THE SAGE-GROUSE OF EMMA PARK – SURVIVAL, PRODUCTION, AND HABITAT USE IN RELATION TO COALBED METHANE DEVELOPMENT

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DECEMBER, 2005

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INTRODUCTION

Dramatic declines in the distribution and abundance of the Greater Sage-Grouse (*Centrocercus urophasianus*) over the past half-century have been documented throughout the western United States. Researchers estimate that the species has declined by as much as 47% during this time period. Furthermore, sage-grouse now occupy only 46% of the historic habitat (Connelly and Braun, 1997). Sage-grouse populations in Utah show similar trends and have declined by over 50% and now occupy 41% of historical habitat (Beck et al 2003). In Utah, the Greater Sage-Grouse is considered a Species of Special Concern on the State Sensitive Species List due to drastic decreases in abundance and distribution of the species in conjunction with specialized habitat requirements. Several petitions have been filed to protect the Greater Sage-Grouse under the Endangered Species Act. Federal listing of this species could have a major impact on the future management of private and public rangelands across the west.

Sage-grouse habitats consist almost exclusively of productive sagebrush communities (Braun et al 1977, Connelly et al 1991, Aldridge and Brigham 2002). Habitat loss and fragmentation are widely considered as the dominant reasons for sage-grouse declines (Kurley 1994, Fischer et al 1997, Connelly et al 2000). Sagebrush steppe communities across the western United States face various threats. Past range management practices aimed at eradicating sagebrush have fragmented many sagebrush communities. Furthermore, urban expansion and oil and gas development activities have increased in these habitats in recent years. Much of the high value sage-grouse habitat in the state of Utah exists as isolated fragments of sagebrush habitat with little potential for interchange between populations. Habitat loss or fragmentation on these isolated habitats could have significant impacts to these populations.

Little has been studied on the potential impacts oil and gas development may have on sage-grouse. Lyon and Anderson (2003) found that nest initiation rates of sage-grouse from leks with significant oil and gas development were lower than grouse from undisturbed areas, furthermore these grouse traveled farther from the lek to nest than grouse from undeveloped areas. Holleran and Anderson (2004) found lek attendance by males decreased dramatically in response to oil and gas development. Fischer et al. (1997) found that habitat disturbances can act to disrupt sage-grouse migrations and fragment existing habitats.

Oil and gas development has increased dramatically in the past decade. Domestic production of oil and natural gas is expected to continue to increase in upcoming years (Bay, 1989). Multiple efforts have been made to streamline the process for drilling on federal lands to increase domestic oil production (National Energy Policy, 2005). In recent years, much of this production is now occurring on sagebrush steppe habitat across the western United States. Geologists have recently discovered vast reserves of coalbed methane associated with the coal reserves that can be economically produced. In Carbon County, Utah gas development has begun in recent years with 963 developed wells and an additional 700 - 1000 wells planned for upcoming years. There are 358 wells that now occur within sage-grouse habitat with several hundred additional wells planned for the near future.

In 2001 a study was initiated to document sage-grouse habitat use by sage-grouse and determine the potential impacts Coalbed Methane development may have on a population of sage-grouse inhabiting the Emma Park area of eastern Utah. The study had the following objectives;

1. Identify and quantify Sage-grouse habitat characteristics.

2. Document Sage-grouse movements, production and survival in relation to Coalbed Methane Development in the Area.

3. Develop sound mitigation guidelines to protect sage-grouse populations during future development.

4. Identify potential habitat enhancement projects to benefit local sage-grouse populations.

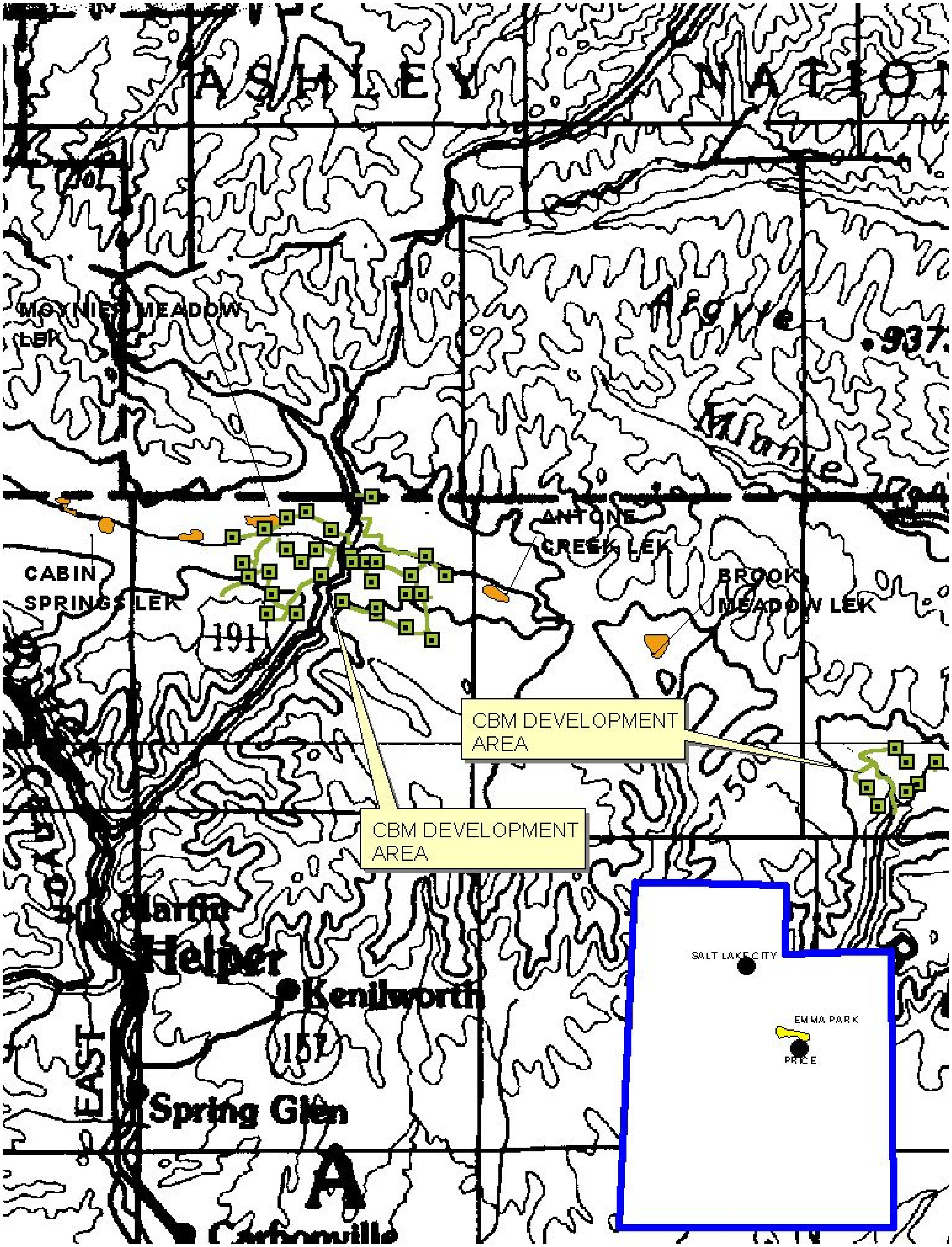
STUDY AREA

The Emma Park area is located in central Utah in western Carbon county and portions of eastern Utah and Wasatch counties. The Sage-grouse habitat in this area consists of 143,469 acres of which approximately 93% is privately owned. Elevations in the area vary from 7,000 to 8,500 feet. The area receives an average of 14.5 inches of precipitation annually, most of which occurs in the form of snow. Mountain big sagebrush (*Artemisia tridentata vaseyana*) is the predominate shrub species in the area. Isolated stands of Basin big sagebrush (*Artemisia tridentata tridentata*) and Rubber rabbitbrush (*Chrysothamnus nauseosus*) occur along the major drainages at lower elevations in Emma Park. Pockets of Quaking aspen (*Populus tremuloides*) and Douglas-Fir (*Psuedotsuga* menziesii) occur at higher elevations in the area. Domestic cattle graze the area during the summer months beginning in Mid June to Mid October.

There is a population of approximately 250 to 300 sage-grouse occupying the area. This sage-grouse population is largely non-migratory with summer and winter areas only a few miles apart, although there is a great deal of individual variation.

Significant coalbed methane development began in 2001. Much of the development is concentrated in a 5 mile by 5 mile area near the center of Emma Park and a 2 square mile area near the east end of Emma Park (Figure 1). Well spacing in this area is one well per 160 acres with a total of 40 active wells drilled in the area during the study. An additional 100 wells are planned for the same area in upcoming years. Periphery areas outside of these areas of concentrated development have not seen significant development and were used for comparison. Five active sage-grouse leks are found in the area. The Moynier Meadow and Antone Creek leks occur within 1 km. of significant Coalbed Methane (CBM) development activities. The Brook Meadow and Cabin Springs leks are located a minimum of 4 kilometers away from these areas of concentrated development.

Figure 1. Map of Emma Park, Carbon County Utah Showing Active Sage-Grouse Leks and Areas of Concentrated Coalbed Methane Development.



METHODS

Capture. A total of 20 adult hen sage-grouse were captured and fitted with a 14 gram necklace style radio transmitter (Advanced Telemetry Systems, 2000). Adult hens were targeted because they were the most likely to nest during the 18 month battery life of the transmitter. Ten hens were captured from the 2 leks, with significant CBM development (ie. wells and/or well roads within 400 meters). An additional 10 grouse were captured from the 2 leks where no CBM development has occurred within 4 km of the lek. Grouse were captured using the spotlight method described by Wakkinen et al. (1992) with minor variations. An ATV was used instead of a truck when high snow and shrub cover and numerous eroded headcuts prevented the use of a truck. We also captured grouse with two observers walking in terrain where vehicle access was impossible. One person would hold a battery pack, spotlight and portable radio, while the other person would hold the net and approach roosting grouse. This method was only feasible in localized areas where grouse were known to roost. Fatigue prevented searching large areas using this method. An additional variation included the use of a net gun (CODA Manufactures, 2000). This was most feasible on nights where there was a bright moon or when large groups of grouse were roosted together preventing a close approach. On these evenings the net gun could be deployed from 4 to 10 meters away improving capture rates.

Monitoring. Monitoring of radio collared sage-grouse was done once a week during May and June and once every 2 weeks for the remainder of the year. One fixed-wing radio telemetry flight was conducted each month during much of the study. The remainder of the locations were achieved from ground telemetry efforts. Each grouse location was marked inconspicuously with colored flagging for vegetation sampling to be done at a later date. Great care was taken to not flush nesting hens. The few that were accidentally flushed from the nest by the observer always abandoned the nest. During the nesting season, observers would circle around sage-grouse locations and deduce the exact nest location based on triangulation and an assessment of suitable nesting cover. These areas were visited after fledging or nest failure to determine the exact nest location and fate.

Lek Counts. Each sage-grouse lek was visited a minimum of three times between March 20 and May 5 each year of the study. Counts were done within the first hour of sunrise. The total number of cocks and hens at each lek was noted and the maximum count of cocks/lek was used for analysis.

