Wildlife Survey (Including Migratory Birds and Raptors) at the National Renewable Energy Laboratory South Table Mountain Site Golden, Colorado

FINAL REPORT

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1.0 INTRODUCTION

A wildlife study of the National Renewable Energy Laboratory (NREL) South Table Mountain (STM) site in Golden, Colorado was conducted in 1987 by The FORUM Associates, Inc. The demographics of the area surrounding the STM site have changed and additional development of the STM site has since occurred. At the request of NREL, Science Applications International Corporation (SAIC) began a four season wildlife study of the STM site in Spring 2004 to update the 1987 data and, at the end of the study, to compare the results of the 2004-2005 wildlife study with the 1987 study. Seasons for the surveys were split into the following quarterly time periods:

Spring – February, March, April
Summer – May, June, July
Fall – August, September, October
Winter – November, December, January

During Spring and Summer 2004, survey protocol were formulated and survey stations were established on site as needed to survey for six wildlife groups: migratory birds, raptors, large mammals, predators, small mammals, and reptiles/amphibians. This report presents the survey protocols, includes the results of all surveys conducted during the 2004-2005 surveys, compares the findings of the 2004-2005 wildlife study with the 1987 study, and makes recommendations for best management practices and mitigation measures. Copies of the quarterly reports submitted to NREL detailing survey results for each season are included in Appendix A. Spring 2005 survey results were not included as part of any quarterly report and are instead included in Appendix A. Appendix B includes copies of the survey protocols. Common and scientific names of all species observed on site during the 2004-2005 study are listed in Appendix C. Photographs are included in Appendix D.

1.1 Site Description

The 327 acre STM site is located on the southeast side of South Table Mountain, north of I-70 and west of the I-70 and Denver West Boulevard interchange in unincorporated Jefferson County, Golden, Colorado (Figure 1). The STM site includes laboratory and office space, a visitor's center, and 177 acres protected by a conservation easement (Figure 2). Approximately 10 acres on the southeast corner of the STM site are designated for a future Jefferson County Open Space trail easement to provide public access to conservation easement lands. There are currently laboratory and test facilities, and several support buildings on the site. The STM site includes acreage on the South Table Mountain mesa top, slope, and toe, and was formerly part of the Colorado National Guard facility, established between 1903 and 1924, at Camp George West.

The 177 acre STM conservation easement prohibits development, thereby permanently protecting the site's natural resources. NREL manages this area to preserve the native ecosystem and maintain the health/viability of that ecosystem. Recreation in the form of hiking is allowed in the area with trails built and maintained by Jefferson County Open Space. Certain existing utility corridors also pass through this area.

Located at the base of the foothills to the Rocky Mountains, the STM site occurs at elevations ranging from 1,752 meters (5,780 feet) to 1,827 meters (6,030 feet) above mean sea level. This elevation range coincides with the interface between two ecological provinces: the Great Plains-Palouse Dry Steppe Province to the east, and the Southern Rocky Mountain Steppe – Open Woodland – Coniferous Forest – Alpine Meadow Province to the west (Bailey 1995). The site occurs within the following legal description: Township 3 South, Range 70 West, Section 36 and Township 4 South, Range 70 West, Section 1.

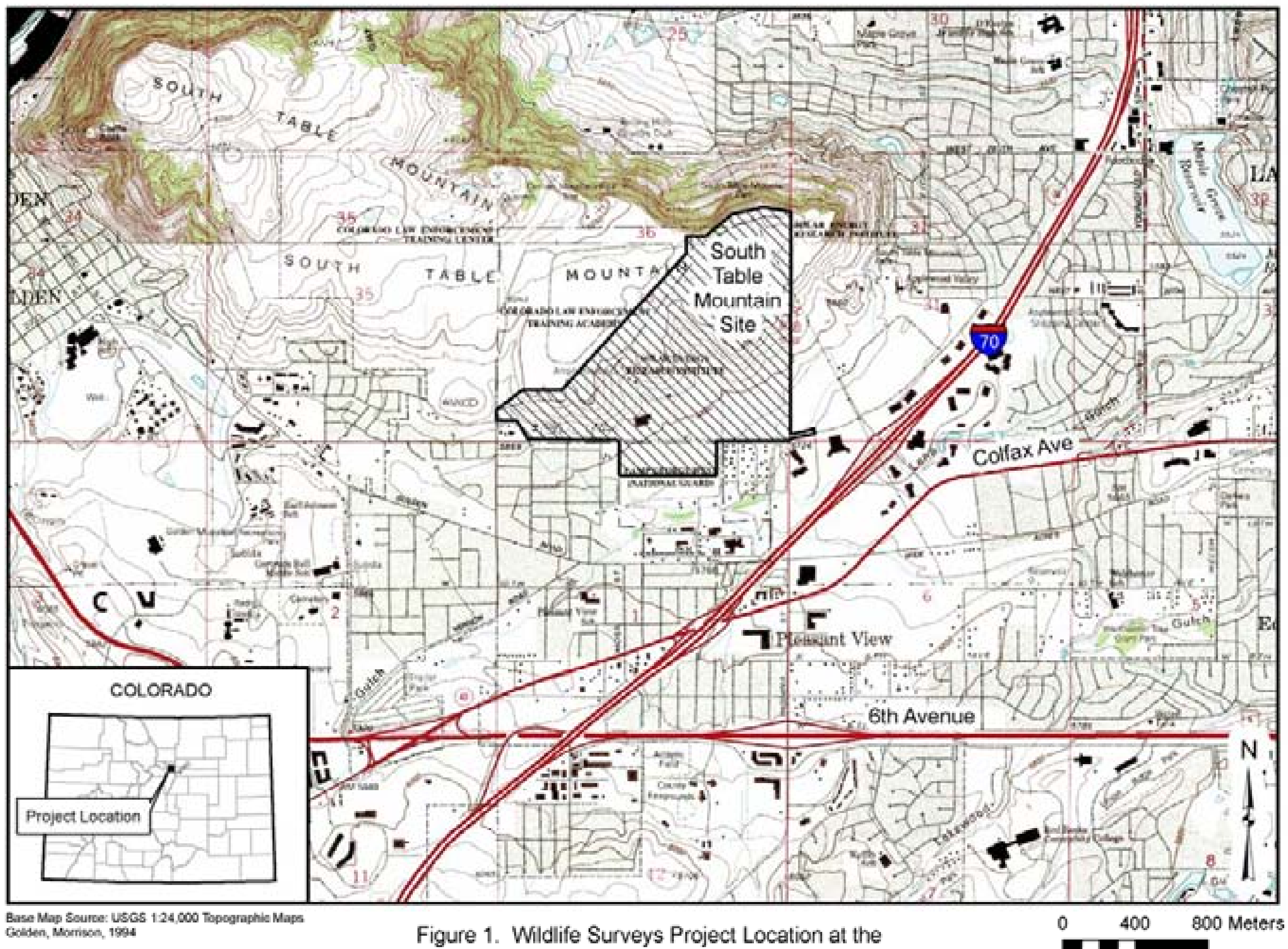
Within the STM site project area eight vegetation types occur: short grass grassland, mixed grass grassland, short shrubland, tall shrubland, ravine shrubland, wetland, disturbed/reclaimed, and developed (Plantae Consulting Services 2002). Table 1 lists the vegetation types and their areal extent. Figure 3 depicts the locations of these eight vegetation types.

Table 1. Vegetation Types at the National Renewable Energy Laboratory South Table Mountain Site, Golden, Colorado.

VEGETATION TYPE	AREA (ACRES)	PERCENT OF SITE
Short grass grassland	124	37.9
Mixed grass grassland	103	31.4
Tall shrubland	19	5.8
Short shrubland	16	4.9
Ravine shrubland	5	1.5
Wetland	<1	0.1
Disturbed/reclaimed	32	9.8
Developed	28	8.6
TOTAL	327	100

Source: Plantae Consulting Services 2002

Figure 1. Wildlife Surveys Project Location, National Renewable Energy Laboratory South Table Mountain Site, Golden, Colorado.



Base Map Source: USGS 1:24,000 Topographic Maps
Golden, Morrison, 1994

Figure 1. Wildlife Surveys Project Location at the National Renewable Energy Laboratory South Table Mountain Site, Golden, Colorado

Figure 2. National Renewable Energy Laboratory South Table Mountain Wildlife Surveys Project Site, Golden, Colorado.

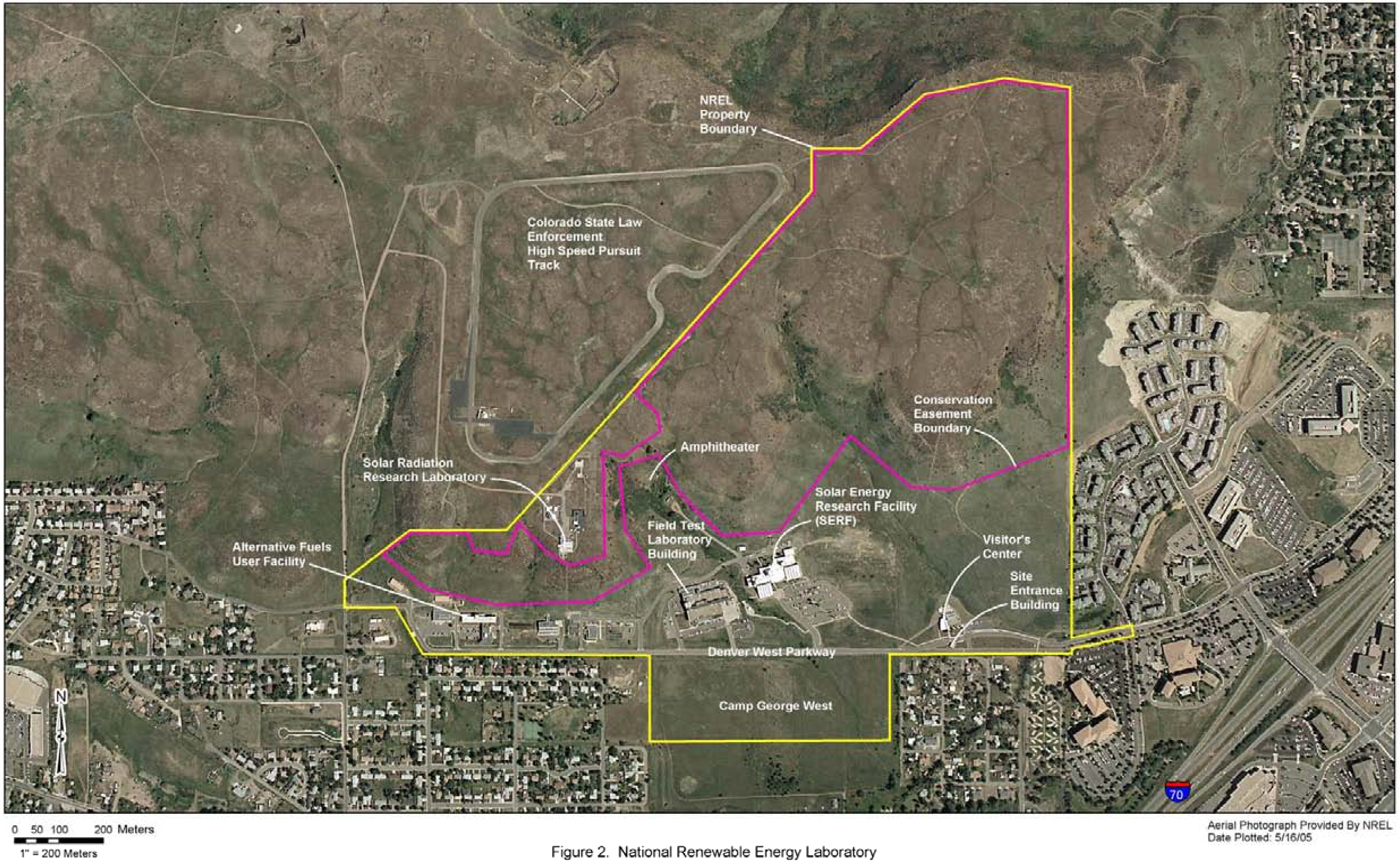


Figure 2. National Renewable Energy Laboratory South Table Mountain Wildlife Survey Project Site, Golden, Colorado.

