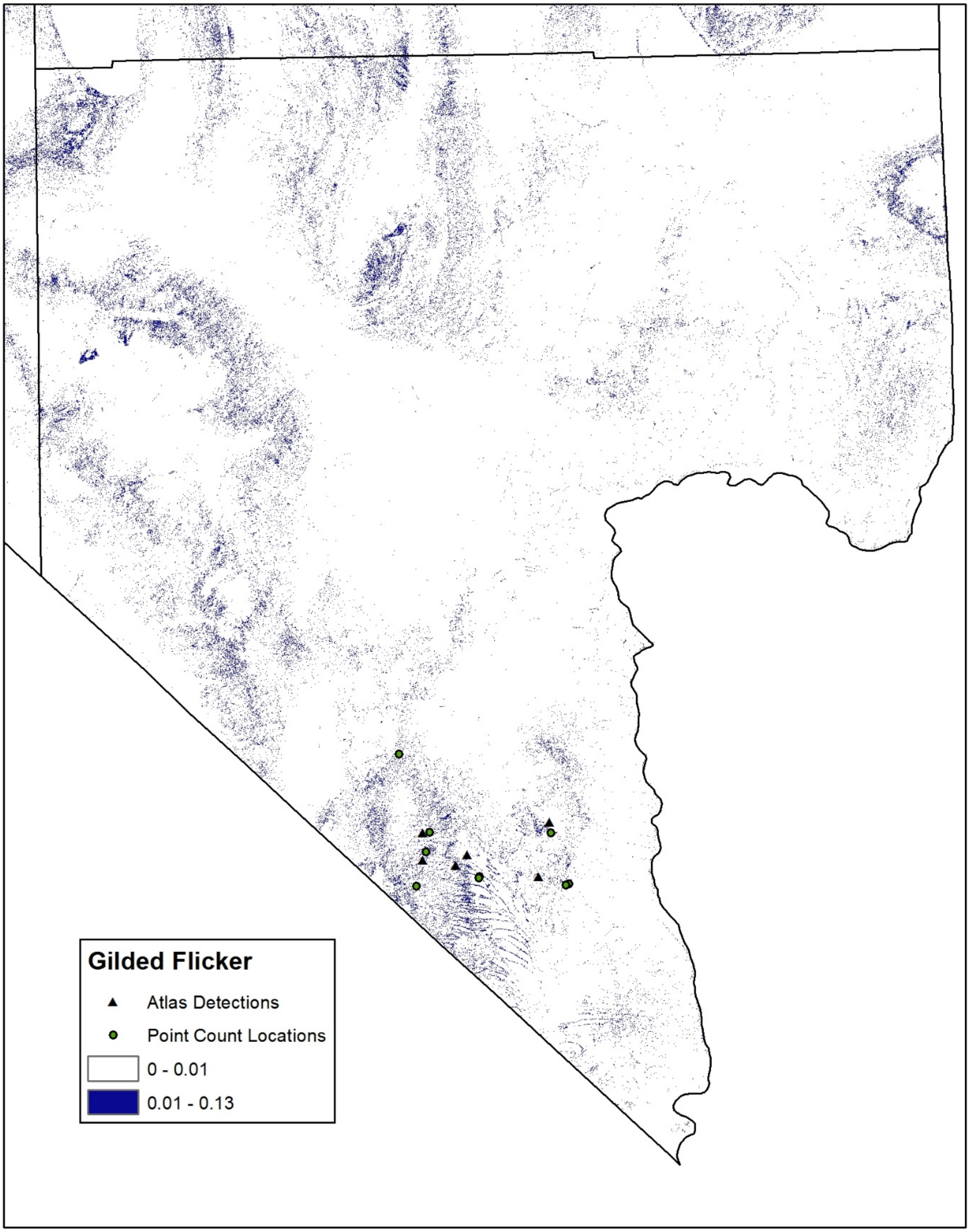

Figure 5. Predictive model map for Gilded Flicker's breeding distribution in Clark County and the greater Mojave region, overlaid with actual detections of the species within the past 10 years. Note that the color and shading is different from previous predictive maps.