Vegetation Sampling. Specific vegetation variables were collected at each sage-grouse location as well as at randomly located points across the study area. The line intercept method was used to estimate shrub cover (Canfield, 1941). Four 25 meter transects were placed at each plot (one in each of the cardinal directions). The point quarter distance method was used at 9 locations in each plot to estimate shrub density, height, and age composition. Ground cover was estimated using methods described by Daubenmire (1959) at the same 9 locations. Lateral cover was measured using a 1 meter Jones cover board from 2, 5, and 10 meter distances in each of the cardinal directions (Jones, 1968). A number of macrohabitat variables were collected at each plot. These included the estimated distances to the nearest wet meadow, road, gas well, stream, tree, and powerline and how many of each occur within a 400 meter radius.

Pellet group and track transects. A 300 meter transect was placed parallel to the road at distances of 5, 50, 100, and 200 meters from the nearest road. These transects were placed in 3 different treatment types; heavily used CBM roads (3 -20 trips per day), existing lightly used roads (< 3 trips per day), and roadless areas. These transects were placed in areas of comparable sage-grouse habitat and abundance. However, it was later noted that no sage-grouse were using the roadless transects and these were dropped from the analysis. Sage-grouse pellet groups were counted along a 1 meter belt along these transects as well as the number of sage-grouse tracks that intercepted the transect line. Tracks could only be reliably noted when fresh snow conditions existed. Each transect was read a minimum of 4 times each winter between January and March.

False nests. Fake nests were placed in suitable sage-grouse nesting habitat in order to determine nest predation rates and nest predators. Six nests were placed in both undeveloped and developed areas in both 2004 and 2005. Each nest contained 4 small chicken eggs and was concealed under a sagebrush plant to mimic a sage-grouse nest. Track plates constructed of plexiglass with coal dust and contact paper surrounded each nest to document the tracks of any animals investigating the nest. Nests were monitored twice a week between May 25 and July 5, 2004 and 2005.

RESULTS

Survival. Annual survival was estimated by determining the percentage of total grouse that survived beyond one year. Adult survival was low during the course of the study. This was due in part to severe drought. Annual survival of adult sage-grouse was 47% with an average life span of only 38 weeks. Adult survival differed substantially between areas with CBM development and those without. Annual survival was five times greater in areas with no development. Although annual survival varied from year to year it was consistantly higher in undeveloped sites. The average life span of adult grouse in the study was three times longer in undeveloped areas as those found in CBM development (Table 1). The differences in average life span between treatments were statistically significant ($t = -2.29$ $p = 0.036$).

Table 1. Comparison of Survival of Adult Sage-Grouse In Areas with Coalbed Methane (CBM) Development to non CBM sites.

	CBM Development	No Development
Sample Size (n)	8	11
Annual Adult Survival	12.5%	73%
Average Life Span (weeks)	18.5	54
Min/Max Life span (weeks)	3/58	4/111

Mortality Factors. Predation was the primary source of known mortality in adult sage-grouse in the study. Forty-six percent of all known mortalities was a result of coyote

(*Canis latrans*) predation. An additional 38% occurred as a result of avian predators, primarily Golden Eagles (*Aquila chrysaetos*). The remaining mortalities were capture induced or could not be determined. Two adult hen sage-grouse captured in April were choked by the radio collar in July and died. In each case a large bolus of succulent forbs was found in the carcass immediately above the radio collar. This has been documented in various other studies and the manufacturer has since made several modifications to alleviate this source of mortality (Advanced Telemetry Systems, 2005). Two sage-grouse lost their radio transmitters after several months of use. The eventual fate of these grouse are obviously not known and not factored in to mortality estimates. Mortality factors differed by treatment (Figure 2). Coyotes were the major mortality source in undeveloped areas, whereas eagles were more common in the sites with CBM development.

Most mortalities of radio collared hens occurred during the nesting and early brood rearing season. This trend was consistent in both developed and undeveloped areas (Figure 3). High mortality rates during this time period would suggest that hens are usually killed by predators in the early brood rearing phase. Hens are very conspicuous in attempting to lure predators away from young chicks at this time. Our data suggest that this was not always the case. The majority of mortalities during the nesting brood rearing season (67%) occurred when coyotes killed incubating hens on the nest. In many cases the remains of the grouse would be found within 3 meters of the nest with the eggs left untouched.

Figure 2. Mortality Factors Among Adult Sage-Grouse in Developed Versus Undeveloped Areas.

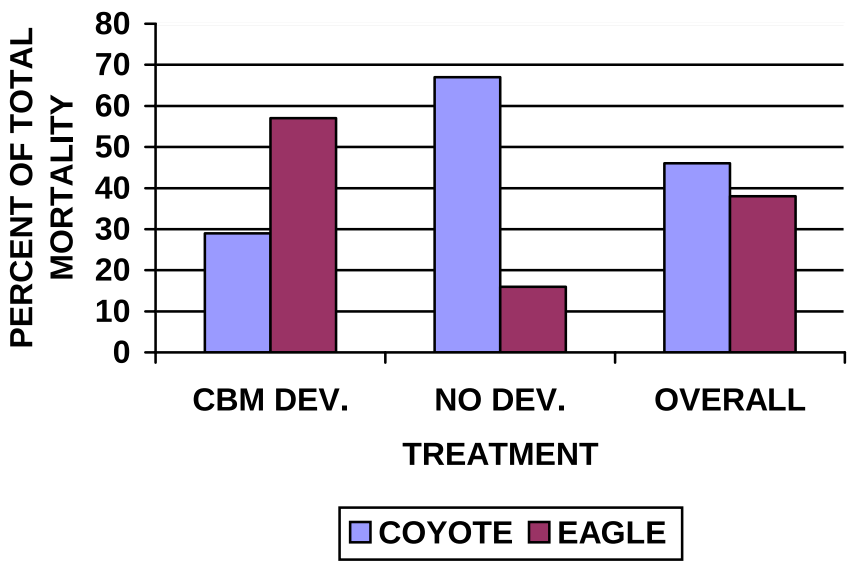
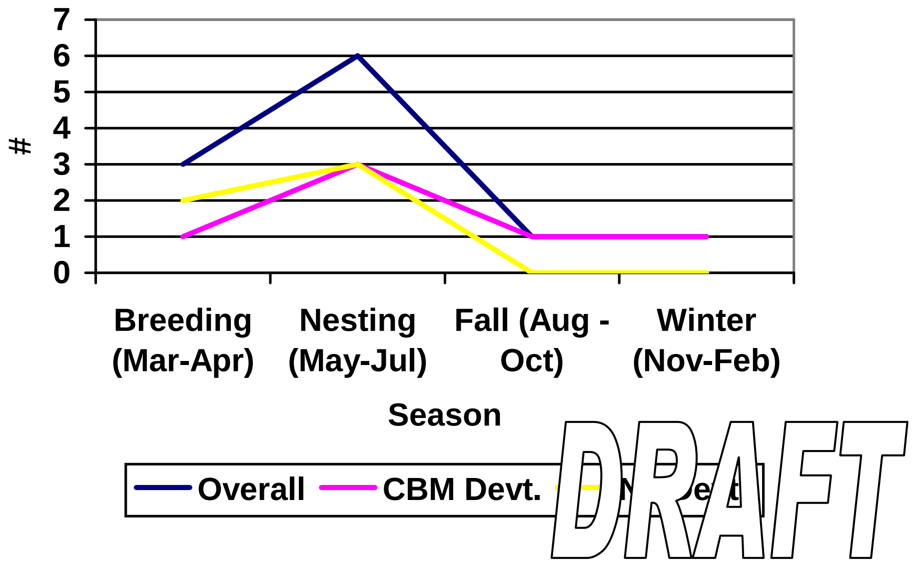
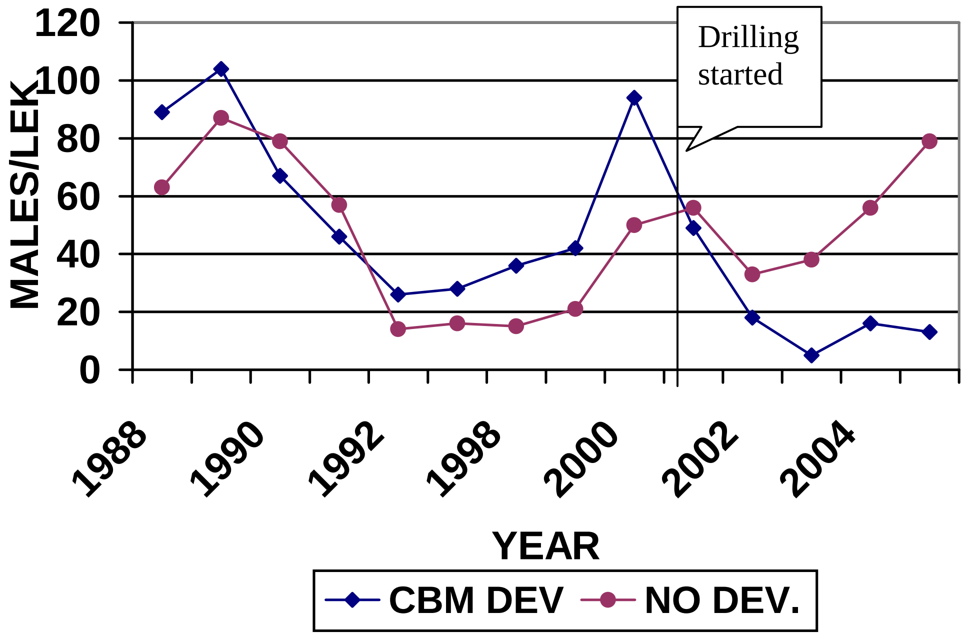


Figure 3. Mortalities of Adult Sage-Grouse Hens by Season, 2000 – 2005.



Lek Attendance. Annual spring lek counts on leks in the area were completed and compared before and during the duration of the study. The estimated population of sage-grouse in the Emma Park area declined by 37% during the 4 year duration of the study. Mean annual declines in male sage-grouse at CBM leks were –44% versus a 15% increase in undeveloped leks during the same time period. These differences were statistically significant ($t=-3.5$, $p = 0.001$). Figure 4 show these trends noting when CBM development was initiated in April of 2001. Despite significant declines in 2000 to 2003, the sage-grouse population in the area has rebounded somewhat, particularly in undeveloped areas with a return of normal precipitation patterns in 2004 and 2005. This is not the case in the developed leks. Lek counts suggest that male sage-grouse were displaced from leks with CBM development and colonized new leks in the surrounding area. The Moynier Meadow lek had a drilling pad within 200 meters of the lek in 2001 (See cover photo). Once construction was complete the pumpjack installed at the well pad put out noises at 45 decibels at a distance of 200 meters (70 decibels at the wellpad 20 meters from the pump). Male attendance at this lek dropped dramatically during construction in 2001 and the lek was abandoned in 2003. Grouse were subsequently found strutting at 2 "new" leks found 3 and 5 miles away from the previous lek and from CBM development. Radio collared hens attending these leks followed the same trends as the males. These 2 "new" leks did not have males strutting in previous years. Furthermore in 2004, the pumpjack at the wellsite on the Moynier Meadow lek needed a workover and was not functioning during April. During this time there was no noise coming from the well. Grouse recolonized the lek and used it in the spring of 2004 for the first time in 2 years.