Figure 3. Vegetation Types at the National Renewable Energy Laboratory South Table Mountain Site, Golden, Colorado.

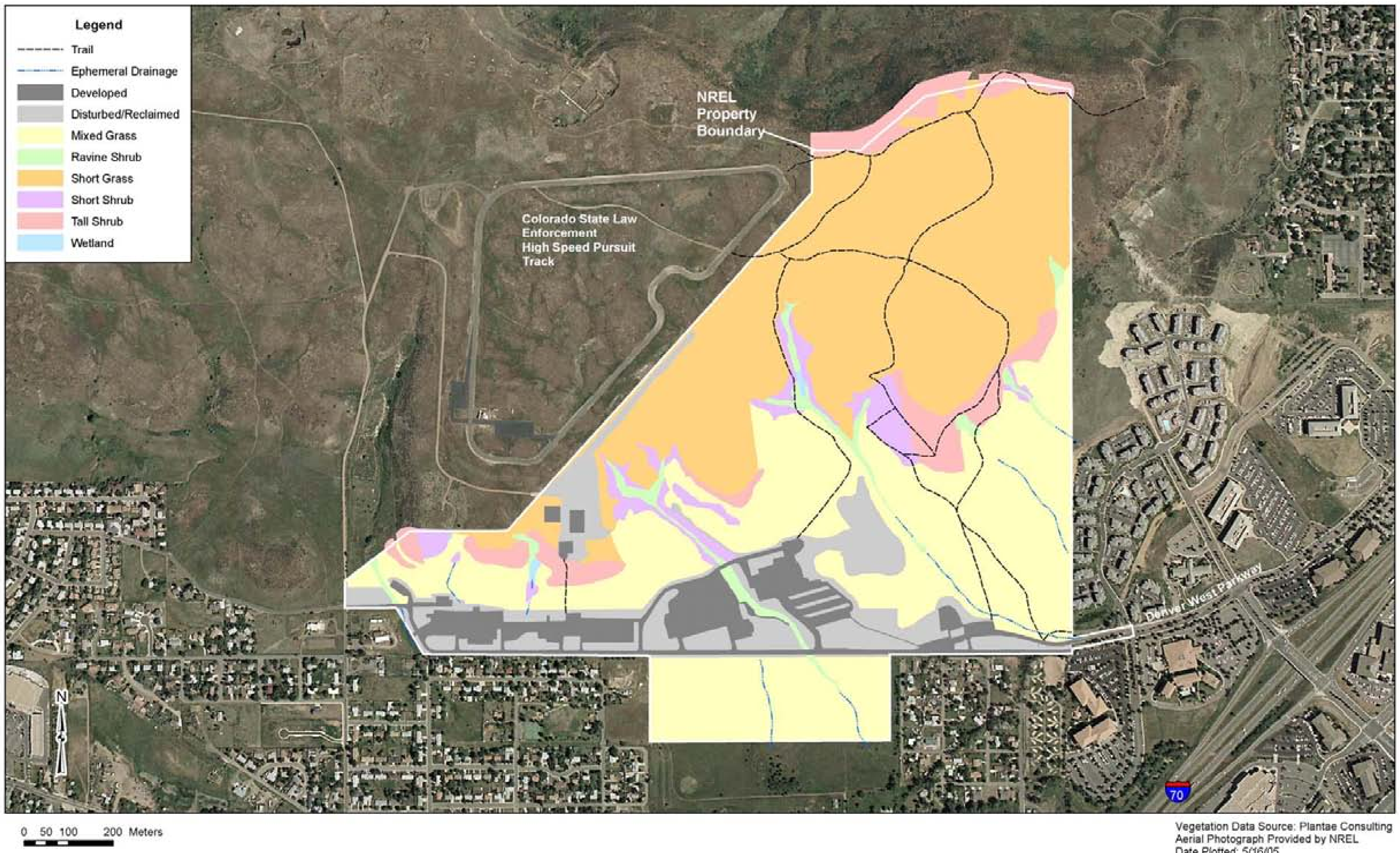


Figure 3. Vegetation Types of the National Renewable Energy Laboratory, South Table Mountain Site, Golden, Colorado.

2.0 DESCRIPTION OF SURVEY PROTOCOLS

This section describes survey protocols used during the four season wildlife study at the NREL STM site. Copies of the literature upon which these protocols are based are included in Appendix B. Any modification of survey protocols included in Appendix B are described below in the appropriate section. Figure 4 shows the locations of all survey stations and transects.

2.1 Migratory Bird Surveys and Nest Searches

Migratory bird surveys were conducted on two consecutive mornings once per season beginning in Spring 2004 using a modified point-transect method (RMBO et al. 2000). Six transects (A, B, C, D, E, and F) were established throughout the site, with interpoint intervals of 250 meters (m). A four-foot-tall, steel t-post was driven in the ground approximately 1 foot at each survey point to mark the location. The point count duration was five minutes at each of 20 points. All birds seen and/or heard during the five minute period were recorded, the distance to each individual was estimated, and the sex of each bird was recorded for each point. Only individuals of low-density target bird species for the vegetation type, as identified in RMBO et al. 2000, were recorded along the transect. The maximum number of individuals of each bird species detected at each survey point during the seasonal point count surveys was used in the analysis and each season was analyzed separately. Nest searches were based on Ralph et al. 1993 in which a biologist conducted an ocular search for bird activity and scanned for potential nest locations. Nest searches were only conducted in Spring and Summer 2004. All nests located were marked using a Garmin Global Positioning System (GPS), model GPSmap 60C, provided by NREL. See Appendix B for the point-transect protocol (RMBO et al. 2000).

Bird species diversity and evenness were calculated using the Simpson’s index of diversity and Simpson’s index of ‘equitability’ or ‘evenness’ (Begon et al. 1990). Species diversity is an index of community diversity that takes into account both species richness and the relative abundance of species (Begon et al. 1990). Richness is the number of species found in a community. Simpson’s index of diversity (D) is calculated as:

$$D = \frac{1}{\sum_{i=1}^{S} P_i^2}$$

where S is the species richness or total number of species and P_i is the proportion that an individual species contributes to the total of the sample. This index takes into account both the total number of species (richness) and how common or rare each species is. Thus, for a given evenness, diversity increases with species richness; similarly, for a given species richness, diversity will increase with evenness (Begon et al. 1990). This index is abstract, but can be used as a benchmark for future surveys. Evenness is a function of the relative abundance of the species that occur in a community. Simpson’s index of evenness (E) is calculated as:

$$E = \frac{D}{S}$$

The Simpson’s index of evenness has a maximum value of one (even composition of each species), and lower values have a more disparate species composition with some species being more common and others being rare.

Figure 4. Wildlife Surveys Transects and Sampling Station locations for the National Renewable Energy Laboratory South Table Mountain Site, Golden, Colorado.

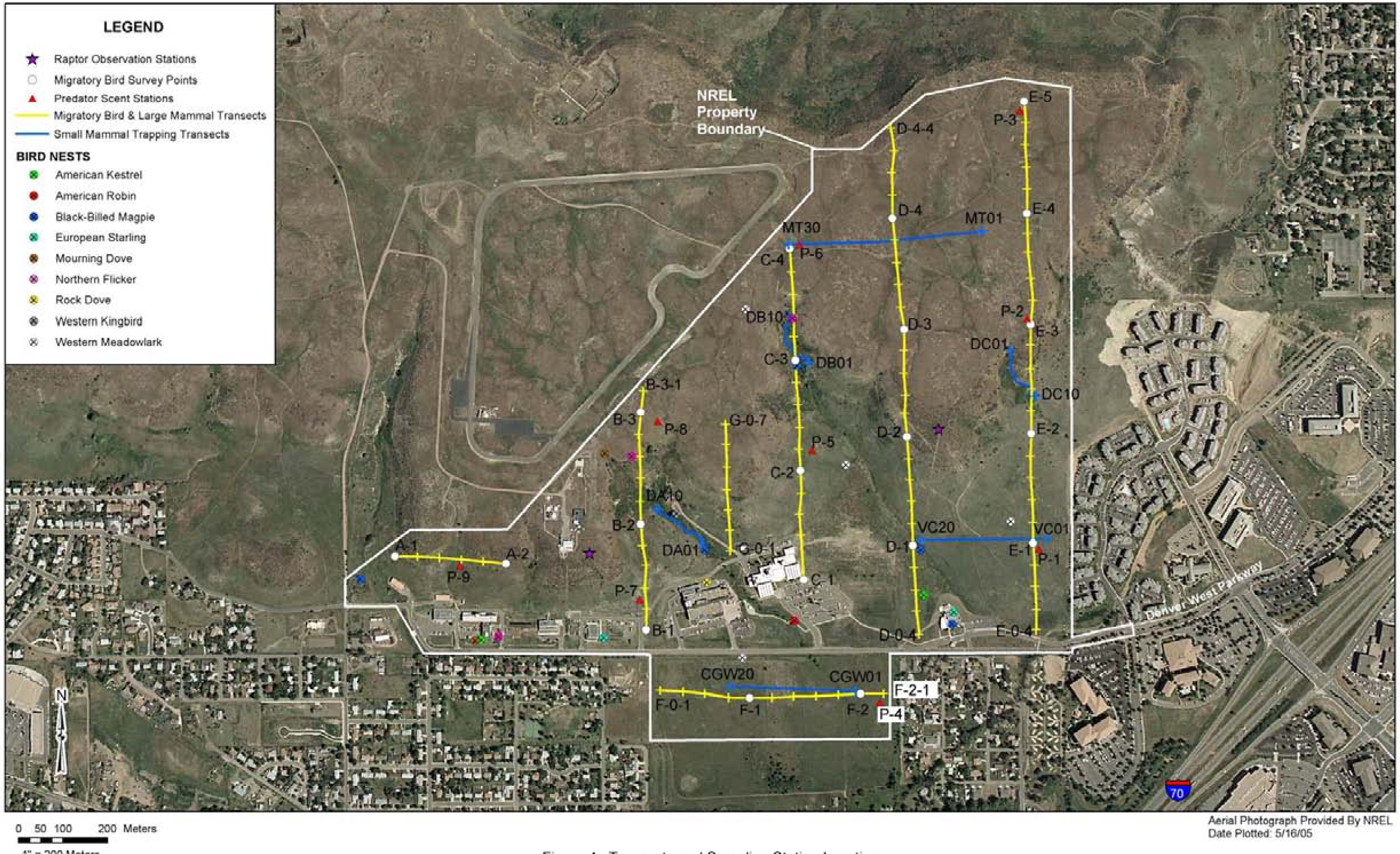


Figure 4. Transects and Sampling Station Locations
for Wildlife Surveys at the National Renewable Energy Laboratory,
South Table Mountain Site, Golden, Colorado.

2.2 Raptor Surveys and Nest Searches

Two 4-hour surveys for raptors were conducted on consecutive mornings, once in Spring 2004 and once in Fall 2004 from two observation points established on site. One 4-hour survey was conducted from one point on one morning and a second 4-hour survey was conducted from the second observation point the next morning from approximately 8:00AM to 12:00PM. Nest searches were conducted on foot following each survey period in Spring 2004 only. All trees were searched and an ocular search for raptor activity conducted. All nests located were marked using the Garmin GPSmap 60C provided by NREL.

2.3 Large Mammal Surveys

Following methods in Neff (1968) (see Appendix B), 100 pellet-group plots were established on site on April 2, 2004. These circular plots, measuring $4m^2$, were placed 50m apart along transects A through F (same transects used for migratory bird surveys) and along transect G, (established only for large mammal surveys). Wood stakes, 30 centimeters in height, were driven into the ground every 50m along transects to mark the center of plots. Where t-posts marked migratory bird survey points, the t-post also served as the center of the pellet plot. All pellets in each plot were removed during set up. Pellet-group plots were checked for new pellet groups in Fall 2004 and Spring 2005 seasons. In the Fall 2004 season, pellet groups observed in plots were recorded and all pellets were removed. Plots were checked again in the Spring 2005 season and all pellet groups observed in plots were recorded.