Habitat Data

Because the sample size of occupied Gilded Flicker sites was too low to perform statistical analysis for habitat selection, we present here a summary of the habitat attributes found at the four occupied sites we have in our current database (Table 4). While it is unclear which of these variables Gilded Flickers select for their breeding territories, they at least present the observed range of conditions for the sites where they do breed that are in our database.

Table 4. Vegetation measurements at four plots where Gilded Flickers were present during point count surveys in Clark County.

Habitat Variable	Average	Range	Comment
Density of woody plants per ha, at 0-0.5 m height	4609	(1247, 10268)	All plots contained woody plants at this height
Density of woody plants per ha, at 0.5-1.5 m height	632	(9, 1861)	All plots contained woody plants at this height
Density of woody plants per ha, at 1.5-4.0 m height	185	(57, 361)	All plots contained woody plants at this height
Density of woody plants per ha, at 4.0-10.0 m height	7	(0, 20)	3 of the 4 plots contained woody plants at this height
Density of woody plants per ha, at > 10 m height	0	(0, 0)	
Frequency of *Acacia*	0.01	(0, 0.03)	
Frequency of *Coleogyne*	0.09	(0, 0.21)	
Frequency of *Larrea*	0.14	(0, 0.43)	
Frequency of Joshua tree	0.25	(0.17, 0.31)	All 4 plots contained Joshua trees
Frequency of other *Yucca*	0.03	(0, 0.12)	
Roads within 400 m present			3 of 4 plots
Water within 1000 m present			None of 4 plots
Dry washes > 5 ft wide present			2 of 4 plots
Mistletoe present			None of 4 plots
Tall cholla present (> 0.9 m tall)			2 of 4 plots had 10-50 individual tall chollas
Creosote present			2 of 4 plots
White bursage present			1 of 4 plots
Cholla present			3 of 4 plots
Joshua tree/Mojave yucca			All 4 plots

Habitat Variable	**Average**	**Range**	**Comment**
present			
Acacia present			2 of 4 plots
Mesquite present			None of 4 plots
Conifers present			None of 4 plots
Yucca baccata present			1 of 4 plots
Tamarix present			None of 4 plots
Hymenoclea present			1 of 4 plots
Ericameria/Chrysothamnus present			2 of 4 plots
Coleogyne present			3 of 4 plots
Atriplex present (other than *A. lentiformis*)			None of 4 plots
Atriplex lentiformis present			None of 4 plots
Lycium (wolfberry) present			2 of 4 plots
Prunus fasciculata present			1 of 4 plots
Either indigo bush, cliffrose, bitterbrush, sagebrush, greasewood, evergreen oak, Gambel's oak, willow, cottonwood, or aspen present			None of 4 plots

Conclusions

In this report, we presented conceptual models that describe likely causes and effects on the ecology of four species exposed to environmental stressors in Clark County. We further provided predictive maps for each of the four species, which describe our current best estimate on where these species are likely to be found in Clark County in areas that have not yet been surveyed but have similar habitat features as those observed in areas where the species have been recorded. Finally for two of the four species, we constructed statistical habitat models based on vegetation surveys that were done alongside the bird population surveys.

For Golden Eagles, we found that based on current nest locations, most foothill cliff areas in Clark County are likely nesting habitat for the species. More detailed habitat suitability modeling efforts are underway by the USFWS's westwide Golden Eagle habitat suitability modeling project, which will likely provide more detailed and possibly more reliable predictive maps than we can within the scope of this project. However, the results of this regional effort will likely not be available until 2016 to the best of our knowledge. Our model will therefore serve as at least an approximation of the final model in the meantime.

Costa's Hummingbird data show that they are most often found in the lower foothills and mid-elevation areas of Clark County that feature at least some cheesebush, dry wash components, deciduous trees, Joshua tree, or have water nearby. They, however, preferred landscapes that were relatively clear of most trees, and they appear to avoid pure creosote stands.