Figure 4. Trend in Sage-Grouse Lek Counts 1988 – 2005 on Leks With and Without CBM Development (Development Initiated in 4/01)

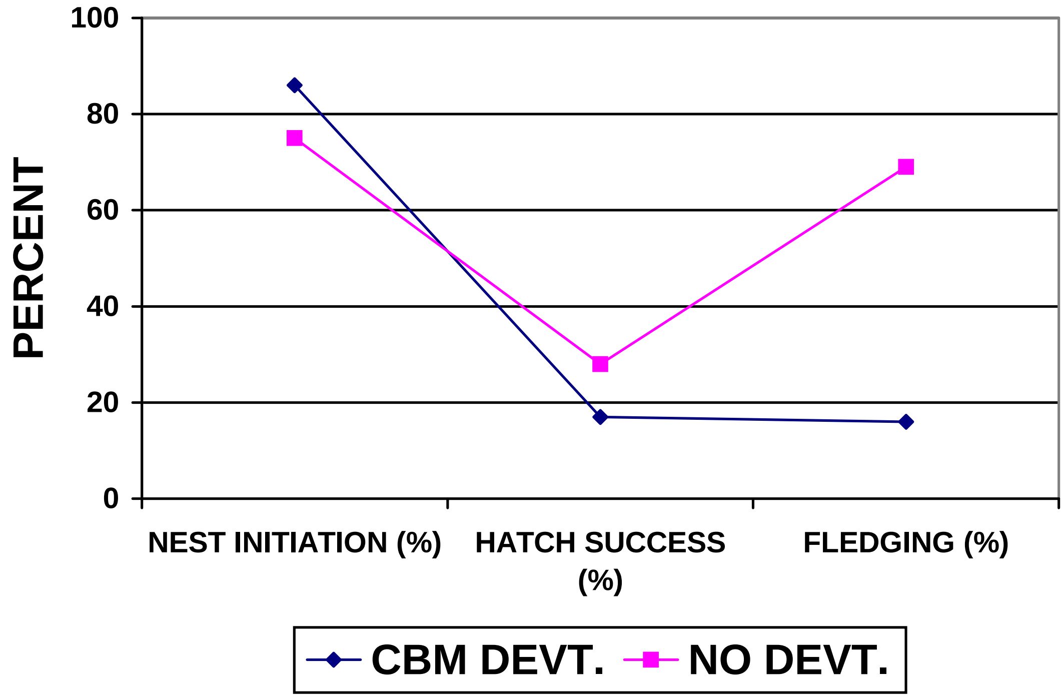


<u>Production.</u> Breeding activities began at each of the leks by March 20 in each year of the study and usually ended by May 5. Peak attendance by males at each lek occurred between April 15 and April 20 each year (n = 24). Peak attendance by females was slightly earlier and occurred near April 11 on average. Hen attendance at leks dropped dramatically after April 20 of each year while males continued to occupy and strut at leks until as late as May 5.

Nest initiation occurred each year between April 23 and May 18 for all first nest attempts (n = 12). Peak nest initiation (when hens begin incubating) occurred between May 1 and May 8. Second nesting attempts by hens began as early as May 4 and extended until June 6. There was not a single successful nest by renesting sage-grouse during the course of the study. Hatching of all successful nests occurred between June 4 and June 6 during the duration of the study.

During the course of the study 83% of all adult hens initiated a nest each year (n = 24). Some hens attempted several nests each year. The percentage of these nests that hatched was 25%. The number of chicks reaching 50 days old or more per radio collared hen was 0.52. Differences existed between hens from CBM developed areas and those without development. Although a higher percentage of hens initiated nests in developed areas, these hens had both lower hatching success (percent of initiated nests that hatched) and fledging success (percent of hens with chicks surviving more than 50 days) than did grouse from undeveloped sites (Figure 5).

Figure 5. Comparison of Nest Initiation, Hatching and Fledging Rates by Adult Hens from CBM Developed Sites and Undeveloped Sites, 2001 – 2005.



Nest fates Each failed nest was investigated in order to determine the cause of nest abandonment or failure. In most cases the exact nest fate was difficult to determine. In 61% of all failed nests, there was no clear evidence as to what depredated the nest. Nest fates could accurately be determined only when some egg fragments were found along with tracks or scat in the immediate vicinity. Mammals accounted for 5 of 13 known depredated or abandoned nests. In two of these cases, coyotes killed incubating hens on the nest and later ate the eggs. The remaining 3 instances were depredation of the nest by either coyotes or ground squirrels, which was subsequently abandoned by the hen. The eight remaining nest fates are unknown. It is likely that one nest was abandoned as a result of being flushed by the observer. Depredation of sage-grouse nests by corvids was assumed to be a major contributing factor as corvids were quite common in the area. Corvids leave very little sign at depredated nests. However, there were no confirmed depredation of sage-grouse nests by corvids.

Fake nests. Fake sage-grouse nests were placed throughout the study area in order to accurately determine potential nest predators and nest predation rates of sage-grouse. Nests were placed in both CBM and undeveloped treatments but were combined for analysis due to extremely low sample sizes. Track plates at each nest were designed to reveal the tracks of any animal picking up eggs from the nest. Track plates had variable success. Rain would wash away any track impressions left on the plate in some cases. High winds would also cover and dry up the track mixture and not allow a legible track to be left on the plate.

Successful “fake” nests were nests that were not depredated during a 40 day period which would mimic the egg laying and incubation period of sage-grouse. By this definition, 45% of all fake nests were “successful” (55% depredation rate). Nest success at fake nests was higher than that of actual sage-grouse during the course of the study (25%) but lower than hatching success rates during 2004 and 2005 (67%) when precipitation was above average in the study area. Depredation of false nests may have showed a different pattern than actual nests. Corvids accounted for 60% of all depredated nests (n = 6), while coyotes (n = 2) and ground squirrels (n = 2) comprised 20% each of all depredated nests. In actual sage-grouse nests mammals made up all of the known nest predation, however, 61% of all nest fates could not be determined. The predominance of corvids as nest predators of fake nests suggests that corvids may have played a significant role in sage-grouse nest predation.

Dispersal/displacement. Equal numbers of hen sage-grouse were captured in CBM and undeveloped sites. Despite this, only 18% of all total observations (n = 123) were located inside the core CBM development areas, suggesting grouse left those areas. Of the grouse captured inside CBM development areas, only 52% of all subsequent locations remained inside CBM development areas. Conversely, of the grouse captured outside CBM development, only 3% of the observations were found inside the core CBM development area, suggesting avoidance of developed sites (Figure 6).

Sage-grouse in the Emma Park area by most definitions are considered a non-migratory population, although individuals within the population showed migratory characteristics. Some grouse would migrate west over 23 km to wintering areas. There was also evidence of sage-grouse from a neighboring population on Anthro Mountain migrating nearly 40 km to summer on Emma Park (Coleman 2004). Although the majority of grouse did not move great distances to winter and summer ranges there was a distinct pattern in where sage-grouse would breed, nest, summer, and winter each year. Nest sites were located anywhere from 80 meters to 12.8 kilometers from leks and averaged 3.0 km (n = 18). Only 67% of all sage-grouse hens nested within 2 miles (3.2km) of leks. A 5 mile (8.1 km) buffer around each lek was necessary to encompass the vast majority of nest sites (94%). Summer adult and brood rearing sites tended to be in the general vicinity of nests and slightly farther away from leks. Sage-grouse hens traveled the greatest distances (ave. = 10.95 km) to winter sites than any time of the year.

Sage-grouse hens caught at leks in the CBM development area traveled greater distances to nest sites, summer brood rearing sites, and winter sites than sage-grouse in the undeveloped area (Table 2). None of these differences were statistically significant. Despite greater travel to these sites overall home range sizes were smaller for grouse caught in CBM areas (10.2 km^2 n=4) than those from undeveloped sites (11.8km^2 n = 6) although these differences were not statistically significant. Home range sizes were highly variable. Appendix A delineates individual home ranges for each collared grouse. Sample sizes were not sufficient to compute all of the seasonal home ranges. Summer home ranges varied from 0.1 km^2 to 7.2 km^2 with summer ranges averaging slightly higher for grouse from undeveloped leks (3.0 km^2 versus 2.38km^2 for CBM grouse).

Table 2. Mean distance (km) Traveled from Leks for Sage-Grouse During Different Seasons.

	LEK TO NEST	LEK TO BROOD SITE	LEK TO WINTER
CBM DEVT.	3.48	6.35	6.83
NO DEVT.	1.86	3.77	5.49

In an effort to determine if sage-grouse were avoiding high traffic CBM development roads we compared the distance to low traffic (ave. < 2 trips/day) two track roads versus high traffic improved CBM roads (ave. = 3 to 20 trips/day). Two sample t-tests showed that the average distance to a low traffic road did not differ between CBM development areas and undeveloped areas for sage-grouse nest sites, brood sites, fall sites, and winter sites. This suggests that either low traffic roads are uniformly distributed across sage-grouse habitat in the area and/or that sage-grouse show no preference or avoidance for low traffic roads. Sage-grouse were found at greater distances from high traffic roads than corresponding low traffic roads within the CBM development area and when compared to sage-grouse in the undeveloped areas (Table 3). Mean distances from high traffic roads were higher for nest sites ($t = 2.16$, $p = 0.046$), non- nesting sites ($t = 2.64$, $p = 0.017$), summer brood sites ($t = 4.32$ $p = 0.0002$), and winter sites ($t = 3.21$, $p = 0.003$).