2.4 Predator Surveys

SAIC conducted scent-station surveys for predators following methods modified from Linhart and Knowlton (1975) (see Appendix B). Nine scent-stations were placed at 0.3 kilometer intervals along transects already established on site for migratory bird surveys (see Section 2.1). Each station consisted of a $1m^2$ circle of sifted dirt with one fatty acid scent predator survey disk (F.A.S. Scented Disk from Pocatello Supply Depot, Pocatello, ID) placed in the center as an attractant. Two surveys, each consisting of three consecutive nights, were conducted during Summer and Fall 2004, Winter 2004-2005, and Spring 2005. Scent disks were replaced with new disks for the third night of surveys based on the volatilization rate of the fatty acid scent (Roughton and Sweeney 1982). All tracks and/or scat left in the stations were identified and recorded and stations were re-sifted each day.

2.5 Small Mammal Surveys

Small mammal trapping followed methods described in Pearson and Ruggiero (2003) (see Appendix B). Six transects were established on site in the mixed grass, short grass, short shrubland and ravine shrubland vegetation types. Large Sherman live traps (7.62cm x 8.89cm x 22.86cm) were located 15m apart on each transect. A total of 100 traps were set each night for four consecutive nights for a total of 400 trap nights per season. The number of traps per transect were as follows (see Figure 4 for transect locations):

- Visitor's Center (VC) – 20 traps were located in the mixed grass vegetation north of the visitor's center.
- Camp George West (CGW) – 20 traps were located in the mixed grass vegetation type in the Camp George West property south of Denver West Parkway.

- Mesa Top (MT) – 30 traps were located in the short grass vegetation type on the mesa top.
- Drainage A (DA) – 10 traps were located in the short shrubland vegetation type south of the amphitheater.
- Drainage B (DB) – 10 traps were located in the ravine shrubland vegetation type in the drainage northeast of the Solar Energy Research Facility (SERF).
- Drainage C (DC) – 10 traps were located in the short shrubland vegetation type of the drainage on the east-central part of the site.

Each trap was baited with a mixture of peanut butter and oats. Polyester fiber batting was placed in each trap for bedding material. Each small mammal caught was identified to species, its age and sex were determined and it was weighed. After recording information, small mammals were released at the trap station. Vegetation types follow Plantae Consulting Services 2002.

2.6 Reptile/Amphibian Surveys

Reptiles and amphibians were surveyed for opportunistically during the following four seasons: Summer and Fall 2004, Winter 2004-2005, and Spring 2005. All reptiles and amphibians encountered on site were identified and recorded.

3.0 ALL WILDLIFE SURVEY RESULTS

Surveys for the six wildlife groups (migratory birds, raptors, large mammals, predators, small mammals, and reptiles and amphibians) were conducted over a one year period. Most surveys were conducted in each of four seasons, however surveys for raptors and large mammals were conducted in each of two seasons. Table 2 identifies the season(s) each survey was conducted.

Table 2. Seasons in Which Wildlife Surveys Were Conducted at the National Renewable Energy Laboratory South Table Mountain Site, Golden, Colorado.

Survey Type	Season				
	Spring 2004	Summer 2004	Fall 2004	Winter 2004-2005	Spring 2005
Migratory Birds	X*	X*	X	X	
Raptors	X*		X		
Large Mammals			X		X
Predators		X	X	X	X
Small Mammals		X	X	X	X
Reptiles/Amphibians		X	X	X	X

* Nest searches also conducted this season.

This section summarizes the results of 2004-2005 wildlife surveys, compares these results with the 1987 wildlife surveys, and identifies any species of concern observed on the STM site. Table 3 identifies all wildlife species observed on the STM site and the season and vegetation type in which the observation was made. Some species identified in Table 3 were observed only in 1987 or only in 2004-2005. Moreover, Table 3 does not represent the only species that occur on site; instead it should be considered a work in progress.

Table 3. All Results For Wildlife Surveys Conducted at the National Renewable Energy Laboratory South Table Mountain Site, Golden, Colorado.

SPECIES COMMON NAME	Status[2]	Observed in 1987 Surveys	SEASON AND VEGETATION TYPE OF OCCURRENCE[1]																																		
			SPRING 2004							SUMMER 2004							FALL 2004							WINTER 2004-2005							SPRING 2005						
			SG	MG	TS	SS	RS	D/R	D	SG	MG	TS	SS	RS	D/R	D	SG	MG	TS	SS	RS	D/R	D	SG	MG	TS	SS	RS	D/R	D	SG	MG	TS	SS	RS	D/R	D
REPTILES AND AMPHIBIANS																																					
Bull snake[3]	--	X																																			
Plains garter snake	--	X									X																										
Six-lined racerunner	--										X																										
Tiger salamander	--															X																					
Western rattlesnake	--	X			X						X	X						X															X				
BIRDS																																					
American crow	a		X																					X													
American kestrel	a	X	X	X							X						X		X											X	X	X					
American robin	a	X	X	X	X		X	X		X	X			X									X														
American tree sparrow	a																								X												
Barn swallow	a										X				X			X																			
Black-billed magpie	a	X		X	X		X	X	X		X	X		X	X	X			X						X	X				X	X						
Black-capped chickadee	a			X	X													X	X				X														
Black-crowned night heron	a																	X																			
Blue jay	a																		X																		
Brewer's blackbird	a	X									X											X														X	
Brown headed cowbird	a	X										X																									
Bullock's oriole	a										X			X	X																						
California gull	a																X	X																			
Canada goose	a		X	X																					X												
Common nighthawk	a	X								X							X																				
Common raven	a		X																							X											
Common snipe	a																														X						
Cooper's hawk	a		X	X														X																			
Dark-eyed junco	a																											X									
Downy woodpecker	a																		X																		
European starling	--	X	X	X	X		X	X	X		X	X			X						X								X		X						
Flycatcher	a			X															X																		
Golden eagle	a, b		X	X																																	
Great blue heron	a									X																											
Horned lark[3]	a	X																																			
House finch	a			X	X				X	X	X	X	X	X	X	X	X	X	X					X	X	X					X						
House sparrow	--			X	X			X			X	X			X			X							X						X						
Killdeer	a	X	X								X																				X						
Lark bunting	a	X								X																											
Loggerhead shrike	a																	X	X																		
MacGillivray's warbler	a																				X																
Mallard	a			X																																	
Mountain bluebird	a	X								X							X							X							X						
Mourning dove	a	X		X						X	X	X			X		X						X								X						
Northern flicker	a	X	X	X	X		X	X	X		X	X					X				X				X	X					X						
Northern harrier	a																X							X													

Table 3. All Results For Wildlife Surveys Conducted at the National Renewable Energy Laboratory South Table Mountain Site, Golden, Colorado.

SPECIES COMMON NAME	Status[2]	Observed in 1987 Surveys	SEASON AND VEGETATION TYPE OF OCCURRENCE[1]																																		
			SPRING 2004							SUMMER 2004							FALL 2004							WINTER 2004-2005							SPRING 2005						
			SG	MG	TS	SS	RS	D/R	D	SG	MG	TS	SS	RS	D/R	D	SG	MG	TS	SS	RS	D/R	D	SG	MG	TS	SS	RS	D/R	D	SG	MG	TS	SS	RS	D/R	D
Osprey	a		X																																		
Prairie falcon	a		X							X							X																				
Red-breasted nuthatch	a																		X			X	X														
Red-tailed hawk	a	X		X							X	X					X	X						X							X	X					
Red-winged blackbird[3]	a	X																																			
Rock dove	--			X				X	X			X			X			X				X				X			X	X		X				X	X
Rock wren	a																X	X																			
Say's phoebe	a			X					X								X														X	X				X	
Sharp-shinned hawk	a		▒	▒	▒	▒	▒	▒	▒								X															X					
Spotted towhee	a			X	X		X	X		X	X	X		X			X	X	X		X										X						
Swainson's hawk	a																														X						
Tree swallow	a		▒	▒	▒	▒	▒	▒	▒	X	X	X					X		X																		
Turkey vulture	a		X	X																											X						
Unidentified sparrow 1	--		X																																		
Unidentified sparrow 2	--		X																																		
Unidentified species	--									X																											
Unidentified warbler	a																		X																		
Vesper sparrow	a									X	X	X					X	X																			
Western kingbird	a	X									X	X					X	X																			
Western meadowlark	a	X	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X					X							X	X					
Western scrub jay	a																															X			X		
White-crowned sparrow	a						X																									X					
MAMMALS																																					
Black-tailed jackrabbit[3]	--	X																																			
Bushy-tailed woodrat[3]	--	X																																			
Coyote	--	X		X						X	X	X					X							X							X	X				X	
Deer mouse	--	X								X	X		X	X			X	X		X	X			X	X		X	X			X	X		X	X		
Fox squirrel	--																														X						
Long-tailed weasel	--																						X														
Mexican woodrat	--												X	X						X	X						X	X						X	X		
Mountain cottontail	--	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Mule deer	--	X	X	X	X		X	X	X		X	X			X	X	X	X	X	X	X	X		X	X	X					X	X	X	X	X		
Prairie vole	--	X								X							X	X						X	X						X	X			X		
Raccoon	--	X																					X														
Red fox[3]	--	X																																			
Western harvest mouse	--	X																X																			
White-tailed jackrabbit	--																							X													
Yellow-bellied marmot[3]	--	X																																			

Notes: This table includes results from wildlife surveys conducted on site in 1987 and 2004-2005, as well as incidental observations of species on site. Vegetation type(s) in which the species were observed is included, if available.

[1] Vegetation type codes follow Plantae Consulting Services 2002 and are as follows: SG – Short grass; MG – Mixed grass; TS – Tall shrubland; SS – Short shrubland; RS – Ravine shrubland; D/R – Disturbed/reclaimed; D – Developed

[2] Status – this column identifies what, if any, Federal statute the species may be protected by.
a – Protected under the Migratory Bird Treaty Act 1918, as amended
b – Protected under the Bald Eagle Protection Act 1940, as amended

[3] Species observed during 1987 survey, but not during 2004-2005 surveys.

▒ Species observed in this season; no specific vegetation type information available.

3.1 Migratory Bird Surveys and Nest Searches

The NREL STM site provides habitat for a diversity of bird species. Vegetation types surveyed for migratory birds at NREL included short grass, mixed grass, tall shrubland, ravine shrubland, disturbed/reclaimed, and developed as defined by Plantae Consulting Services 2002. During the four seasonal point transect surveys conducted in 2004-2005, 37 species of birds were detected, while the total number of bird species observed on site in 2004-2005 due to incidental observation was 56 (Appendix C). This list represents a work in progress that can be expanded as additional bird species are observed at the NREL STM site.

Bird Community

The highest number of species and individual birds observed occurred during the Spring and Summer surveys (Table 4). Most birds observed during these surveys were songbirds, detected by their breeding songs, and therefore probably breed on or adjacent to the STM site. During the Fall and Winter surveys a majority of the observed birds were detected visually, as opposed to calling or singing. Bird species diversity was similar for Spring and Winter surveys, while diversity increased in the Summer, and was highest in the Fall season. Species evenness remained similar during the Spring, Summer, and Fall seasons, but increased during the Winter survey. The higher evenness value indicates a more equal distribution of the species observed during the Winter season.

Table 4. Number of Species and Individual Birds Observed Seasonally During Point Transect Surveys at the National Renewable Energy Laboratory South Table Mountain Site, Golden, Colorado.

Season	Number of Species (Richness)	Number of Birds	Species Diversity[1]	Species Evenness[2]
Spring 2004	20	164	6.5	0.33
Summer 2004	20	193	7.6	0.39
Fall 2004	23	121	8.5	0.37
Winter 2004-2005	13	58	6.1	0.47

[1]Species diversity: the number of different species in a particular area weighted by some measure of abundance such as number of individuals
[2]Species evenness: the relative abundance with which each species is represented in an area

Low-density target bird species for the grassland vegetation type included greater roadrunner, mountain plover, upland sandpiper, burrowing owl, loggerhead shrike, and Cassin's sparrow, and for mountain shrubland vegetation type, sharp-tailed grouse (RMBO et al. 2000). Raptors were target species for all vegetation types. No target species were observed during Spring and Summer surveys. During Fall surveys, loggerhead shrike, American kestrel, red-tailed hawk, and sharp-shinned hawk were detected. American kestrel, northern harrier, and red-tailed hawk were detected during Winter surveys. Greater roadrunner, mountain plover, and upland sandpiper are not known to occur in Jefferson County and only one winter occurrence of Cassin's sparrow has been documented in the county (Andrews and Righter 1992). Burrowing owls typically occur near prairie dog towns and no prairie dogs occur on the STM site.