The Loggerhead Shrike had a strikingly similar predicted distribution to that of Costa's Hummingbird, and the habitat variables selected by shrikes apparently include the presence of cheesebush, cliffrose, dry washes, and at least some trees nearby. Finally, the Gilded Flicker is predicted to occur in a much larger region than previous records of them suggest, which is primarily based on the fact that the basic habitat type used by them is much wider spread that their current known distribution in Clark County. However, we emphasize that these regions are still undersurveyed for birds in general and the Gilded Flicker in particular. Most breeding bird surveys take place at a later time than when Gilded Flicker typically commence breeding, which makes it entirely possible that this species has been underreported in other areas of Clark County than the historically known breeding sites. From the four plots where Gilded Flickers were recorded and for which we have vegetation data, we assume that the species is strictly associated with Joshua trees on the landscape and, unlike in other regions of their range, they are not associated with riparian vegetation. We therefore recommend that all Joshua tree areas that are under consideration for development be surveyed for Gilded Flickers in early April, which is when their nesting season typically begins.

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Appendix 1: Conceptual model of threats to the Golden Eagle (primary breeding habitat of the species is cliffs) in Clark County.

Ecological Stressors → **Important Habitat Effects** → **Expected Golden Eagle Responses**

Ecological Stressors

Structural Change

- Off-road vehicle recreation
- Habitat conversion: urbanization, industrial/energy development, transportation corridors, catastrophic fires
- Increased artificial structures (energy facilities, roads, buildings)

Change in Processes

- Introduced weeds
- Climate change
- Prolonged drought
- Change in fire regime
- Plant pathogens
- Fluctuation in prey populations

Important Habitat Effects

Habitat Loss

- Fragmentation and loss of desert scrub
- Loss of shrub cover
- Loss of undisturbed/remote tall cliff areas

Habitat Degradation

- Loss of shrub diversity
- Loss of intact soils and burrows
- Loss of foraging plants for prey
- Reduced prey populations (lagomorphs and large rodents) and prolonged prey cycles
- Increased temperatures at nest
- Higher prey fluctuations

Expected Golden Eagle Responses

Nesting

- Loss of suitable nest sites
- Increased territory/home range sizes
- Increased nest failure rate
- Decreased reproductive output

Survival

- Longer travel for foraging
- Reduced foraging success
- Increased unpredictability of prey
- Stress response to loss of water and thermal shelters
- Increased vehicle/structure collision

Population

- Reduced recruitment of young
- Reduced site fidelity
- Decreased population size due to lower survival
- Fragmented population
- Increased population fluctuations

Recommendations for the Development of Indicators of Golden Eagle Population Effects:
Baseline data on territory sizes, locations, nests (and nest success, if possible) in randomly selected occupied sites in Clark County. Research on prey use and availability to develop a simple indicator prey species monitoring plan. Long-term population monitoring of Golden Eagles.

Appendix 2: Conceptual model of threats to the Costa's Hummingbird (primary breeding habitat of the species is *Yucca*/Mojave desert scrub) in Clark County.

Ecological Stressors → **Important Habitat Effects** → **Exp. Costa's Hummingbird Responses**

Ecological Stressors

Structural Change

- Off-road vehicle recreation
- Habitat conversion: urbanization, industrial/energy development, transportation corridors, catastrophic fires

Change in Processes

- Introduced weeds
- Climate change
- Prolonged drought
- Change in fire regime
- Ungulate grazing
- Plant pathogens
- Fluctuations in nectar plant availability
- Introduction of (feral) pets

Important Habitat Effects

Habitat Loss

- Fragmentation and loss of *Yucca*/cholla cactus stands
- Loss of riparian-associated vegetation
- Loss of shrub cover
- Loss of flowering shrubs and forbs

Habitat Degradation

- Reduced shrub diversity, native herbaceous covers, litter cover, and cryptobiotic soils
- Increased mortality of *Yucca* and other flowering species
- Changes in flowering phenology and duration
- Decreased water availability in soils
- Decreased invertebrate populations
- Higher prey fluctuations

Exp. Costa's Hummingbird Responses

Nesting

- Loss of suitable nest sites
- Increased territory sizes
- Increased nest failure rate
- Increased nest predation
- Decreased reproductive output

Survival

- Longer travel for foraging
- Reduced foraging success
- Increased unpredictability of prey and nectar sources
- Stress response to loss of thermal shelters

Population

- Reduced recruitment of young
- Reduced site fidelity
- Decreased population size
- Fragmented population
- Increased population fluctuations

Recommendations for the Development of Indicators of Costa's Hummingbird Population Effects: Study of territory sizes, locations, nests (and nest success, if possible) in randomly selected occupied sites in Clark County. Identification of foraging plants. Long-term population monitoring of Costa's Hummingbird.