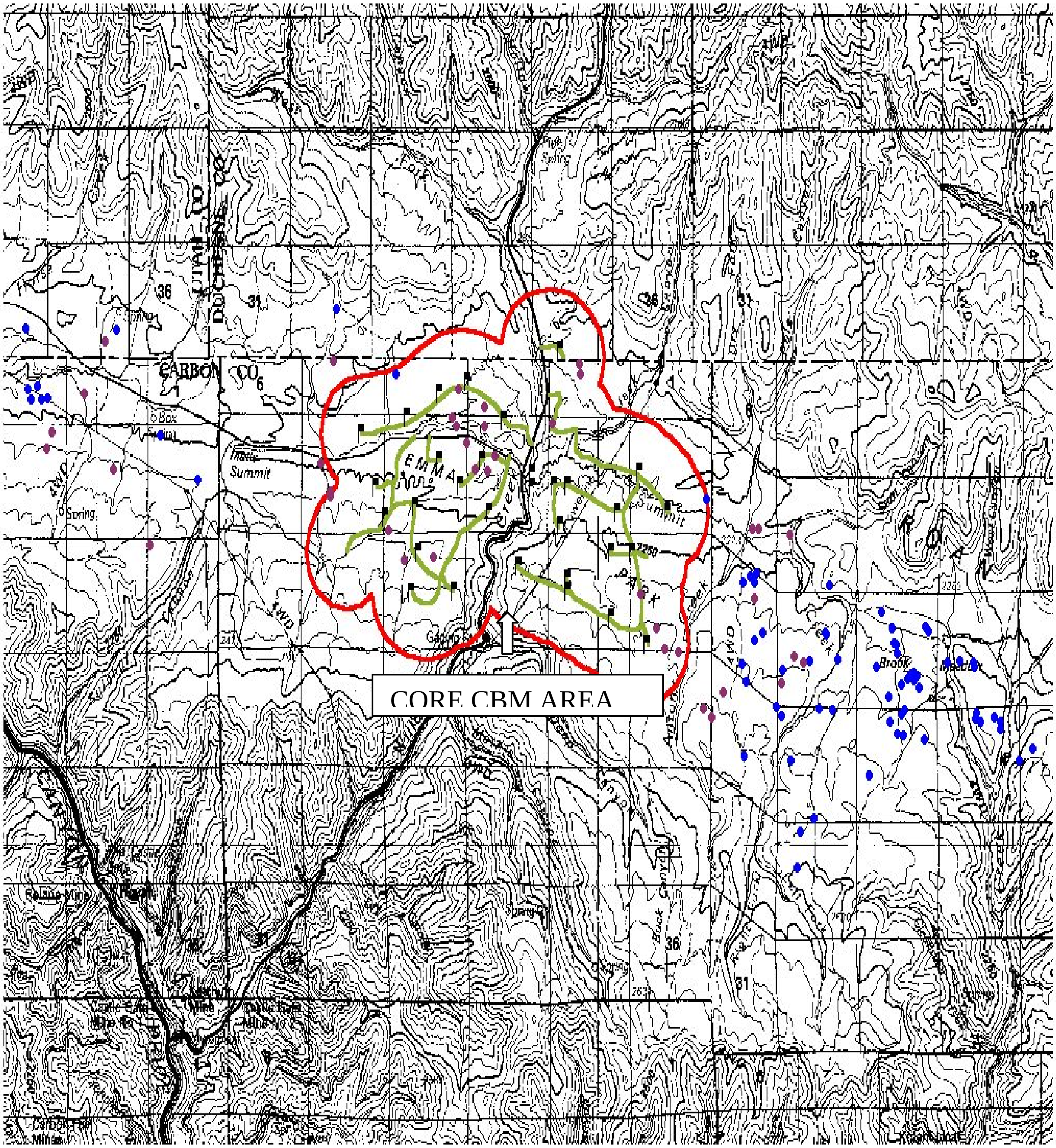
Table 3. Mean Distances (meters) From Sage-Grouse Locations to High and Low Traffic Roads in CBM Development and Undeveloped Areas

	Dist. to Low Traffic Road in CBM area (m)	Dist. To High Traffic Road in CBM area (m)	Dist. To Low Traffic Road in Undeveloped Area
Lek Sites (n = 10)	257	257	145
Nest Sites (n = 6)	239	2284	355[b]
Non-nesting Hens (n=8)	354	1034[a]	328[b]
Summer/Brood Sites (n = 12)	483	2646[a]	267[b]
Winter Sites (n=6)	316	1187[a]	468[b]

[a] denotes statistically significant differences in means between low traffic and high traffic roads within the CBM area with alpha = 0.05.

[b] denotes statistically significant differences in means between distances to high traffic roads in CBM sites and corresponding low traffic roads in undeveloped sites. Alpha = 0.05.

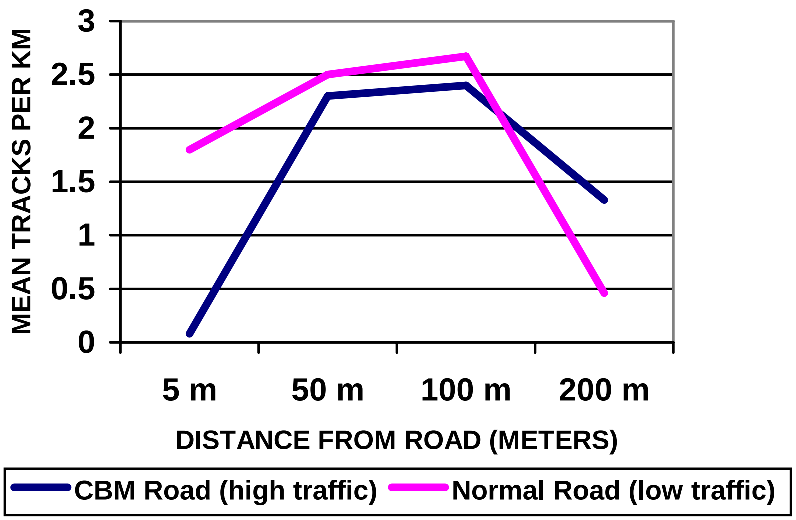
Figure 6. Map Depicting Sage-Grouse Locations in relation to CBM Development. Blue locations denote grouse caught at undeveloped leks, purple locations denote grouse captured from CBM leks.



Track Transects.

Sage grouse tended to avoid areas immediately adjacent to established roads during the winter months (Figure 7). These tendencies were more pronounced on transects that were parallel to heavy traffic CBM development roads (3 - 20 trips per day). Where there was very little use of the area within 50 meters of the road. This suggests avoidance by grouse of high traffic areas typical of construction of new well sites. The number of tracks observed peaked at a 100 meter distance from roads in both treatments and declined substantially by the 200 meter distance. This is likely a result of the nature of the small patches of habitat inhabited by sage-grouse during the winter months. Areas that were 200 meters from an established road were likely at the edges of sagebrush habitat near adjacent pinyon-juniper cover or a different sagebrush type which presumably would be less favorable sage grouse habitat.

Figure 7. Mean Number of Sage-Grouse Tracks per Kilometer near High Traffic CBM Roads versus Low Traffic Roads.



Vegetation Sampling

Each sage-grouse observation was overlaid on digital vegetation coverages created by UDWR to assess habitat type selection by sage-grouse (UDWR, 2005). All locations were assigned to one of 5 major habitat types; mountain big sagebrush communities (the predominate habitat type), mixed shrubs type (mixed stands of mountain big sagebrush with other browse species), Basin big sagebrush/ Rubber rabbitbrush type (typical of the major basins of Emma Park), wet meadows, and finally habitats that had been chemically or mechanically treated in the past 10 years. Bonferonni Simultaneous Confidence

Intervals were calculated to assess preference or avoidance of sage-grouse of these vegetation types by season (Byers et al. 1984) (Table 4).

Table 4. Proportions of Seasonal Sage-Grouse Locations in each Habitat Type. Asterisk denotes Use is Statistically Different than Available.

	Mt. Big Sagebrush	Mixed Shrubs	Basin Sage/ Rabbitbrush	Wet Meadows	Treated Sage
Available	0.772	0.088	0.024	0.035	0.082
Nest sites	.78 (.5 - .96)	.07 (0 - .24)	.14 (0 - .38)	0	0
Brood sites	.58 (.37 - .79)	.17 (.01 - .34)	0	.12 (0 - .25)	.12 (0 - .25)
Fall sites	.73 (.5 – 1.0)	.13 (0 - .31)	0	.04 (0 – 0.2)	.13 (0 - .31)
Winter sites	.5 (.26 -.74)*	.07 (0 - .19)	.25 (.04 -.46)*	.11 (0 - .25)	.07 (0 - .19)
All sage-grouse	.62 (.5 - .74)*	.12 (.04 -.2)	.08 (.01 - .15)	.08 (.01 -.14)	.09 (.02- .16)

Different habitat types were more important during certain times of the year. In most cases habitat types were used in proportions similar to that which was available indicating little habitat type selection. The exceptions were the preference of basin big sagebrush/rabbitbrush stands by wintering sage-grouse over mountain big sagebrush stands. This habitat type typically had taller brush that would be available for food and cover despite heavy snow accumulations. Nesting sage-grouse tended to use Mountain big sagebrush and mountain brush communities for nesting substrate. The wet meadow habitat type was used in greater proportion than was available by brood groups, although this selection was not statistically significant. Specific attention was paid to use or avoidance by sage-grouse of treated habitats in an effort to assess the impacts or benefits of future sagebrush treatment projects. Sage-grouse used treated habitats in proportion to that which was available indicating little selection or avoidance with the exception of nest sites which were never found in treated areas.

Vegetation variables were collected at most sage-grouse locations and at randomly located plots across the study area. Means of habitat variables were used to define microsite habitat selection by sage-grouse when compared to random locations. Statistically significant differences in means are noted in Tables 5a and 5b.

Sage-grouse nest sites in Emma Park were located in sagebrush stands in relatively close proximity to numerous wet meadows. Sagebrush cover in nest stands averaged 25.5 percent with an average height of 0.64 meters with above average shrub density. Each of these three variables was statistically different than the same variables from random plots. Despite relatively dense stands of sagebrush with high cover, nest stands had higher than average herbaceous cover of grasses, forbs and understory shrubs although these differences were not statistically significant.

Sage-grouse brood locations were either in or in close proximity to numerous wet meadows although these variables were not statistically significant. Brood sites had lower shrub density and higher forb cover than random sites. The amount of Broom snakeweed cover was also significantly less than snakeweed cover at random sites suggesting an avoidance of sites dominated by this annual weed.

Summer non brood locations appeared less selective than other use types. Summer non brood groups were often found in open areas previously mechanically treated. Means of variables were very similar to those found at random sites with only one significant difference in means (herbaceous grass cover).

Winter sage-grouse locations were similar to nest sites. They were most often found along the lower basins of Emma Park where the water table was closer to the surface and taller Basin big sagebrush and Rubber rabbitbrush were found. Winter use sites had significantly higher sagebrush cover (38%), sagebrush height (0.83 meters), and shrub density (34,384 plants/ha) than random sites. These variables describe dense sagebrush habitats that provide tall sagebrush cover when snow covers much of the low lying vegetation.

Table 5a. Means of Macrohabitat Variables and Understory Vegetation Cover Comparing Seasonal Use Locations to Random Locations.

Type	Dist. To Meadow(m.)	Dist. to Stream(m)	# of meadows	% grass cover	%Forb cover	%Shrub cover	# of trees
Random	406	441	1.6	15.3	11.9	12.2	45.9
Adult Summer	373	541	1.5	27.7[a]	13.5	11.5	28.2
Winter	450	171[a]	0.7	7	4	12	16.2
Brood	259	394	2.5	28.2	22.3[a]	8.2	211
Nest	281	374	2.8	17.4	12	14.2	26

[a] denotes a significant difference in means between seasonal locations and random locations.

Table 5b. Means of Shrub Density, Height and Cover Values Comparing Seasonal Use Locations to Random Locations.

Type	Shrub Height (m)	Shrub Density Stems/ha	Sage Density Stems/ha	ARTR cover	ARNO cover	CHNA cover	GUSA cover	AMAL Cover
Random	.46	16231	17013	12.9	2.5	1.5	0.9	0.2
Adult Summer	.47	15537	21693	12.9	0.4	1.3	2.2	0.2
Winter	.83[a]	34384[a]	25957[a]	38.3[a]	0.0[a]	5.5	3.0	0
Brood	.41	3664[a]	3913[a]	9.7	0.5	0.8	0.2[a]	0
Nest	.64[a]	26867[a]	24048	25.5[a]	0.5	4.0	0.9	1.1

[a] denotes a significant difference in means between seasonal locations and random locations.

DISCUSSION

Although results from this project provide interesting trends in the Emma Park Sage-Grouse population, broad conclusions from this study should be cautiously made. Sample sizes in most cases were not sufficient provide enough data to show statistically valid results. An additional shortfall is the lack of predevelopment data. The study examines sage-grouse from 2 areas of comparable habitat quality, one with CBM development and one without. An ideal study design would have evaluated sage-grouse habitat use patterns in both areas prior to development and compared those values with data from sage-grouse in the same area after development had initiated.