Individual Species

The western meadowlark was the most abundant species detected during the Spring and Summer surveys (51 and 45 birds, respectively) and was also the most widespread species during these survey periods. The house finch was the most abundant species during the Fall and Winter surveys (32 and 16 birds, respectively). The house finch was also the most widespread species during the Fall surveys, while the black-billed magpie was the most widespread species in the Winter season. Spring surveys resulted in the highest number of species (nine) rare in abundance and distribution with only one bird at one survey point. Summer, Fall, and Winter surveys resulted respectively in four, five, and four species rare in abundance and distribution.

Habitat Associations

At the community level, the ravine shrubland vegetation type supported the highest bird abundance (all species) per survey point during Spring and Winter surveys. Disturbed/reclaimed and tall shrubland vegetation types supported the highest bird abundance per survey point during Summer and Fall surveys, respectively. Although the mixed grass and short grass vegetation types had low bird abundance per survey point compared with the other vegetation types, the highest total numbers of birds (54 and 42, respectively) were detected at these points during Spring surveys.

Nest Searches

During Spring and Summer 2004, a total of 21 nests representing nine species were located and GPS locations taken. Species comprising the 21 nests include: five black-billed magpie, four western meadowlark, three northern flicker, two American kestrel, two European starling, two mourning dove, one American robin, one rock dove (pigeon), and one western kingbird. See Figure 4 for nest locations.

Upland Game Birds

No upland game birds or their sign were detected during the four seasonal point transect surveys or during other site visits throughout the 2004-2005 surveys. Grouse are not known to occur in the area (Andrews and Righter 1992, Kingery 1998, McKee 2004). In general, other upland game birds (i.e., turkey, quail, pheasant) occur in vegetation types not represented on the STM site.

3.2 Raptor Surveys and Nest Searches

During the Spring 2004 surveys, 12 raptors representing five species were observed while during the Fall 2004 surveys, 18 raptors representing six species were observed (Table 5). The osprey was only observed during the Spring survey and the northern harrier and prairie falcon were only observed during the Fall survey. Only one raptor species, the American kestrel, was noted nesting on the STM site. Both nests observed were located in artificial nest boxes (See Figure 4). While a total of seven species of raptors were observed during surveys, two additional raptor species were observed during other site visits, the golden eagle and the Swainson’s hawk.

Table 5. Raptor Species Observed During Two Surveys at the National Renewable Energy Laboratory South Table Mountain Site, Golden, Colorado.

COMMON NAME	SPRING 2004	FALL 2004	TOTAL
American kestrel	3	7	10
Cooper's hawk	2	1	3
Northern harrier	--	1	1
Osprey	1	--	1

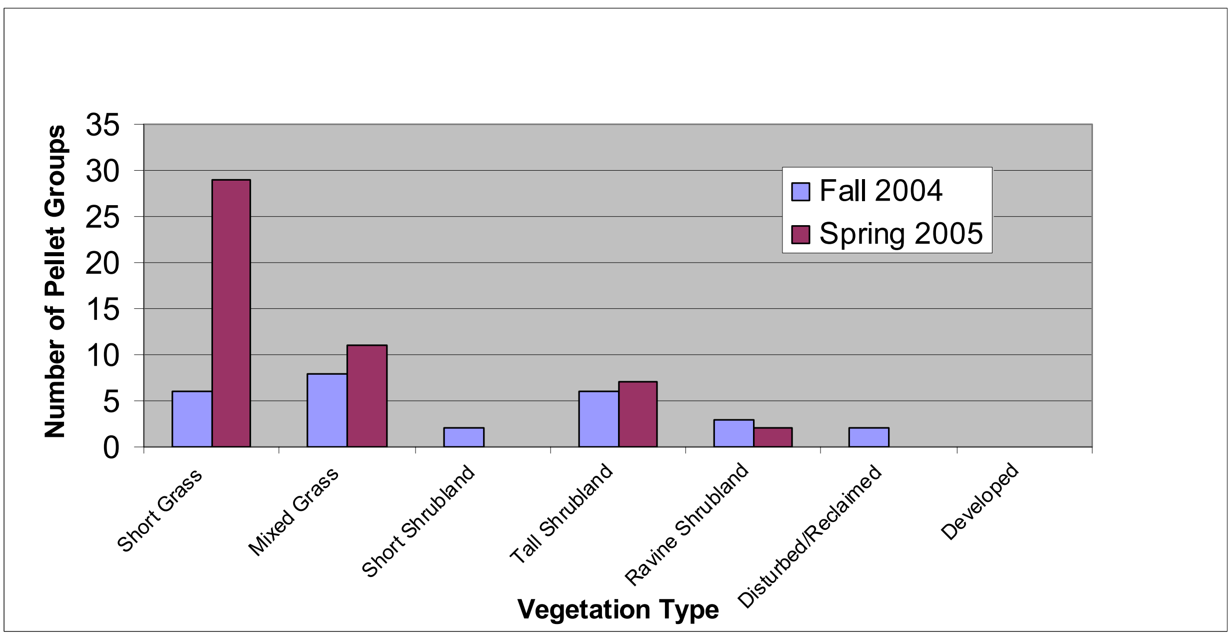
Table 5. Raptor Species Observed During Two Surveys at the National Renewable Energy Laboratory South Table Mountain Site, Golden, Colorado.

COMMON NAME	SPRING 2004	FALL 2004	TOTAL
Prairie falcon	--	1	1
Red-tailed hawk	5	6	11
Sharp-shinned hawk	1	2	3
TOTAL	12	18	30

3.3 Large Mammal Surveys

The Fall 2004 pellet plot surveys resulted in 27 pellet groups observed in 18 of 97 plots, while the Spring 2005 surveys resulted in 49 pellet groups observed in 33 of 97 plots. In each season, three plots were removed or destroyed and not counted in the analysis (See Appendix A for details). Figure 5 shows the number of pellet groups observed in each vegetation type.

Figure 5. Number of Pellet Groups Observed Per Vegetation Type During the 2004-2005 Large Mammal Surveys at the National Renewable Energy Laboratory South Table Mountain Site, Golden, Colorado.



Mixed grass vegetation had the highest number of pellet groups (eight) during the Fall surveys with short grass and tall shrubland vegetation types following with six pellet groups each. Spring surveys resulted in short grass and mixed grass having the highest number of pellet groups (29 and 11, respectively). Mixed grass and short grass vegetation types had the greatest number of plots among the vegetation types and also represent the two largest vegetation types on site.

3.4 Predator Surveys

Throughout the seasonal surveys, only one predator species, the coyote, was detected. No predator species were detected during Winter surveys, although coyote tracks were observed during winter incidentally outside of scent stations. Scent station P-3, located in the northeast section of the mesa top, was the only scent station in which coyote tracks were never observed.

3.5 Small Mammal Surveys

Small mammal surveys were conducted in Summer and Fall 2004, Winter 2004-2005 and Spring 2005. During the Summer survey, due to inclement weather (i.e., heavy rain and temperatures below 45 degrees) and the associated increased risk of mortality of individuals in traps, two nights of surveys occurred one week, and the other two nights of surveys occurred during a separate week. All other surveys occurred during four consecutive nights as indicated in the protocol.

A total of four small mammal species were caught during the surveys: deer mouse, Mexican woodrat, prairie vole, and western harvest mouse. Of the four species, deer mouse was the most abundant species caught each season (Table 6), followed by Mexican woodrat, prairie vole, and western harvest mouse. Trapping success rates ranged from a low of 28 percent in Summer to a high of 51 percent in Winter.

Table 6. Season, Vegetation Type, and Small Mammal Species Captured During 2004-2005 at the National Renewable Energy Laboratory South Table Mountain Site, Golden, Colorado.

SEASON AND VEGETATION TYPE	SPECIES			
	Deer mouse	Mexican woodrat	Prairie vole	Western harvest mouse
SUMMER 2004				
Mixed grass	37	0	0	0
Short grass	22	0	3	0
Short shrubland	7	14	0	0
Ravine shrubland	20	10	0	0
TOTAL (113)	86	24	3	0
FALL 2004				
Mixed grass	56	0	2	1
Short grass	50	0	10	0
Short shrubland	2	15	0	0
Ravine shrubland	34	21	0	0
TOTAL (191)	142	36	12	1
WINTER 2004-2005				
Mixed grass	54	0	6	0
Short grass	53	0	6	0
Short shrubland	13	10	0	0
Ravine shrubland	52	10	0	0
TOTAL (204)	172	20	12	0
SPRING 2005				
Mixed grass	33	0	4	0
Short grass	30	0	7	0
Short shrubland	8	11	0	0
Ravine shrubland	37	10	0	0
TOTAL (140)	108	21	11	0
GRAND TOTAL	**511**	**101**	**38**	**1**

Deer mice were the only species caught in all four vegetation types. Mexican woodrats were only found in two vegetation types, short shrubland and ravine shrubland. Prairie vole captures were also limited to two vegetation types, mixed grass and short grass, although one dead prairie vole was observed adjacent to a trap in Drainage A, short shrubland vegetation type, in Spring 2005. Only one western harvest mouse was captured during the four surveys and it was in the mixed grass vegetation type. The deer mouse had the highest overall relative abundance (78.4 percent), followed by Mexican woodrat (15.6 percent), prairie vole (5.9 percent), and western harvest mouse (0.2 percent).

3.6 Reptile/Amphibian Surveys

Reptiles or amphibians were observed in three of four seasons. No reptiles or amphibians were observed on the STM site during the Winter season, when reptiles and amphibians hibernate. Western rattlesnake was the only species of reptile observed in three seasons. Two other reptiles were observed during the Summer season (plains garter snake and six-lined racerunner) and one amphibian species, the tiger salamander, was observed during the Fall season.

3.7 Comparison of 2004-2005 Wildlife Survey With 1987 Wildlife Survey

Design of the 2004-2005 wildlife surveys was based, in part, on the 1987 study. Types of wildlife were sorted into similar groups (i.e., migratory birds, small mammals, etc.) and surveys were conducted during a similar timeframe (four seasons). The survey protocol used typically differed from 1987 to 2004-2005 and differences are described below for each survey type. The primary differences between the 1987 and 2004-2005 surveys are changes in sample locations and changes in survey protocol. The 1987 survey report did not identify GPS locations of sample points and thus different locations were identified for 2004-2005 surveys. For example, SAIC established new transects and survey stations to sample the major vegetation types. In addition, changes in survey protocol were due to new information in the scientific literature, changes in regulations of the STM site, or other factors. Differences in sample point locations and protocol limit comparison of data collected by the two surveys; however where possible, comparisons were made for each type of survey conducted on the STM site.

Migratory Bird Surveys

Driving and walking transects were established for migratory bird surveys during the 1987 wildlife study and surveys were conducted on three consecutive mornings each season. The 2004-2005 surveys followed the point-transect method and conducted these surveys on two consecutive mornings per season. The point-transect method adds the transect component to point counts, increasing the possibility of observing birds that tend to occur in lower densities. No driving transects were conducted during the 2004-2005 study, as driving is not currently permitted off the main roads of the STM site and the walking point-transect method is considered a better method for surveying migratory birds compared to driving.

A total of 17 bird species (species richness) was observed during the four 1987 bird surveys, whereas 37 bird species were observed during the four 2004-2005 bird surveys. Two species observed in 1987 were not observed during the 2004-2005 surveys: horned lark (spring) and red-winged blackbird (spring). Horned larks and red-winged blackbirds are both known to breed in Jefferson County (Kingery 1998). The fewest species of birds were observed during the winter surveys for both the 1987 and 2004-2005 studies.

There are multiple methods for calculating species diversity and evenness. In the 1987 study, diversity and evenness for migratory birds was calculated by habitat in each season; however, the indices for calculating these statistics were not identified. The 2004-2005 study calculated diversity and evenness indices for the overall site per season rather than by habitat. Since the 1987 and 2004-2005 surveys calculated diversity and evenness at different scales and since the indices were not identified by the 1987 survey, diversity and evenness indices for the two surveys cannot be compared.