Appendix 3: Conceptual model of threats to the Loggerhead Shrike (primary breeding habitats of the species are *Yucca*/Mojave scrub and salt desert) in Clark County.

Ecological Stressors → **Important Habitat Effects** → **Expected Loggerhead Shrike Responses**

Ecological Stressors

Structural Change

- Off-road vehicle recreation
- Habitat conversion: urbanization, industrial/energy development, transportation corridors, catastrophic fires

Change in Processes

- Introduced weeds
- Climate change
- Prolonged drought
- Change in fire regime
- Ungulate grazing
- Plant pathogens
- Fluctuation in prey populations
- Introduction of (feral) pets

Important Habitat Effects

Habitat Loss

- Fragmentation and loss of *Yucca*/cholla cactus stands and salt desert sites
- Loss of shrub cover and substrate vegetation for large insects

Habitat Degradation

- Reduced shrub diversity, native herbaceous covers, litter cover, and cryptobiotic soils
- Increased mortality of *Yucca*/cholla and woody species
- Decreased water availability in soils
- Decreased invertebrate populations
- Higher prey fluctuations

Expected Loggerhead Shrike Responses

Nesting

- Loss of suitable nest sites
- Increased territory sizes
- Increased nest failure rate
- Increased nest predation
- Decreased reproductive output

Survival

- Longer travel for foraging
- Reduced foraging success
- Increased unpredictability of prey
- Stress response to loss of thermal shelters

Population

- Reduced recruitment of young
- Reduced site fidelity
- Decreased population size
- Fragmented population
- Increased population fluctuations

Recommendations for the Development of Indicators of Loggerhead Shrike Population Effects:
Multi-year nest study on territory sizes, locations, nests (and nest success, if possible) in randomly selected occupied sites in Clark County. Study of prey species in Clark County.
Long-term population monitoring of Loggerhead Shrike.

Appendix 4: Conceptual model of threats to the Gilded Flicker (primary breeding habitats of the species are *Yucca*/Mojave scrub) in Clark County.

Ecological Stressors → **Important Habitat Effects** → **Expected Gilded Flicker Responses**

Ecological Stressors

Structural Change

- Off-road vehicle recreation
- Habitat conversion: urbanization, industrial/energy development, transportation corridors, catastrophic fires

Change in Processes

- Introduced weeds
- Climate change
- Prolonged drought
- Change in fire regime
- Ungulate grazing
- Plant pathogens
- Fluctuation in prey populations

Important Habitat Effects

Habitat Loss

- Fragmentation and loss of *Yucca*/cholla cactus stands
- Loss of shrub cover

Habitat Degradation

- Reduced shrub diversity, native herbaceous covers, litter cover, and cryptobiotic soils
- Increased mortality of *Yucca*/cholla and woody species
- Decreased water availability in soils
- Decreased ground invertebrate populations
- Higher prey fluctuations

Expected Gilded Flicker Responses

Nesting

- Loss of suitable nest sites
- Increased territory sizes
- Increased nest failure rate
- Decreased reproductive output

Survival

- Longer travel for foraging
- Reduced foraging success
- Increased unpredictability of prey
- Stress response to loss of thermal shelters

Population

- Reduced recruitment of young
- Reduced site fidelity
- Decreased population size
- Fragmented population
- Increased population fluctuations

Recommendations for the Development of Indicators of Gilded Flicker Population Effects: Multi-year nest study on territory sizes, locations, nests (and nest success, if possible) in randomly selected occupied sites in Clark County. Determination of prey species and other habits in *Yucca* habitats. Long-term population monitoring of Gilded Flicker.