Both adult sage-grouse survival (47%) and nest success were low during the course of the study (25%). Adult survival rates were within the range of those found by Wallestad (1975) and Connelly et al. (1994) but were on the low end. Likewise nest initiation rates, hatch rates, and fledging success were lower than most studies, even when compared to studies completed during the same time period (Schroeder 1997, Burkepile et al. 2004, Coates and Delehanty 2004, Kolada et al. 2004). The only study with comparably low reproductive output was that of Lyon and Anderson (2003) which also examined sage-grouse inhabiting areas with significant oil and gas development. Much of this can be attributed to extreme drought in the area through much of the duration of the study. Annual precipitation was less than 55% of normal precipitation levels in 2001 – 2003. During those years spring and summer rainfall was particularly low with precipitation being less than 20% of normal (NRCS, 2005). Forb and insect availability during these dry conditions would have been limited at best which can contribute to lower survival of hens and chicks (Hanf et al 1994, Fischer et al 1996).

Distinct differences in survival and nest success were found between CBM development areas and undeveloped areas. Grouse from undeveloped areas showed trends comparable to the literature and had significantly higher rates than grouse from CBM sites for annual survival (73% vs. 12%), hatching success (30% vs 18%), and fledging success (70% vs. 18%). Most adult mortality was a result of predation during nesting and early brood rearing periods. Road networks, power lines and construction facilities associated with CBM development could provide more efficient travel lanes for coyotes and additional perch sites for Golden Eagles which could lead to higher predator efficiency in these areas. Both coyotes and Golden eagles are abundant in both treatments. Two known Golden eagle nests can be found in the study area (UDWR, 2005)

Higher predator efficiency by coyotes and eagles may have also led to lower nest success rates on CBM sites as well. Common ravens have been shown to be a significant nest predator (Niemuth 1992, Vander Haegen et al 2002, Baxter et al 2005) Vander Haegan et al (2002) found that nest predators such as Common ravens and magpies were 9 times more abundant and effective in fragmented habitats than in corresponding undisturbed habitats. Although no nest predation by ravens was documented on actual sage-grouse nests in this study, 60% of the nest predation at fake nests was by ravens. This suggests that corvids could play a significant role in nest success of sage-grouse particularly in areas fragmented by Coalbed Methane Development or by other vegetation manipulation practices.

Trends in survival and brood production merits concern. Although based on a low sample size, these trends suggest sage-grouse populations in areas of CBM development are decreasing despite stable to increasing populations from surrounding undeveloped areas. With proliferation of CBM development in sage-grouse habitat a larger proportion of the available sage-grouse habitat could be fragmented and show similar survival and production trends as found here. Furthermore, grouse from other populations nest at times in this area. Impacts could extend beyond the immediate area of development. These impacts if validated could have serious long term ramifications for sage-grouse populations.

Fischer et al. (1997) found that habitat disturbances such as fire disrupted sage-grouse migration patterns. This could act to fragment the existing sage-grouse habitat. CBM development could have a similar role in disrupting sage-grouse habitat use patterns. Sage-grouse abandoned leks that were within 250 meters of a CBM well. Lek abandonment in this case appeared to be associated with the noise associated with the well rather than vehicle traffic to and from the well. This well emitted more noise than most wells in the area (45 – 50 decibels at 200 meters away versus 37.6 decibels for surrounding wells). Sage-grouse recolonized the lek while it was down for maintenance in 2004 despite regular if not increased vehicular traffic to the site. The noise levels (> 45 db) associated with wells within 250 meters of the lek disrupted breeding activities, presumably because well noises did not permit grouse to hear vocalizations during breeding activities. Lek attendance in CBM areas declined markedly (-44%) when compared to undeveloped sites (+15%) during the same time period. Holleran and Anderson (2004) documented similar declines as lek attendance decreased by 32% in areas within 2 miles of a CBM well. Braun (1986) suggested that declines in strutting males at leks near development were a result of poor recruitment of yearling males from the previous year. This suggests development activity near leks may indirectly impact nest success and brood production.

Increased vehicle traffic associated with CBM development also influenced sage-grouse habitat use patterns. Wintering sage-grouse flocks avoided areas within 50 meters of high traffic CBM roads despite relatively small patch sizes of suitable winter habitat adjacent to these roads. Summer nesting and brood rearing sites were also located from 3 to 9 times farther away from high traffic CBM roads than low traffic roads. Lyons and Anderson (2003) found that sage grouse from CBM developed areas traveled twice as far to nest and brood sites than undisturbed sage-grouse. They suggested these greater travel distances were a result of medium traffic (<12 trips/day) during breeding and early nesting phases. Sage-grouse are often found along low traffic roadways foraging in twilight hours. Grouse often flush as a vehicle approaches. The regular traffic patterns of CBM roads (3 to 20 trips/day in our study) particularly during early construction phases may lead to grouse avoiding these areas altogether despite preferable habitat. This acts to further fragment existing sage-grouse habitats and reduce the available habitat.

The seasonal habitat requirements of sage-grouse are well documented (Connelly et al 1991 and 2000, DeLong 1995, Huwer et al 2004). These habitat requirements were validated on Emma Park. Nesting sage-grouse selected mountain Big sagebrush stands with moderate canopy cover (25%) and sagebrush height (64cm) with adequate understory production. Brood rearing areas tended to be in or in close proximity to wet meadows where grass and forb (and presumably insect) production was greater. Winter habitats were located in microsites with high shrub cover (38%) and height (83cm). Habitat selection did not differ between CBM and non-CBM sites suggesting habitat quality was the same throughout the study.

Efforts should be made to protect all aspects of sage-grouse habitat. Nesting and brood rearing habitats appear to be the limiting habitats to sage-grouse in the area. Range management practices that maintain large stands of sagebrush with moderate canopy cover and productive grass and forb ground cover should be encouraged. Wet meadow areas tend to be areas where livestock and big game tend to congregate and potentially overutilize. Care should be taken to maintain healthy wet meadows by carefully monitoring utilization. These practices coincide with sound livestock production practices. A common approach among range managers is to remove large acreages of sagebrush through mechanical or chemical means to improve forage production for livestock. The benefits of these treatments are variable. Grass production is improved, but in many cases the area is invaded by dense stands of Rubber rabbitbrush several years after the treatment. While sagebrush treatment is often necessary to provide a mosaic of age classes of sagebrush in the area, care should be taken to not take large blocks. Nesting and wintering grouse in this study made no use of these areas. Fall flocks were the only groups that tended to prefer these treated areas. Bunting et al. (1987) suggested not treating more than 20% of the total area within a 20 year period which represents the recovery time of mountain big sagebrush. The best current estimate is that around 10% of the acreage has been treated in recent years.

Habitat use patterns can be used to model known and potential seasonal sage-grouse habitats (Appendix C). These habitats should be used in analyzing impacts of future CBM development or other management practices. Wet meadows and riparian habitats were a limiting factor particularly during the dryer years of this study. Sage-grouse use of areas with numerous wet meadows was pronounced during the late summer months. Grouse from various areas would congregate in localized areas. The Kernal Home Range (citation) constructed for all non-lek grouse locations highlights the importance of these late summer habitats as virtually all of the identified core use areas include these wet meadow complexes (Figure 10). Proposed future CBM development is overlaid on Figure 10. Great consideration should be given to minimizing and/or mitigating development in these core use areas given the potential fragmentation issues CBM development creates. Other management practices such as changes in grazing regime, herbicide or mechanical treatment should also be carefully considered in these core use areas.

MANAGEMENT RECOMMENDATIONS

1. Noise levels at any leks should be less than 40db. Wells should not be located within 1500 meters of active leks. Where wells already exist inside this buffer, appropriate mufflers or fencing to reduce noise levels should be added.
2. Avoid CBM development or vegetation treatment in the core use areas shown in Figure 10. Furthermore an 8 km buffer around each lek was necessary to include over 90% of the nests in the area. This buffer would include all of the core use areas mentioned.
3. Restrict traffic near leks from 5 am to 10 am during March 15 through May 10 to reduce disturbance at leks.
4. When wells are to be placed in sage-grouse habitat, select dry ridges or previously treated sagebrush over wet meadows, ephemeral stream channels, and shallow basins with good sagebrush cover.
5. A 50 meter buffer along all heavy traffic roads should be used to calculate habitat lost due to development particularly in winter sage-grouse habitats.
6. Where possible, new roads and wells should be constructed in adjacent pinyon-juniper habitat that typically has less wildlife value.
7. Directional drilling minimizes the number of wells and associated road network which in turn minimizes fragmentation of sage-grouse habitat.
8. Use the seasonal habitat maps found in Appendix C to assess potential impacts to sage-grouse, where necessary these maps should be developed for surrounding areas.
9. Nesting/Summer habitat was found to be the most critical time for sage-grouse survival and production during this study. Protection of summer/nesting habitats should be prioritized.

Figure 8a. Kernal Home Range of all Combined Sage-Grouse Locations, Emma Park, Utah, showing Core Use Areas. Blue polygons denote leks, green locations denote active CBM development.