Raptor Surveys

The 1987 surveys consisted of driving and walking surveys once in winter and once in spring. The 2004-2005 surveys consisted of monitoring the site from a fixed observation point one morning and another fixed observation point a second consecutive morning once in the Spring and once in the Fall. Two species of raptors were observed during the 1987 wildlife surveys, American kestrel and red-tailed hawk. During the 2004-2005 raptor surveys, SAIC observed seven species of raptors: American kestrel, Cooper's hawk, northern harrier, osprey, prairie falcon, red-tailed hawk, and sharp-shinned hawk. Surveys during 2004-2005 coincide with raptor migration season, April and late September/early October. Peak migration for raptors occurs during mid-April (Rectenwald 2004). The 1987 surveys identified red-tailed hawks as nesting on site, while the 2004-2005 surveys documented only American kestrels nesting on site. Two additional raptor species were observed on the STM site outside of the 2004-2005 raptor surveys periods, the golden eagle and the Swainson's hawk.

Large Mammal Surveys

The 1987 and 2004-2005 surveys both used protocol by Neff (1968) for pellet group surveys. The 1987 survey established two transects with a total of 50 plots. To survey more habitat types, the 2004-2005 survey established 100 plots on seven transects. During the 2004-2005 Fall and Spring seasons, three plots were removed or destroyed and not counted in the analysis (See Appendix A for details). No pellet groups were identified during the 1987 winter survey of 50 pellet group plots, nor were any data collected during the 1987 summer survey due to the unexplained removal of the transect staking. The 1987 study did note that mule deer were observed on site during the winter, spring and summer periods.

SAIC observed mule deer on site during all four seasons and pellet groups were observed in 18 of the 97 pellet plots during Fall 2004 and in 33 of the 97 pellet plots during Spring 2005 surveys. Although these data cannot determine the number of deer on site, general habitat use patterns could be determined if additional annual seasonal surveys were conducted. Spring surveys resulted in nearly double the amount of pellet groups observed as well as the number of plots the pellet groups were observed in. This may suggest that winter use of the STM site by deer may be higher than summer use, although this is only based on one year of data.

Predator Surveys

Different methods of attracting predators were used in the 1987 and 2004-2005 scent station surveys. The 1987 study used three scents (canine, feline, and mustelid [weasel]), with one scent in each circle per station. In an attempt to reduce the number of variables, the 2004-2005 study used one scent (fatty acid) in one circle per station. The 1987 study noted three medium-size mammals that visited the predator scent post stations: coyote, raccoon, and fox. The coyote was the most abundant species and was observed in all four seasons. A total of one raccoon and one fox were observed and these observations occurred only in the winter season. Coyotes were the only predator detected in the scent stations during the 2004-2005 surveys.

Coyotes were detected in the scent stations in all seasons except Winter. In the Winter season, coyote tracks were incidentally observed at other locations on site.

Small Mammal Surveys

Similar to predator surveys, the 1987 and 2004-2005 small mammal surveys utilized different methods for trapping. The 1987 study established three trap grids on site each with 40 traps for three consecutive nights each season for a total of 360 trap nights per season. Bait consisted of dry oatmeal. To sample more habitat types, the 2004-2005 survey established six transects throughout the site for a total of 100 traps and conducted the survey for four consecutive nights each season for a total of 400 trap nights per season. It has been suggested that transects result in higher success rates for trapping small mammals than grids (Pearson and Ruggiero 2003). Bait consisted of oats mixed with peanut butter for the 2004-2005 surveys.

Three of the four species captured during the 1987 small mammal trapping surveys were also captured during the 2004-2005 surveys: deer mouse, prairie vole, and western harvest mouse. Different species of woodrats were captured; in 1987 bushy-tailed woodrats were trapped and in 2004-2005, Mexican woodrats were trapped. Although different species of woodrats were trapped, both species were captured only in the drainages where shrubs are common. Bushy-tailed woodrats and Mexican woodrats are similar in appearance; however, Mexican woodrats have a bi-colored, short-haired tail and are generally smaller than bushy-tailed woodrats. Mexican woodrats range in weight from 149 to 255 grams, while bushy-tailed woodrats generally weigh 270 to 299 grams (Fitzgerald et al. 1994). The largest woodrat trapped during the 2004-2005 surveys weighed 258 grams. Weights of bushy-tailed woodrats were not identified in the 1987 study. Trapping success rates ranged from seven to 14 percent in the 1987 study and from 28 to 51 percent in the 2004-2005 study. Similar to the 1987 survey, deer mice were captured in all vegetation types during the 2004-2005 surveys. Overall, deer mice were the most abundant species captured during the 1987 and 2004-2005 surveys, with woodrats, prairie voles and western harvest mice following.

Reptile/Amphibian Surveys

Three species of reptiles were observed during the 1987 wildlife survey of the STM site (bull snake, common garter snake, and rattlesnake). During the 2004-2005 wildlife surveys, SAIC observed two of these three species (garter snake and rattlesnake). SAIC also confirmed the 1987 expectation of tiger salamanders occurring on the STM site when one was observed in Fall 2004 near the site entrance building. SAIC observed one additional reptile species during the 2004-2005 study, the six-lined racerunner. Sightings of reptiles/amphibians were opportunistic for the 1987 and 2004-2005 surveys.

3.8 Species of Concern

For this report, a species of concern is defined as those species protected under Federal statute including the Endangered Species Act of 1973, as amended, the Bald Eagle Protection Act of 1940, as amended, and the Colorado Division of Wildlife list of endangered, threatened, and wildlife species of concern. Federal agencies are also required to abide by the Migratory Bird Treaty Act of 1918, as amended, but for this report, these species are not included as species of concern.

SAIC reviewed the U.S. Fish and Wildlife Service proposed, endangered, threatened, experimental, and candidate species and habitat list (USFWS 2004) and the Colorado Division of Wildlife (CDOW) listing of endangered, threatened and wildlife species of special concern list

(CDOW 2003) for species observed on the STM site. No species observed on the STM site during the 1987 or the 2004-2005 wildlife surveys were present on either agency's list. However, golden eagles were incidentally observed on the STM site (outside of raptor surveys) and are protected under the Bald Eagle Protection Act. Golden eagles were observed flying over the site and may use the site for hunting. No golden eagle nests or nesting activities were observed on the STM site.

3.9 Discussion

The 2004-2005 wildlife study identified and inventoried wildlife present on the NREL STM site. Where possible, the study used current standard protocols published in the scientific literature to sample wildlife on the STM site. The study represents a sample or snapshot in time of what species occurred on the site and is not intended to reflect a complete census of wildlife on the site. Survey effort was limited by available time and budget. More intensive surveys (i.e., more days in the field) may have yielded observations of additional species (i.e., higher diversity) and/or more individuals (i.e., higher evenness) of each species on the STM site; however, regardless of the level of effort, all one-year survey results can be affected by weather; habitat conditions on site, at adjacent sites, and on wintering grounds; observer variation; and population fluctuations in species due to disease and other factors. Long-term, annual surveys using the same sample locations, methods, and indices can be used to establish and detect change in trends for a particular site like NREL STM. However, it should be noted that for highly mobile species not restricted to the NREL STM site (e.g., migratory birds), absence or downward trends in these species may reflect offsite conditions or other factors beyond the control of NREL.

As there is natural variability in wildlife populations, especially breeding bird communities, the continuation of like wildlife surveys throughout the years would allow trends to be established regarding populations of species. The U.S. Fish and Wildlife Service Breeding Bird Survey (BBS) is an example of long-term wildlife survey results used to detect trend. Differences in the bird community were evident between seasons during the 2004-2005 surveys and between the 1987 and 2004-2005 data, as several species were observed in one year and not the other. Several bird species associated with disturbed areas, such as European starlings and house sparrows, were found at the project site. As the landscape becomes more developed, these bird species may become more abundant. European starlings in particular displace native birds from tree cavities where they build their nests and were observed nesting in cavities excavated by northern flickers on the STM site. Studies conducted over several years may give some indication of temporal variation however, long-term studies conducted over decades may provide additional information regarding patterns in bird populations and communities, including species turnover (Wiens 1989a).

There are limitations associated with sampling wildlife populations, especially breeding birds. Species characteristics and observer differences can influence and affect the results of breeding bird surveys. Mayfield (1981) found that some species cannot be counted effectively during brief listening periods. Some species sing loudly from prominent points and others may sing softly while hidden in dense vegetation (Wiens 1989b). Song frequency can vary among species. Observer variability also plays a role in detecting birds during point counts. Wiens (1989b) found that two observers with equivalent experience, when surveying simultaneously for breeding birds in the same location using the same method, did not necessarily obtain the same results.

Results of the surveys conducted in 2004-2005, including the wildlife species list, should be viewed as a work in progress. Not all species that reside on or migrate through the site may have been observed. For example, no specific surveys for bats were conducted as part of the 2004-2005 wildlife surveys and although no bats were observed during any site visit, nocturnal surveys were not conducted and bats could potentially utilize the site. Some species of wildlife may be difficult to observe because they are secretive, nocturnal, or occur in low densities. Nighttime security workers may observe nocturnal species not otherwise observed during daytime wildlife surveys.

Migratory Birds and Raptors

Many species of migratory birds were observed on the STM site, with many of these species potentially nesting on site. In addition, the STM site may provide important migration and winter habitat for migratory birds. For example, the American tree sparrow was only observed on site during Winter surveys and the northern harrier was observed hunting on site only in the Fall and Winter seasons. Several species were only observed during the Fall season including downy woodpecker, red-breasted nuthatch, blue jay, loggerhead shrike, and rock wren, suggesting that these species may use the STM site as a stopover during migration. Habitat for migrating birds is important, as some of these species may migrate as far south as Central and South America.

Species diversity and evenness can be calculated using multiple methods and the results for an individual site can change annually due to a number of factors including but not limited to weather, changes in winter habitat conditions, and population fluctuations. However, over time, comparison of annual diversity and evenness indices for the same site (e.g., NREL STM), that are based on the same methods, can provide trend data. A similar comparison of the NREL STM site 2004-2005 diversity and evenness indices with other sites along the Colorado Front Range would be problematic due to variation in habitats sampled, habitat condition of the sampled site and surrounding area, survey methods, index calculation methods, and weather.

Several species of raptors were observed at the STM site and, two species were observed by both studies (1987 and 2004-2005) nesting on site, the red-tailed hawk and the American kestrel. Both of these species were observed hunting on site during the 2004-2005 surveys, in addition to the Cooper's hawk. The NREL STM site provides habitat and a prey base of small birds and small mammals for these raptor species. Species such as the Swainson's hawk migrate thousands of miles each year, wintering as far south as Argentina, and returning to the western United States and Canada to breed. Areas such as the STM site may provide a prey source for the Swainson's hawk and other species during migration.

Large Mammals

Mule deer at the STM site have been observed in all habitat types. Mule deer were often observed in the amphitheater drainage or in the tall shrubland on the slope above Transect A. When approached on the mesa top, the mule deer tended to move away from the disturbance and into the amphitheater drainage. The tall shrubland vegetation type may provide important hiding cover for this species. Spring pellet group surveys resulted in nearly double the amount of pellet groups and plots the pellet groups were observed in than Fall surveys. This may suggest that winter use of the STM site by deer may be higher than summer use or that deer utilize different habitats on site for these periods as affected by the availability of habitats and the location of survey plots, although the single year of data is not sufficient to draw conclusions regarding seasonal variation.

Predators

Coyotes are one of the most widespread and adaptable carnivores in North America and occur at all elevation levels and in all ecosystems in Colorado (Fitzgerald et al. 1994). Lagomorphs (rabbits) and rodents are an important part of the coyote's diet, both of which are abundant on the STM site. Evidence of predation on cottontail rabbits (i.e., entrails and fur) was observed during site visits. Coyotes may breed on the STM site as two potential dens were observed on site; one in Drainage B and one in the amphitheater drainage.