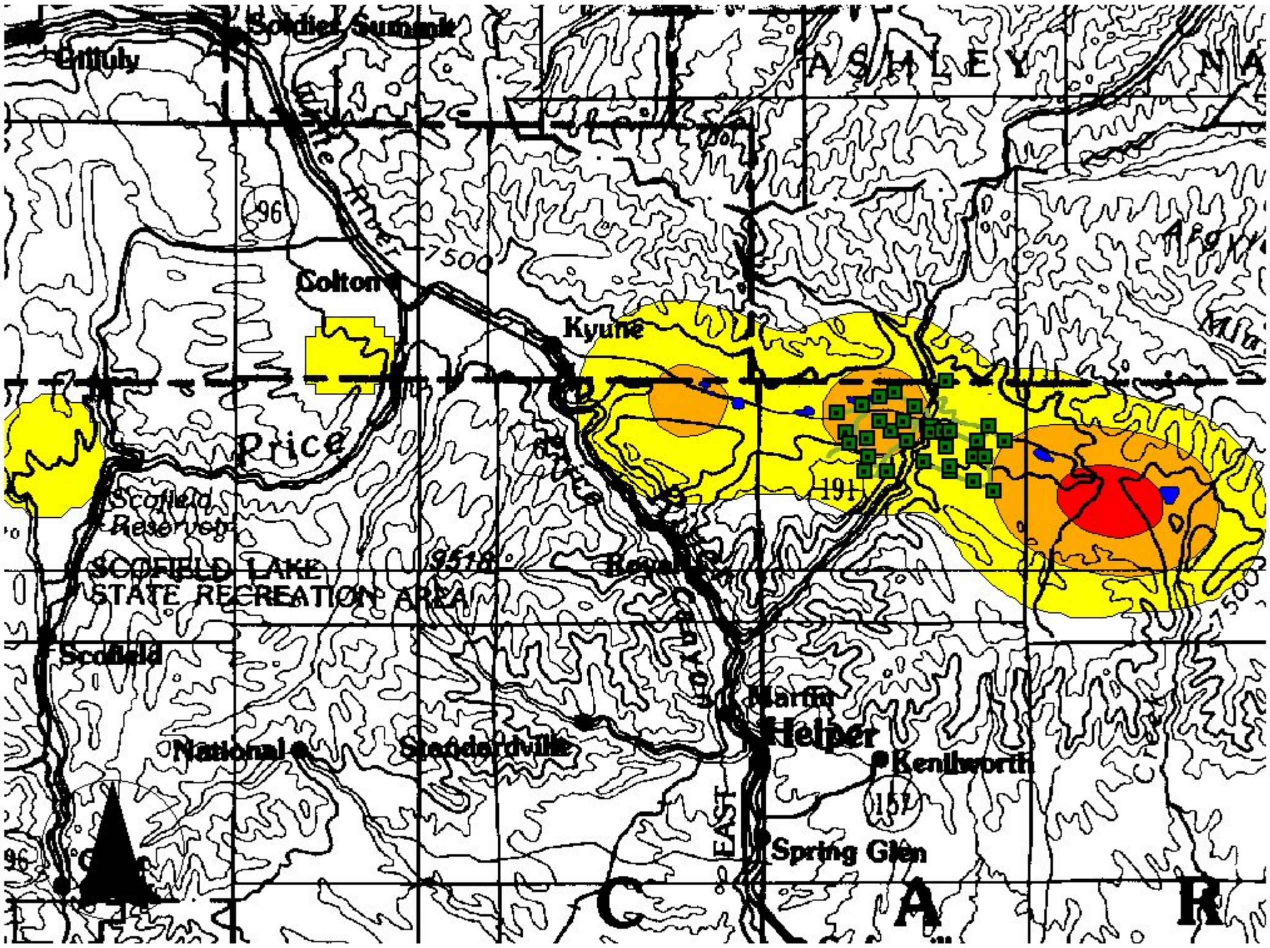
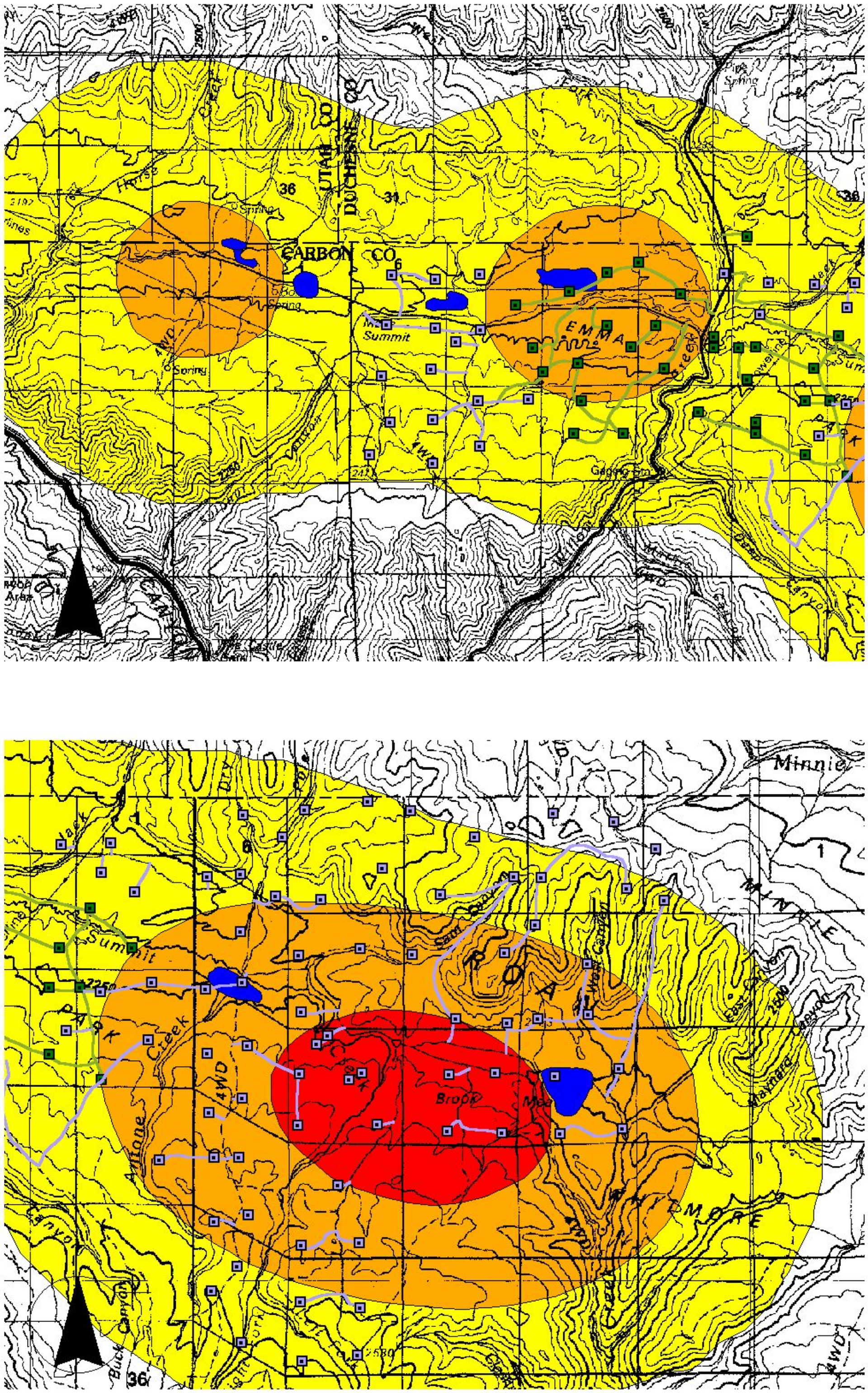


Figure 8b. Fine Scale Kernal Home Range Polygons for All Sage-Grouse Locations, Showing Core Sage-Grouse Use Areas in West Emma Park (upper map) and East Emma Park (lower map). Current CBM Development (green) and Proposed Development (purple) are denoted by Squares.



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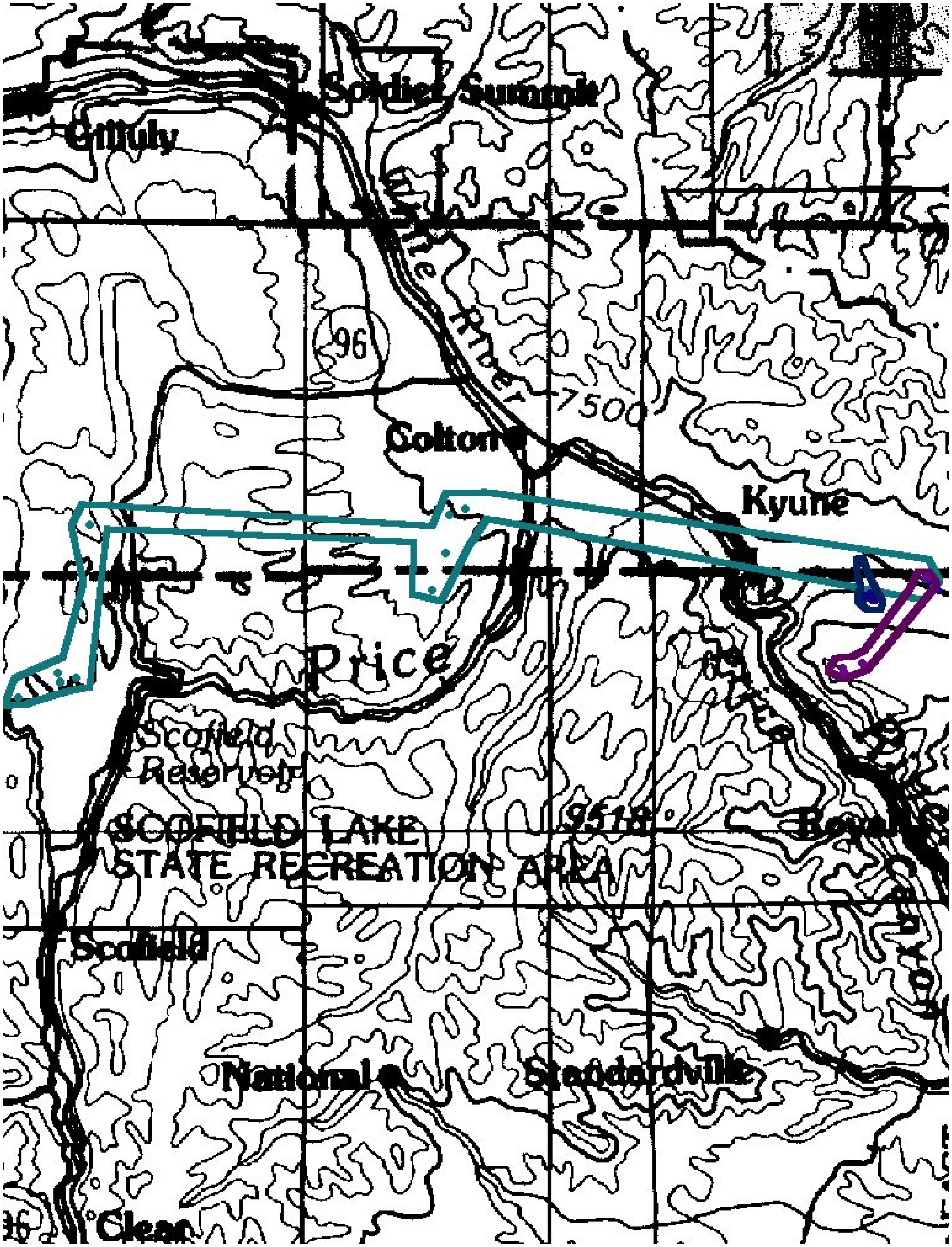
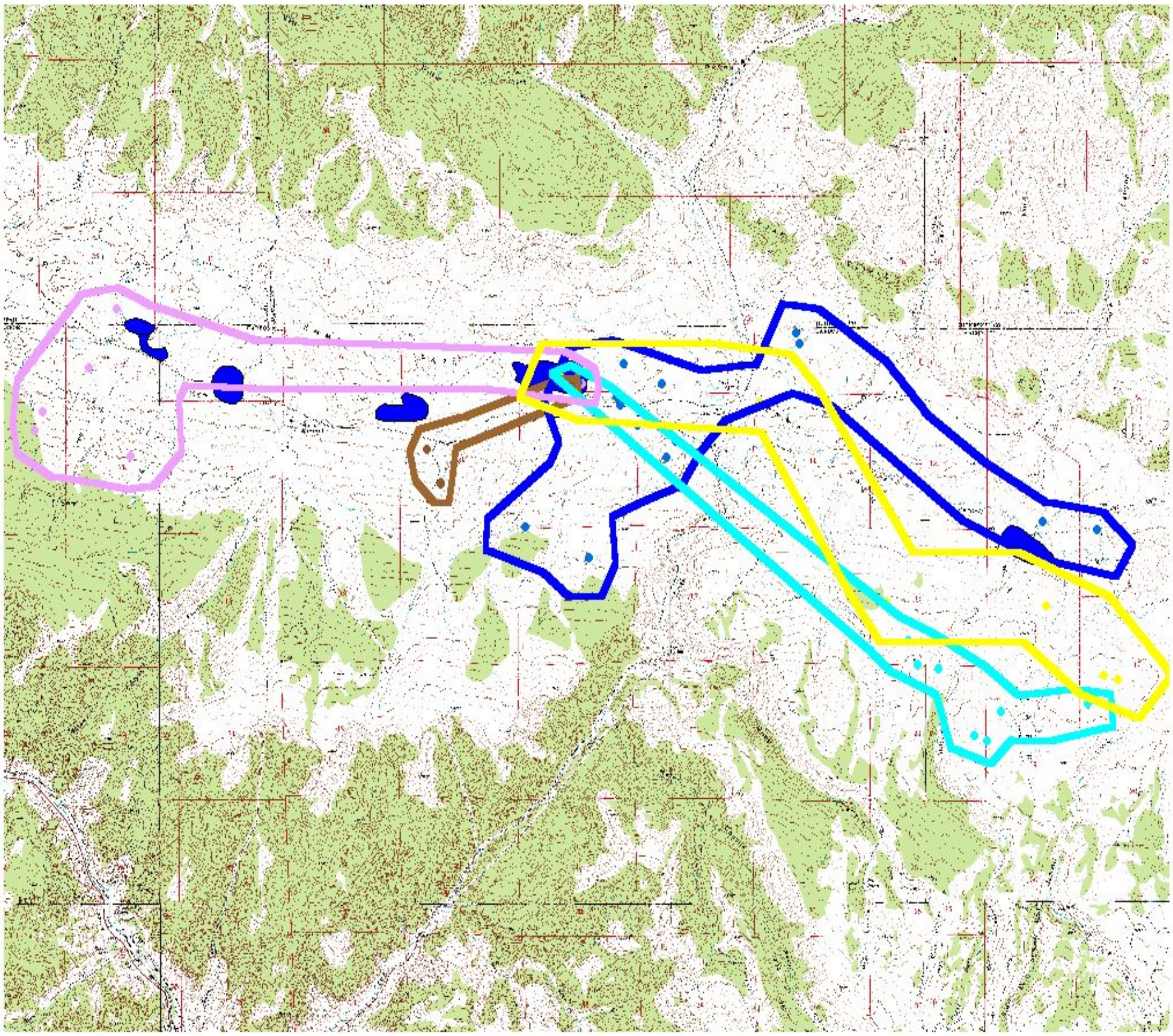
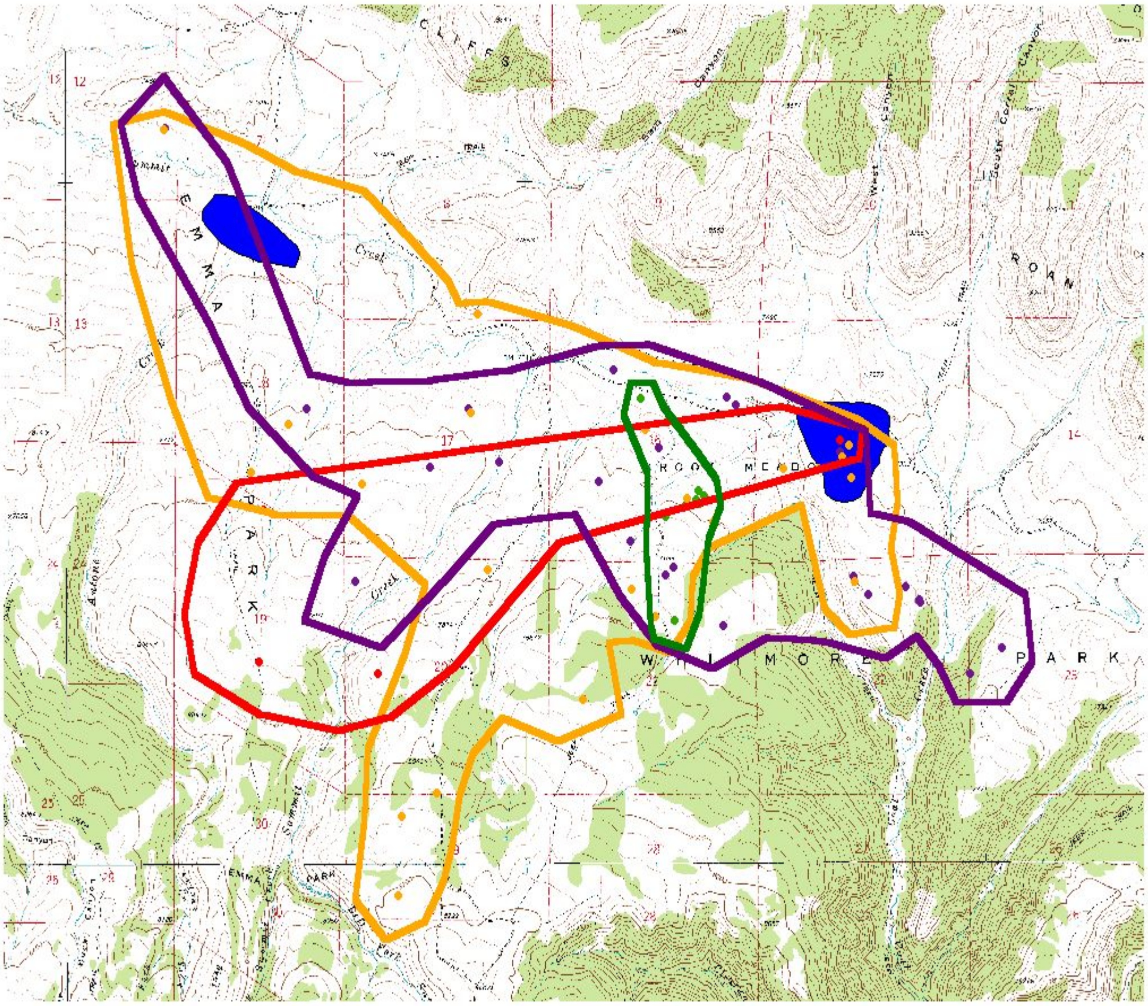
Appendix A1. Individual Home Ranges of 3 Sage-Grouse Hens Captured at Non-CBM Sites, 2001-2005.



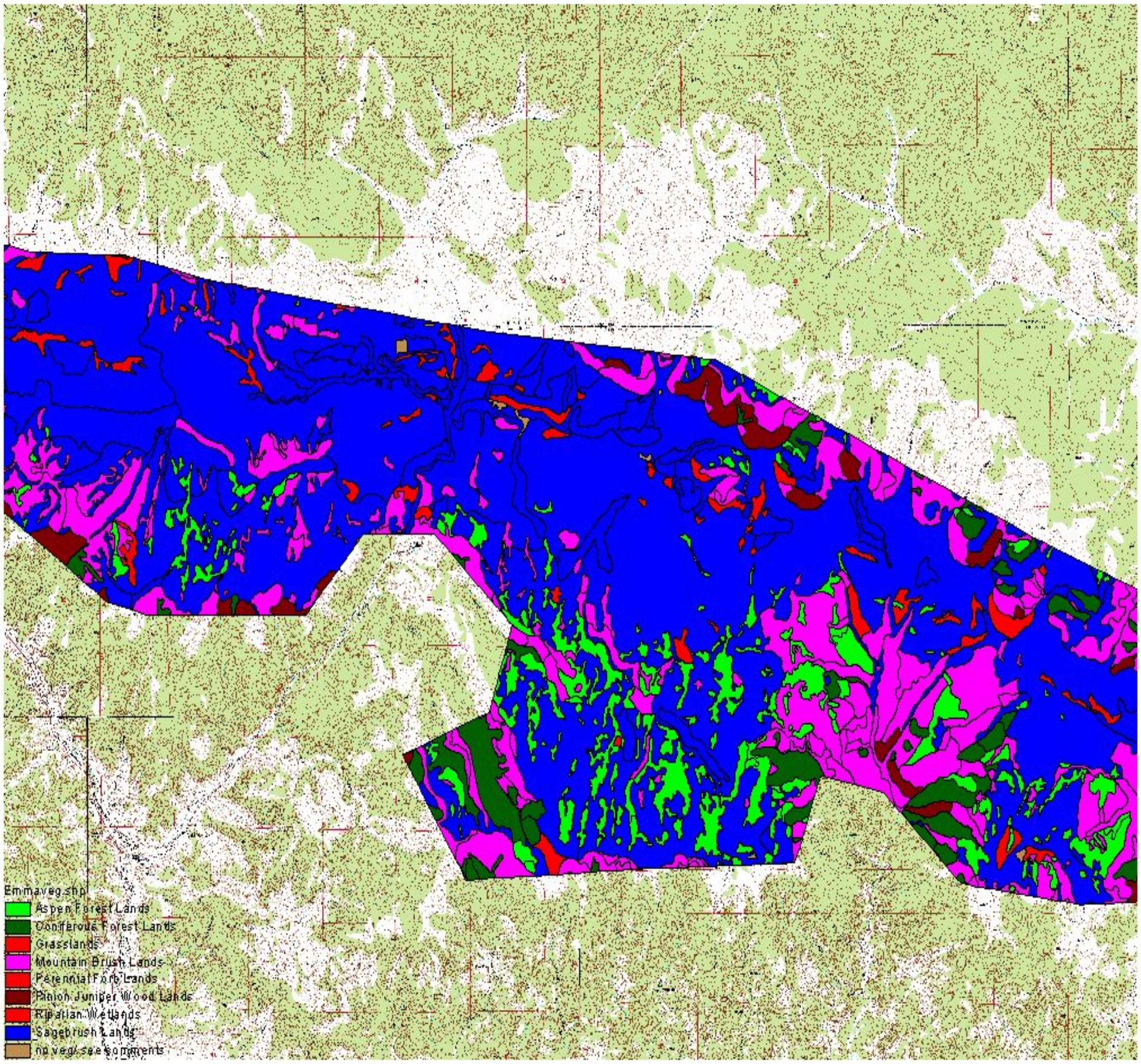
Appendix A2. Individual Home Ranges of 5 Sage-Grouse Hens Captured at CBM Sites, 2001-2005.