Small Mammals

The deer mouse is the widest ranging and commonest small mammal in North America (Fitzgerald et al. 1994) and based on the 1987 and 2004-2005 survey data, it is also the most common small mammal on the NREL STM site. Deer mice can occur anyplace where cover occurs (Fitzgerald et al. 1994) and were observed in the four vegetation types sampled on the STM site. This species is a generalist and is known to exploit disturbed habitats. Mexican woodrats and prairie voles were more restricted than the deer mouse in the habitats they occupied on the STM site. Mexican woodrats are associated with rocky slopes and do not build dens away from rocky areas (Fitzgerald et al. 1994). This species is therefore limited as to where it can occur on the STM site. Prairie voles are adapted to the grasslands, constructing burrows and runway systems throughout the grassland, essentially limiting this species to the short grass and mixed grass vegetation types on the STM site. All of these species are active throughout the year. Winter surveys (2004-2005) were conducted during a warm weather trend, which may have contributed to the highest number of small mammals caught compared to the three other surveys.

Reptiles/Amphibians

Several rattlesnakes were observed on the STM site, more often in rocky areas, but also in the grassland. A rattlesnake den may be present in the rocks near the top of the mesa slope north of the Visitor's Center (near E-2-3) as four rattlesnakes were observed within a few feet of each other, one in the open and three in a rock crevice. Hibernation generally occurs in rock outcrops, with this species usually active from mid-April through late-September (Hammerson 1999). Although only three species of reptiles and one species of amphibian were observed on the STM site, no specific survey methods were employed to identify or count these groups of wildlife at STM.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The NREL STM site provides vegetation types for a variety of wildlife species including birds, mammals, and reptiles and amphibians. The variety of vegetation types present on site attracts species that may use the site as year-round habitat, for breeding only, during migration, or as winter habitat. To avoid or minimize disturbance to wildlife species on site, the following site-wide best management practices and mitigation measures are recommended for consideration during normal site operations and future construction projects. Some of the following recommendations may also serve as mitigation for future, unavoidable impacts to wildlife.

Migratory Birds and Raptors

- Avoid starting ground-disturbing construction projects during breeding season for migratory birds (approximately April 15 – July 15) and raptors (approximately January – July). By avoiding initiating ground disturbing activities during the breeding season, the potential for *take* of bird species and nests, as defined by the Migratory Bird Treaty Act, would be minimized.

- Conduct migratory bird and raptor surveys and nest searches 30 days prior to the start of construction if breeding season can not be avoided. Contact the U.S. Fish and Wildlife Service if nests are found for their determination of what action should be taken.
- During breeding season, grassland areas within construction zones should be mowed as needed to maintain grass heights of less than three inches to minimize the potential of nesting birds within the construction zone. Mowing may begin before breeding season and continued until construction starts in lieu of bird surveys, provided grass heights of less than three inches are maintained throughout the breeding season.
- Migratory bird and raptor surveys and nest searches should be conducted by a person with the following minimum qualifications: Bachelor's degree in natural resources field with at least 2 years experience conducting bird surveys, or other applicable training.

Mammals

- Maintain movement corridors for larger wildlife (e.g., deer, coyotes), including access to Lena Gulch.
- Consider designing new fences with wildlife movement corridors in mind by working with CDOW to establish wildlife friendly fences that funnel wildlife to where wildlife can cross fences (e.g., one-way gates).

All Wildlife

- Continue the integrated weed management component of the vegetation management program to prevent new weed infestations, eradicate small weed populations, manage existing weed populations, and monitor for new weed infestations as recommended in Plantae Consulting Services 2002.
- Consider partnering with adjacent landowners and other agencies regarding the control of weed species.
- Continue using eradication of weeds as habitat enhancement to mitigate loss of other habitat on site.
- When possible, conserve native vegetation and habitats to support wildlife diversity.
- Continually update the species list identified in Table 3. Consider posting or disseminating (e.g., NREL website) Table 3 throughout the NREL facility to increase awareness of wildlife and educate employees about wildlife conservation.

General Site Operations

- Consider developing and electronically integrating institutional controls, as part of NREL's Environmental Management System (EMS) and budgetary system, to facilitate future NREL project planning with the goals of: 1) incorporating environmental consideration early in project planning; 2) budgeting for environmental planning, review, and compliance; and 3) minimizing impacts to natural resources.
- Consider developing an interactive Geographic Information System (GIS) spatial tool for the NREL STM site to include the location, value, and capacity of all infrastructure (built and natural). This tool could be used to display and manage wildlife locations (e.g., nests, sightings, etc.), inform employees of wildlife hazards (e.g., rattlesnake sightings during summer), educate employees about wildlife conservation, and bank and account for natural infrastructure value and capacity. This tool could be integrated with other programs to also provide security, maintenance, and operation benefits.

- Consider installing one or more Webcams on the site to monitor wildlife viewing opportunities (e.g., active bird nest) and to educate employees about wildlife conservation.
- Consider mitigating impacts from light pollution through the use of appropriate lighting, facility design, and operational controls.

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APPENDIX A

2004-2005 Wildlife Surveys Quarterly Reports

TO: Maureen Jordan, NREL

FROM: Madeline Terry, SAIC

CC: Margaret Mortenson (NREL)
Robert Henke (SAIC)
Mark Deffley (SAIC)

DATE: August 16, 2004

SUBJECT: National Renewable Energy Laboratory Wildlife Surveys Project – Summer Letter Report (SAIC Project No. 01-0203-04-8269-xxx)

1.0 INTRODUCTION

A wildlife study of the National Renewable Energy Laboratory (NREL) South Table Mountain (STM) site in Golden, Colorado was conducted in 1987 by The FORUM Associates, Inc. The demographics of the area surrounding the STM site have changed and there has been significant additional development of the STM site since that time. At the request of the Department of Energy (DOE), Science Applications International Corporation (SAIC) began a four season wildlife study of the STM site in Spring 2004 to update the 1987 data and, at the end of the study, to compare the results of the 2004 - 2005 wildlife study with the 1987 study. During Spring and Summer 2004, survey protocols and stations were established on site as needed to survey for birds, raptors, large mammals, predators, small mammals and reptiles and amphibians. This report summarizes the results of the Spring 2004 season in which migratory bird and raptor surveys were conducted and the Summer 2004 season in which migratory bird, predator and small mammal surveys were conducted. Reptiles and amphibians were surveyed for opportunistically during both seasons. Scientific names are listed in Appendix A.

2.0 DESCRIPTION OF SURVEY PROTOCOLS

2.1 Site-wide Bird Survey and Nest Search

Migratory bird surveys and nest searches were conducted on April 5 and 6, 2004 (Spring) and June 8 and 9, 2004 (Summer) using point transects (RMBO et al. 2000). Six transects (A, B, C, D, E and F) were established throughout the site, with interpoint intervals of 250 meters (m) (Figure 1 found in Appendix B). A four foot tall t-post was placed at each survey point. The point count duration was five minutes at each of 20 points. All birds seen and/or heard were recorded, the distance to each individual was estimated, and the sex of each bird was recorded for each point. Only individuals of target bird species for the habitat type, as identified in RMBO et al. 2000, were recorded along the transect. The maximum number of individuals of each bird species detected at each survey point during the two point count surveys per season was used in the analysis. Spring and Summer season data were analyzed separately. Nest searches were based on Ralph et al. 1993 in which an SAIC biologist conducted an ocular search for bird activity and scanned for potential nest locations. All nests located were marked using a Garmin Global Positioning System (GPS), model GPSmap 60C, provided by NREL.

Bird species diversity and evenness were calculated using the Simpson's index of diversity and Simpson's index of 'equitability' or 'evenness' (Begon et al. 1990). Species diversity is an index of community diversity that takes into account both species richness and the relative abundance of species (Begon et al. 1990). Richness is the number of species found in a community. Simpson's index of diversity (D) is calculated as:

$$D = \frac{1}{\sum_{i=1}^{S} P_i^2}$$

where S is the species richness or total number of species and P_i is the proportion that an individual species contributes to the total of the sample. This index takes into account both the total number of species (richness) and how common or rare each species is. Thus, for a given evenness, diversity increases with species richness; similarly, for a given species richness, diversity will increase with evenness (Begon et al. 1990). This index is abstract, but can be used as a benchmark for future surveys. Evenness is a function of the relative abundance of the species that occur in a community. Simpson's index of evenness (E) is calculated as:

$$E = \frac{D}{S}$$

The Simpson's index of evenness has a maximum value of one (even composition of each species), and lower values have a more disparate species composition with some species being more common and others being rare.

2.2 Site-wide Raptor Survey and Nest Search

Two 4-hour surveys for raptors were conducted on April 15 and 16, 2004 (Spring) from two observation points established on site. One 4-hour survey was conducted from one point one morning and a second 4-hour survey was conducted from the second observation point the next morning from approximately 8:00AM to 12:00PM. Nest searches were conducted on foot following each survey period. All trees were searched and an ocular search for raptor activity conducted. All nests located were marked using the Garmin GPSmap 60C provided by NREL.

2.3 Site-wide Large Mammal Survey

Following methods in Neff (1968), 100 pellet-group plots were established on site on April 2, 2004. These circular plots measuring $4m^2$ were placed 50m apart along transects A through F, set up for migratory bird surveys, and along transect G, established only for large mammal surveys. Stakes, 30 centimeters in height, were placed every 50m along the transects to mark the center of the plots. Where t-posts marked migratory bird survey points, the t-post was the center of the pellet plot. All pellets in each plot were removed during set up. The plots will be checked for new pellets in the Fall 2004 season. Plots containing pellets will be recorded and all pellets will be removed. Plots will be checked again in the Spring 2005 season.

2.4 Site-wide Predator Survey

SAIC conducted scent-station surveys for predators following methods modified from Linhart and Knowlton (1975). Nine scent-stations were placed at 0.3 kilometer intervals along transects already established on site for migratory bird surveys (See Section 2.1). Each station consisted of a 1-m^2 circle of sifted dirt with one fatty acid scent predator survey disk (F.A.S. Scented Disk from Pocatello Supply Depot, Pocatello, ID) placed in the center as an attractant. Two surveys, each consisting of three consecutive nights, were conducted during the Summer quarter. Stations were re-sifted each day. Scent disks were replaced with new disks for the third night of surveys based on the volatilization rate of the fatty acid scent (Roughton and Sweeney 1982).

2.5 Site-wide Small Mammal Survey

Small mammal trapping followed methods described in Pearson and Ruggiero (2003). Six transects were established on site in the major habitat types. Large Sherman live traps (3”x3.5”x9”) were used and were located 15m apart on each transect. A total of 100 traps were set each night for four consecutive nights for a total of 400 trap nights. Trapping began the night of June 15, 2004 and continued on June 16, 2004. Due to inclement weather (i.e., heavy rain and temperatures below 45 degrees) and the possibility of increasing mortality of individuals in traps, surveys were not conducted the following two nights as the method indicates. Trapping for the two remaining nights was resumed when the weather improved on July 1 and 2, 2004. The number of traps per transect were as follows (see Figure 1 for transect locations):

- Visitor’s Center (VC) – 20 traps were located in the mixed grass habitat north of the visitor’s center.
- Camp George West (CGW) – 20 traps were located in the mixed grass habitat in the Camp George West property south of Denver West Parkway.
- Mesa Top (MT) – 30 traps were located in the short grass habitat on the mesa top.
- Drainage A (DA) – 10 traps were located in the short shrubland habitat south of the amphitheatre.
- Drainage B (DB) – 10 traps were located in the ravine shrubland habitat in the drainage northeast of the Solar Energy Research Facility (SERF).
- Drainage C (DC) – 10 traps were located in the short shrubland habitat of the drainage on the east-central part of the site.

Each trap was baited with a mixture of peanut butter and oats. Polyester fiber batting was placed in each trap for bedding material. Each small mammal caught was identified to species, its age and sex were determined and it was weighed. Small mammals were released at the trap station. Habitat types follow Plantae Consulting Services 2002.

2.6 Site-wide Reptile and Amphibian Survey

Reptiles and amphibians were surveyed for opportunistically during the Spring and Summer 2004 seasons. All reptiles and amphibians encountered on site were identified and recorded.

3.0 DOCUMENTATION OF SURVEY RESULTS

3.1 Migratory Bird Surveys and Nest Searches

NREL provides habitat for a diversity of bird species. Habitat types surveyed for migratory birds at NREL included short grass, mixed grass, tall shrubland, ravine shrubland, disturbed/reclaimed and developed as defined by Plantae Consulting Services 2002. The total number of bird species observed on site during Spring and Summer 2004 was 34 (Appendix A). This list is a work in progress that can be expanded as additional bird species are observed at NREL during the four season wildlife surveys.

3.1.1 Spring 2004

Bird Community

A total of 20 species and 164 birds were recorded during the Spring 2004 point transect surveys (Table 1). Of the 20 species recorded, 11 species and 128 birds (78% of the total birds recorded) were songbirds. Most songbirds were detected by their breeding songs and therefore probably breed at NREL. Bird species diversity and equitability for NREL in Spring 2004, as measured by Simpson's index was 6.5 and 0.33, respectively. Target bird species for grassland habitats include greater roadrunner, mountain plover, upland sandpiper, burrowing owl, loggerhead shrike, and Cassin's sparrow and for mountain shrubland habitats, sharp-tailed grouse. None of the target bird species were observed along the transects.

Table 1. Number of Breeding Birds Detected During Spring 2004 Surveys at the National Renewable Energy Laboratory, Golden, Colorado.

Species	Number of Birds Detected	Number of Survey Points Observed (n = 20)
American crow	1	1
American kestrel	1	1
American robin	22	14
Black-billed magpie	9	7
Black-capped chickadee	2	2
Common raven	3	2
European starling	19	6
Golden eagle	1	1
House finch	8	4
House sparrow	8	5
Mourning dove	1	1
Northern flicker	16	15
Red-tailed hawk	1	1
Rock dove	4	2
Say's phoebe	1	1
Spotted towhee	13	8
Unidentified sparrow 1	1	1
Unidentified sparrow 2	1	1
Western meadowlark	51	19
White-crowned sparrow	1	1
All Species Spring 2004	164	20

Individual Species

The western meadowlark and the American robin were the most abundant species (51 and 22 birds, respectively). The western meadowlark was also the most widespread species, occurring at 19 survey points. The next most abundant species were the European starling (19 birds), northern flicker (16 birds), and spotted towhee (13 birds). The northern flicker and the American robin were the next most widespread species occurring at 15 and 14 survey points, respectively. Nine species were rare in abundance and distribution with only one bird at one survey point.

Habitat Associations

At the community level, the ravine shrubland habitat type supported the highest bird abundance (all species) per survey point (Table 2). Although the mixed grass and short grass habitats had low bird abundance per survey point compared with the other habitats, the highest total numbers of birds (54 and 42, respectively) were detected at these points during Spring surveys.

Table 2. Average Number of Birds Detected Per Survey Point for Habitat Types During Spring 2004 Surveys at the National Renewable Energy Laboratory, Golden, Colorado.

Species	Short Grass n=7	Mixed Grass n=7	Tall Shrubland n=3	Ravine Shrubland n=1	Disturbed/ Reclaimed n=1	Developed n=1
American crow	0.14	0.00	0.00	0.00	0.00	0.00
American kestrel	0.00	0.14	0.00	0.00	0.00	0.00
American robin	1.00	1.00	1.33	3.00	1.00	0.00
Black-billed magpie	0.00	0.29	1.67	1.00	0.00	1.00
Black-capped chickadee	0.00	0.14	0.33	0.00	0.00	0.00
Common raven	0.43	0.00	0.00	0.00	0.00	0.00
European starling	0.29	0.14	3.00	5.00	2.00	0.00
Golden eagle	0.00	0.14	0.00	0.00	0.00	0.00
House finch	0.00	0.71	0.00	0.00	0.00	3.00
House sparrow	0.00	0.57	0.33	0.00	3.00	0.00
Mourning dove	0.00	0.14	0.00	0.00	0.00	0.00
Northern flicker	0.57	0.86	1.33	1.00	1.00	0.00
Red-tailed hawk	0.00	0.14	0.00	0.00	0.00	0.00
Rock dove	0.00	0.29	0.00	0.00	2.00	0.00
Say's phoebe	0.00	0.00	0.00	0.00	0.00	1.00
Spotted towhee	0.00	0.86	1.33	2.00	1.00	0.00
Unidentified sparrow 1	0.14	0.00	0.00	0.00	0.00	0.00
Unidentified sparrow 2	0.14	0.00	0.00	0.00	0.00	0.00
Western meadowlark	3.29	2.29	2.00	2.00	2.00	2.00
White-crowned sparrow	0.00	0.00	0.00	1.00	0.00	0.00
Average Number of Birds (all species) per Survey Point	**6.00**	**7.71**	**11.32**	**15.00**	**12.00**	**7.00**

n – Number of survey points

Upland Game Birds

No upland game birds were detected during Spring 2004 point transect surveys or during other site visits.

3.1.2 Summer 2004

Bird Community

A total of 20 species and 193 birds were recorded during the Summer 2004 point transect surveys (Table 3). Of the 20 species recorded, eight were species not detected during Spring 2004 surveys. Seven species detected during the Spring 2004 surveys were not detected during Summer 2004 surveys. Most songbirds were detected by their breeding songs and therefore probably breed at NREL. Bird species diversity and equitability for NREL in Summer 2004, as measured by Simpson's index were 7.6 and 0.39, respectively, reflecting an increase from Spring 2004 surveys. None of the target bird species were observed along the transects.

Table 3. Number of Breeding Birds Detected During Summer 2004 Surveys at the National Renewable Energy Laboratory, Golden, Colorado.

Species	Number of Birds Detected	Number of Survey Points Observed (n = 20)
American kestrel	2	1
American robin	6	4
Barn swallow	4	3
Black-billed magpie	10	7
Brewer's blackbird	1	1
Brown headed cowbird	1	1
Bullock's oriole	6	3
European starling	8	5
House finch	44	17
House sparrow	9	4
Killdeer	1	1
Mourning dove	10	6
Northern flicker	5	4
Rock dove	3	2
Spotted towhee	18	12
Tree swallow	6	5
Unidentified species	1	1
Vesper sparrow	7	6
Western kingbird	6	3
Western meadowlark	45	20
All Species Summer 2004	193	20

Individual Species

The western meadowlark and the house finch were the most abundant species (45 and 44 birds, respectively). The western meadowlark was also the most widespread species, occurring at all 20 survey points. The next most abundant species were the spotted towhee (18 birds), black-billed magpie (10 birds), and mourning dove (10 birds). The house finch and the spotted towhee were the next most widespread species occurring at 17 and 12 survey points, respectively. Four species were rare in abundance and distribution with only one bird at one survey point.

Habitat Associations

At the community level, the disturbed/reclaimed habitat type supported the highest bird abundance (all species) per survey point (Table 4). The mixed grass habitat had a higher bird abundance compared with Spring 2004 surveys. The mixed grass and short grass habitats had the highest total numbers of birds detected during Spring 2004 surveys (54 and 42, respectively) and Summer 2004 surveys (75 and 51, respectively).

Table 4. Average Number of Birds Detected Per Survey Point for Habitat Types During Summer 2004 Surveys at the National Renewable Energy Laboratory, Golden, Colorado.

Species	**Short Grass** n=7	**Mixed Grass** n=7	**Tall Shrubland** n=3	**Ravine Shrubland** n=1	**Disturbed/ Reclaimed** n=1	**Developed** n=1
American kestrel	0.00	0.29	0.00	0.00	0.00	0.00
American robin	0.14	0.43	0.00	2.00	0.00	0.00
Barn swallow	0.00	0.43	0.00	0.00	1.00	0.00
Black-billed magpie	0.00	0.57	0.67	2.00	1.00	1.00
Brewer's blackbird	0.00	0.14	0.00	0.00	0.00	0.00
Brown headed cowbird	0.00	0.00	0.33	0.00	0.00	0.00
Bullock's oriole	0.00	0.57	0.00	1.00	1.00	0.00
European starling	0.00	0.71	0.67	0.00	1.00	0.00
House finch	1.71	1.86	2.00	6.00	3.00	4.00
House sparrow	0.00	0.71	0.67	0.00	2.00	0.00
Killdeer	0.00	0.14	0.00	0.00	0.00	0.00
Mourning dove	0.29	0.29	1.00	0.00	3.00	0.00
Northern flicker	0.00	0.43	0.67	0.00	0.00	0.00
Rock dove	0.00	0.00	0.67	0.00	1.00	0.00
Spotted towhee	0.57	1.29	1.33	1.00	0.00	0.00
Tree swallow	0.14	0.57	0.33	0.00	0.00	0.00
Unidentified species	0.14	0.00	0.00	0.00	0.00	0.00
Vesper sparrow	0.71	0.14	0.33	0.00	0.00	0.00
Western kingbird	0.00	0.43	1.00	0.00	0.00	0.00
Western meadowlark	3.57	1.71	1.67	1.00	1.00	1.00
Average Number of Birds (all species) per Survey Point Summer 2004	**7.27**	**10.71**	**11.34**	**13.00**	**14.00**	**6.00**
Average Number of Birds (all species) per Survey Point Spring 2004	**6.00**	**7.71**	**11.32**	**15.00**	**12.00**	**7.00**

n – Number of survey points

Upland Game Birds

No upland game birds were detected during Summer 2004 point transect surveys or during other site visits.

3.1.3 Nest Searches – Spring and Summer 2004

During Spring and Summer 2004, a total of 21 nests representing nine species were located and GPS locations taken. Of the 21 nests, five were black-billed magpie, four were western meadowlark, three were northern flicker, two were American kestrel, two were European starling, two were mourning dove and one American robin nest and one rock dove (pigeon) nest, and one western kingbird nest were located. See Figure 1 for nest locations.

3.2 Raptor Surveys and Nest Searches

Surveys for raptors were conducted in mid-April to coincide with peak raptor migration season (Rectenwald 2004). Five species of raptors were observed during surveys: osprey, sharp-shinned hawk, Cooper's hawk, red-tailed hawk, and American kestrel. Two raptor nests were observed on site, both occupied by American kestrels, and both in nest boxes. One other raptor species observed on site (not during surveys) was the golden eagle.

3.3 Predator Surveys

Only one predator species, the coyote, was detected during the Summer 2004 season at the scent stations. During the first survey, coyote tracks were detected in P-8 after the first night and P-6 after the third night. During the second survey, coyote tracks were observed in P-1 and P-5 after the first night and in P-1 after the second night. Other species that visited the scent stations included mule deer, cottontail, and black-billed magpie. See Figure 1 for scent station locations.

3.4 Small Mammal Surveys

In 400 trap nights (100 traps x 4 nights), a total of 113 small mammals were caught for a trapping success rate of 28 percent. Three species of small mammals were caught during the Summer 2004 season: deer mouse, Mexican woodrat, and prairie vole. Deer mice were the most abundant species caught (86), with Mexican woodrats (24) and prairie voles (3) following (Table 5). Of the four habitats represented, deer mice were the only species caught in all four habitat types. Prairie voles were trapped in only the short grass habitat. Mexican woodrats, while found in two habitat types, were only found in the drainages on the project site where shrubs are common. No mortality occurred during trapping.

Table 5. Number of Small Mammals Caught Per Habitat Type During Summer 2004 Trapping Survey at the National Renewable Energy Laboratory, Golden, Colorado.

	Habitat Type				
Species	**Short Grass (30 traps)**	**Mixed Grass (40 traps)**	**Short Shrubland (20 traps)**	**Ravine Shrubland (10 traps)**	**Total**
Deer mouse	22	37	7	20	86
Mexican woodrat	0	0	14	10	24
Prairie vole	3	0	0	0	3
Total	25	37	21	30	113

3.5 Large Mammal Surveys

Pellet-count plots were established and all pellets were removed in the Spring 2004 season. SAIC observed in July that two stakes (D-2-4 and D-4-3) representing pellet plots had been removed. SAIC will replace these stakes during the Fall 2004 season and include them in the Spring 2005 analysis. SAIC also observed that t-post D-3 had been moved; SAIC returned this t-post to its original location.