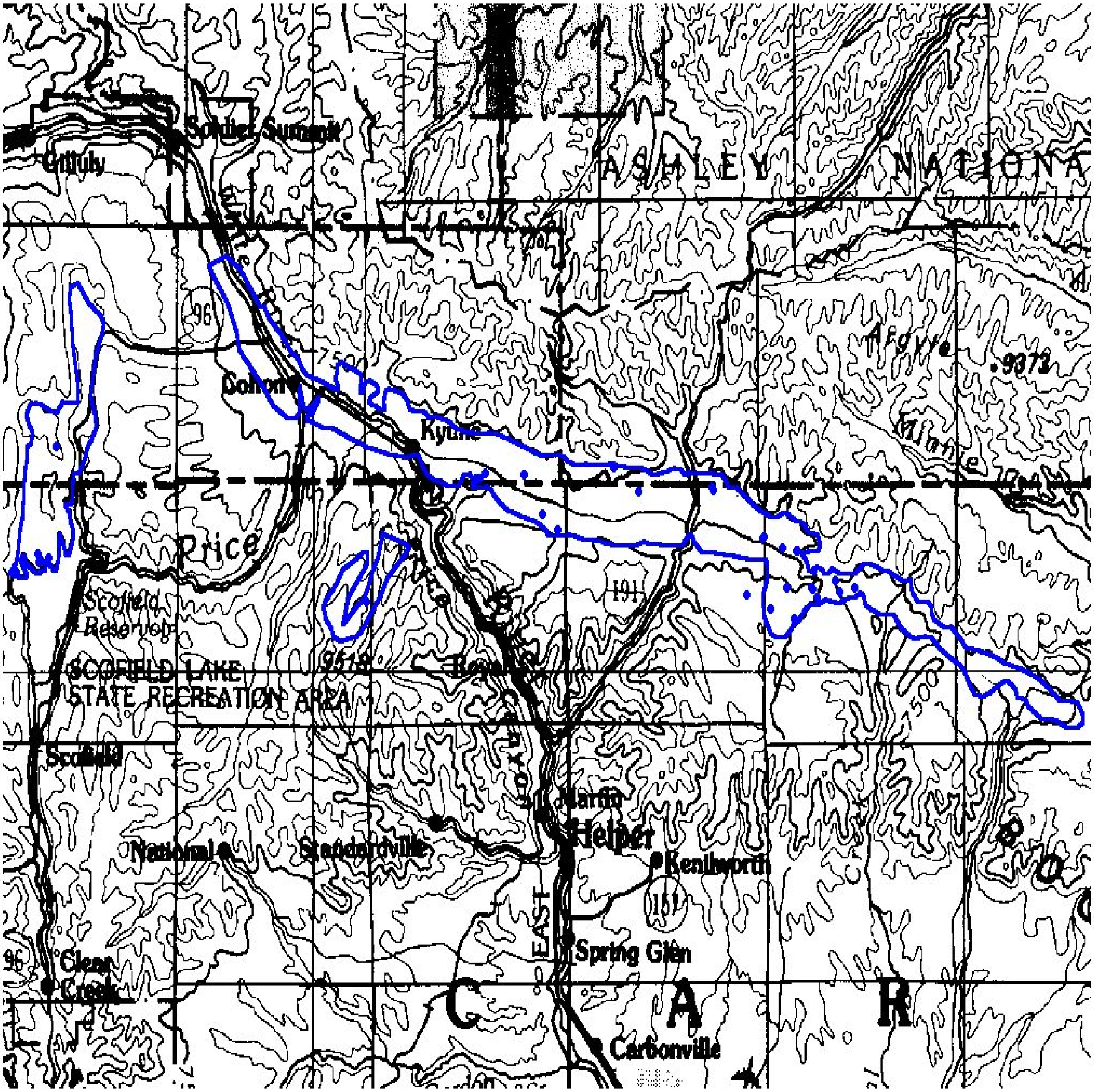
Appendix A3. Individual Home Ranges of 4 Sage-Grouse Hens Captured at Non-CBM Sites, 2001-2005.



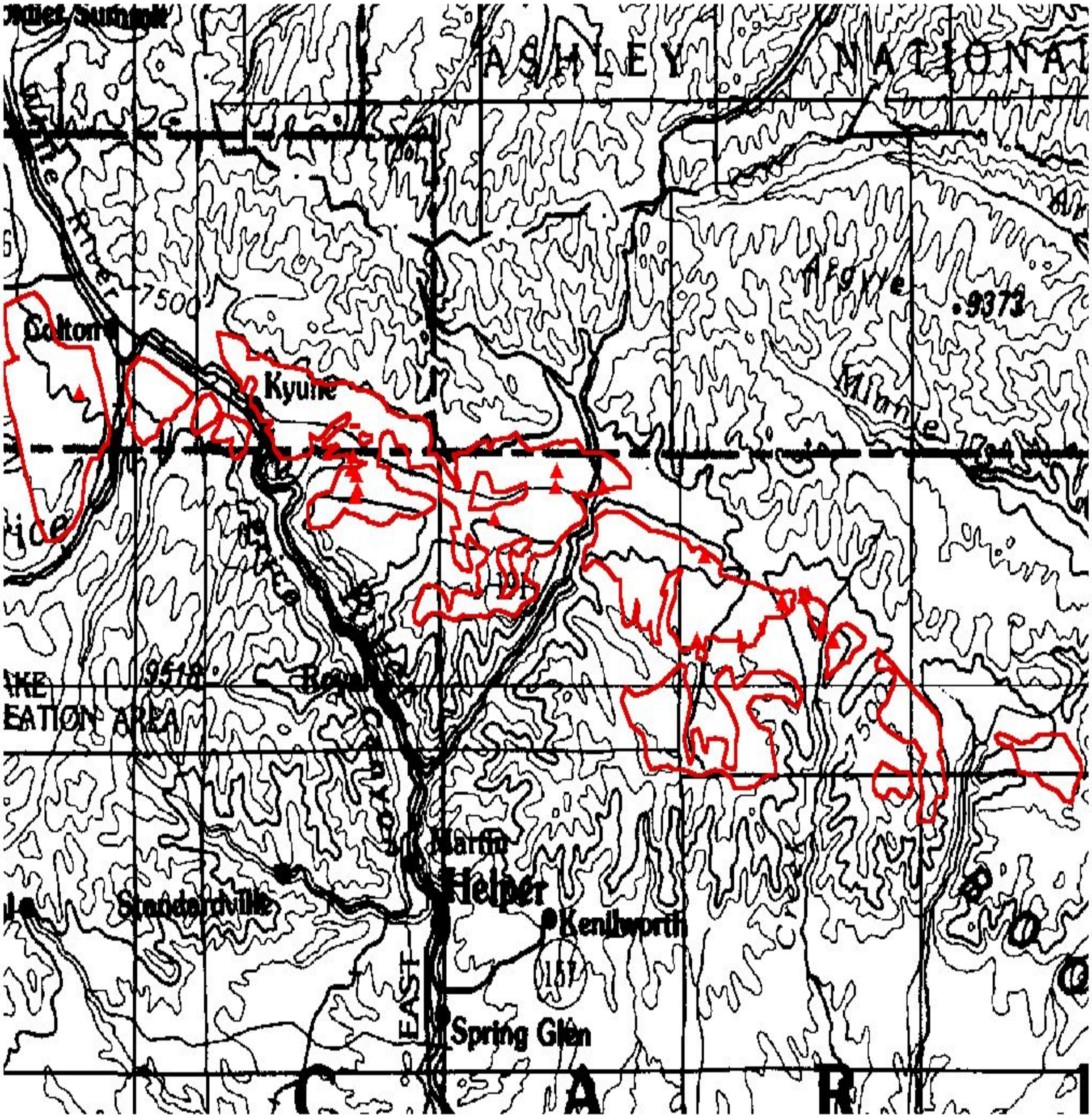
Appendix B1. Vegetation Map of Emma Park Showing Major Habitat Types.



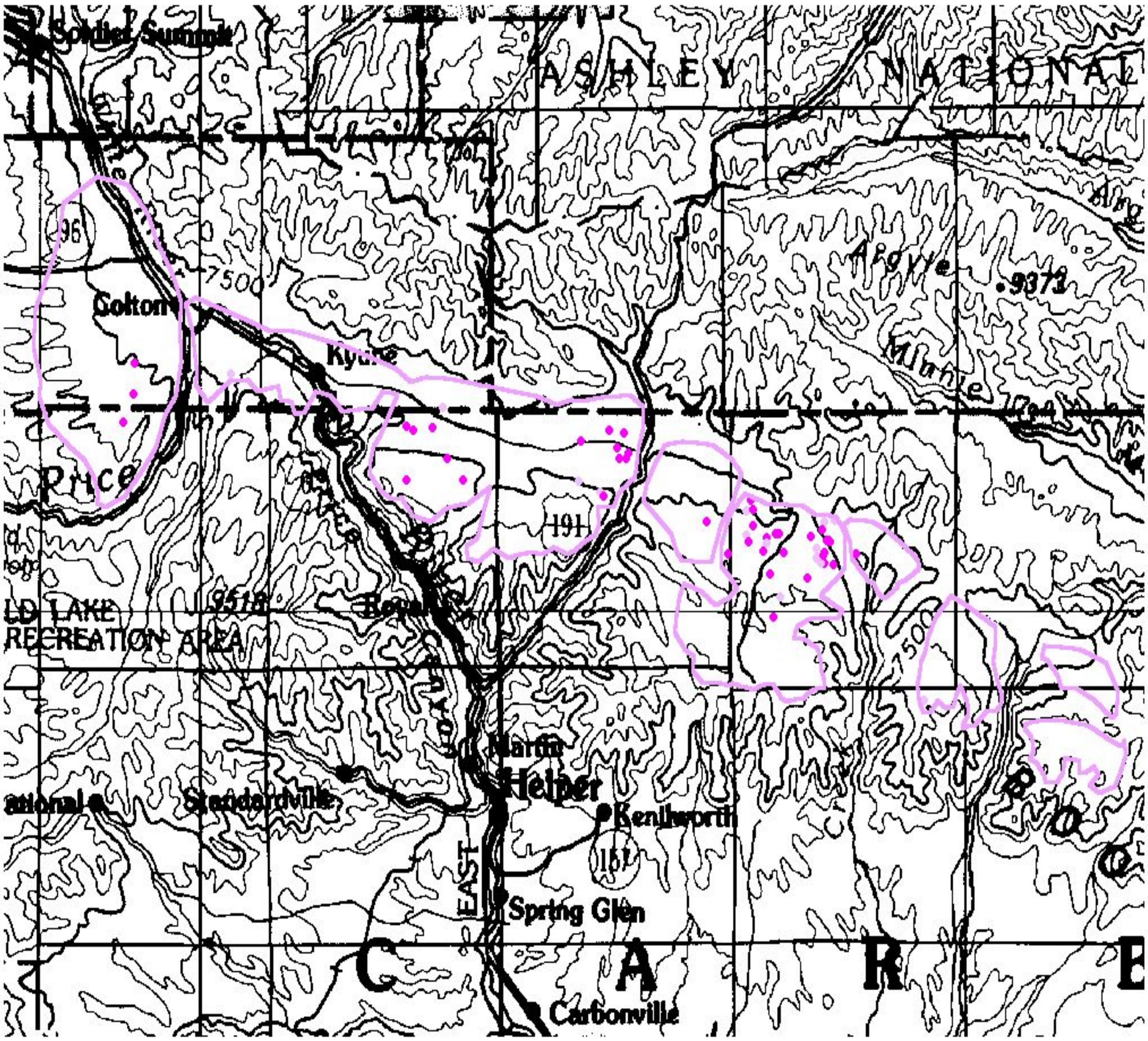
Appendix C1. Winter Sage-Grouse Habitat in Emma Park, Showing Actual Winter Locations and Modeled Winter Habitat Based on Similar Vegetative Features.



Appendix C2. Sage-Grouse Nesting Habitat in Emma Park, Showing Actual Nest Locations and Modeled Nesting Habitat Based on Similar Vegetative Features.



Appendix C3. Sage-Grouse Brood Rearing and Summer Habitat in Emma Park, Showing Actual Locations and Modeled Brood Rearing/Summer Habitat Based on Similar Vegetative Features.



Appendix C4. Sage-Grouse Lek Habitat in Emma Park Showing Active Leks (dark blue) and Historic Leks (light blue). Actual Grouse Locations Outside the Leks are Denoted by Yellow Points.