3.6 Reptile/Amphibian Surveys

Reptile species observed on site included western rattlesnake, garter snake, and six-lined racerunner. Rattlesnakes were observed in the amphitheatre, in the grassland near the Visitor's Center and on the mesa slopes, usually near rocks. A garter snake was observed in the grassland of the Camp George West property. Two six-lined racerunners were observed along Transect A.

4.0 DISCUSSION AND RECOMMENDATIONS FOR MITIGATION MEASURES

As there is natural variability in wildlife populations, especially breeding bird communities, the continuation of wildlife surveys throughout the years would allow trends to be established regarding populations of species. Differences in the bird community were evident when Spring 2004 and Summer 2004 surveys were compared. Several bird species associated with disturbed areas, such as European starlings and house sparrows, were found at the project site. As the landscape becomes more developed, these bird species may become more abundant. European starlings in particular displace native birds from tree cavities where they build their nests.

There are limitations associated with sampling wildlife populations, especially breeding birds. Species characteristics and observer differences can influence and affect the results of breeding bird surveys. Mayfield (1981) found that some species cannot be counted effectively during brief listening periods. Some species sing loudly from prominent points and others may sing softly while hidden in dense vegetation (Wiens 1989). Song frequency can vary among species. Observer variability also plays a role in detecting birds during point counts. Wiens (1981) found that two observers with equivalent experience, when surveying simultaneously for breeding birds in the same location using the same method, did not necessarily obtain the same results.

At this time there are no recommendations for mitigation measures.

5.0 REFERENCES

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Appendix A

Wildlife Species Observed at the National Renewable Energy Laboratory
South Table Mountain Site, Golden, Colorado

Wildlife Species Observed at the National Renewable Energy Laboratory
South Table Mountain Site, Golden, Colorado.

COMMON NAME	SCIENTIFIC NAME
Reptiles	
Plains garter snake	*Thamnophis radix*
Six-lined racerunner	*Cnemidophorus sexlineatus*
Western rattlesnake	*Crotalus viridus*
Birds	
American crow	*Corvus brachyrhynchos*
American kestrel	*Falco sparverius*
American robin	*Turdus migratorius*
Barn swallow	*Hirundo rustica*
Black-billed magpie	*Pica hudsonia*
Black-capped chickadee	*Poecile atricapilla*
Brewer's blackbird	*Euphagus cyanocephalus*
Brown headed cowbird	*Molothrus ater*
Bullock's oriole	*Icterus bullockii*
Common nighthawk	*Chordeiles minor*
Common raven	*Corvus corax*
Cooper’s hawk	*Accipiter cooperii*
European starling	*Sturnus vulgaris*
Golden eagle	*Aquila chrysaetos*
House finch	*Carpodacus mexicanus*
House sparrow	*Passer domesticus*
Killdeer	*Charadrius vociferous*
Mallard	*Anas platyrhynchos*
Mourning dove	*Zenaida macroura*
Northern flicker	*Colaptes auratus*
Red-tailed hawk	*Buteo jamaicensis*
Rock dove	*Columba livia*
Say's phoebe	*Sayornis saya*
Sharp-shinned hawk	*Accipiter striatus*
Spotted towhee	*Pipilo maculates*
Tree swallow	*Tachycineta bicolor*
Turkey vulture	*Coragyps atratus*
Unidentified sparrow 1	-
Unidentified sparrow 2	-
Unidentified species	-
Vesper sparrow	*Pooecetes gramineus*
Western kingbird	*Tyrannus verticalis*
Western meadowlark	*Sturnella neglecta*
White-crowned sparrow	*Zonotrichia leucophrys*
Mammals	
Coyote	*Canis latrans*
Deer mouse	*Peromyscus maniculatus*
Mexican woodrat	*Neotoma mexicana*
Mountain cottontail	*Sylvilagus nuttalli*
Mule deer	*Odocoileus hemionus*
Prairie vole	*Microtus ochrogaster*

Appendix B

Figure 1

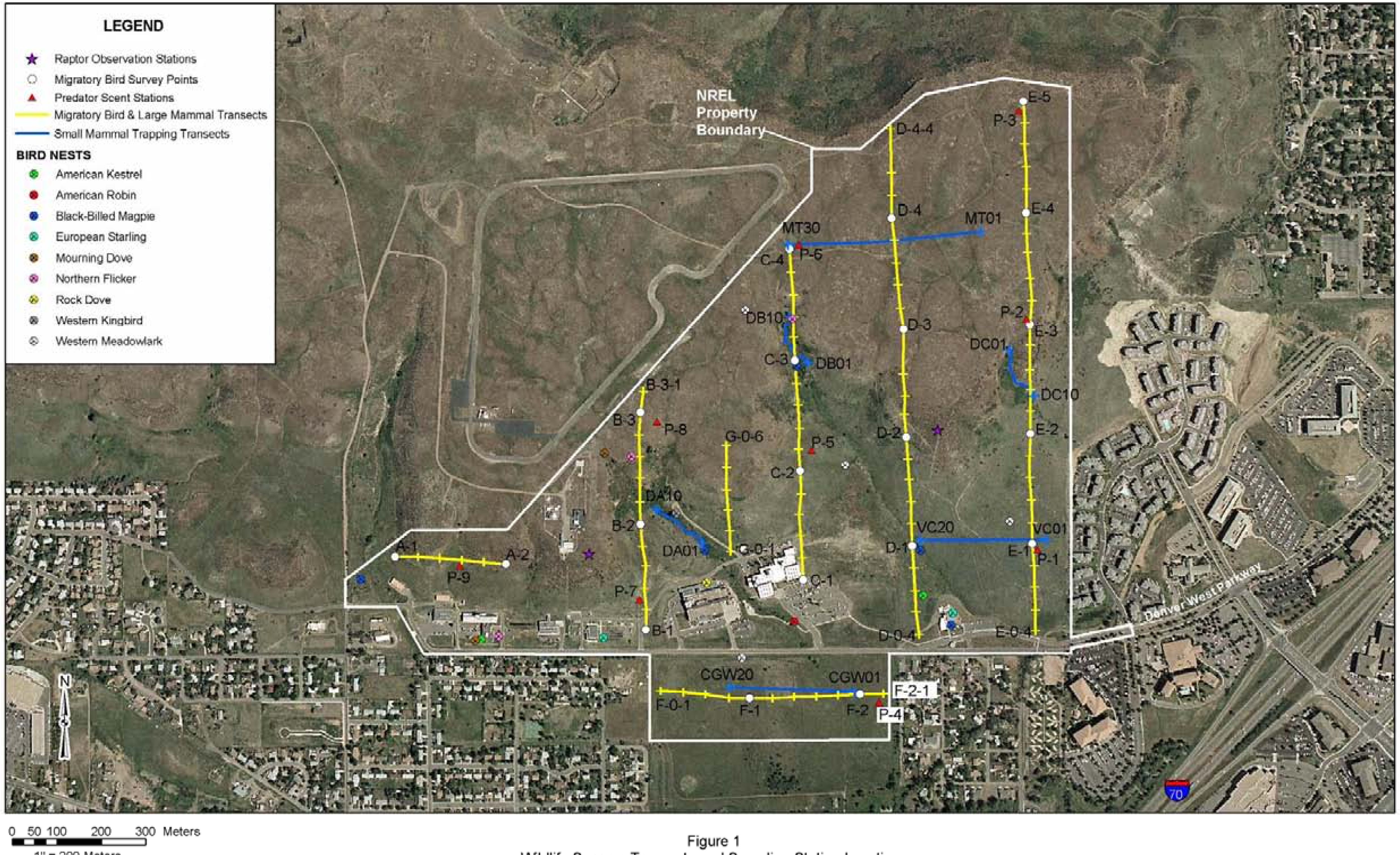

Figure 1
Wildlife Surveys Transects and Sampling Station Locations
for the U.S. Department of Energy's National Renewable Energy Laboratory Site,
Golden, Colorado

Science Applications International Corporation
An Employee-Owned Company

TO: Maureen Jordan, NREL

FROM: Madeline Terry, SAIC

CC: Margaret Mortenson (NREL)
Robert Henke (SAIC)
Mark Deffley (SAIC)

DATE: November 15, 2004

SUBJECT: National Renewable Energy Laboratory Wildlife Surveys Project – Fall Letter Report (SAIC Project No. 01-0203-04-8269-xxx)

1.0 INTRODUCTION

A wildlife study of the National Renewable Energy Laboratory (NREL) South Table Mountain (STM) site in Golden, Colorado was conducted in 1987 by The FORUM Associates, Inc. The demographics of the area surrounding the STM site have changed and additional development of the STM site has occurred since that time. At the request of the NREL, Science Applications International Corporation (SAIC) began a four season wildlife study of the STM site in Spring 2004 to update the 1987 data and, at the end of the study, to compare the results of the 2004 - 2005 wildlife study with the 1987 study. During Spring and Summer 2004, survey protocols and stations were established on site as needed to survey for birds, raptors, predators, small mammals, large mammals, and reptiles and amphibians. This report summarizes the results of the Fall 2004 season in which migratory bird, raptor, predator, small mammal, and large mammal surveys were conducted. Reptiles and amphibians were surveyed for opportunistically during the season. Survey protocol were described in the Summer 2004 Letter Report (SAIC 2004). Scientific names are listed in Appendix A. A map of the site, with survey station locations, is in Appendix B.

2.0 DOCUMENTATION OF SURVEY RESULTS

2.1 Migratory Bird Surveys

NREL provides habitat for a diversity of bird species. Habitat types surveyed for migratory birds at NREL include short grass, mixed grass, tall shrubland, ravine shrubland, disturbed/reclaimed, and developed as defined by Plantae Consulting Services 2002. A total of 47 bird species were observed on site during Spring, Summer, and Fall 2004 (Appendix A). Appendix A represents a work in progress that can be expanded as additional bird species are observed at NREL during the four season wildlife surveys.

Bird Community

A total of 23 species and 121 birds were recorded during the Fall 2004 point transect surveys (**Table 1**). A majority of the observed birds were detected visually, as opposed to calling or singing. Fall surveys occurred during migration and not during breeding (i.e., Spring and Summer) when birds tend to sing more often. In Spring and Summer fewer species (20), but more birds (164) were recorded.

Table 1. Number of Breeding Birds Detected During Fall 2004 Surveys at the National Renewable Energy Laboratory, Golden, Colorado.

Species	Number of Birds Detected	Number of Survey Points Observed (n = 20)
American kestrel	4	3
American robin	6	4
Barn swallow	3	1
Black-billed magpie	2	2
Black-capped chickadee	1	1
Brewer's blackbird	1	1
European starling	6	1
Flycatcher sp.	2	1
House finch	32	15
House sparrow	4	2
Loggerhead shrike	2	2
Mourning dove	6	4
Northern flicker	18	12
Red-breasted nuthatch	1	1
Red-tailed hawk	1	1
Rock dove	4	2
Rock wren	2	2
Say's phoebe	2	2
Spotted towhee	6	6
Unidentified warbler	1	1
Vesper sparrow	3	3
Western kingbird	2	2
Western meadowlark	12	8
All Species Fall 2004	121	23

Bird species diversity and evenness for NREL in Fall 2004, as measured by Simpson's index, were 8.5 and 0.37, respectively. Comparatively, in Spring and Summer both diversity and evenness were slightly lower at 6.5 and 0.33, respectively. Species diversity is an index of community diversity that takes into account both species richness and the relative abundance of species (Begon et al. 1990). Richness is the number of species found in a community. This index takes into account both the total number of species (richness) and how common or rare each species is. Thus, for a given evenness, diversity increases with species richness; similarly, for a given species richness, diversity will increase with evenness (Begon et al. 1990). Evenness is a function of the relative abundance of the species that occur in a community. The Simpson's index of evenness has a maximum value of one (even composition of each species), and lower values have a more disparate species composition with some species being more common and others being rare.

Target bird species for grassland habitats include greater roadrunner, mountain plover, upland sandpiper, burrowing owl, loggerhead shrike, Cassin's sparrow, and raptors (RMBO et al. 2000). Mountain shrubland habitats included sharp-tailed grouse. Two loggerhead shrikes were observed at survey point D-3, a short grass habitat. Raptors are target species for all habitats. During surveys, red-tailed hawk, sharp-shinned hawk, and American kestrel were observed, all species previously recorded on site.

Individual Species

The house finch was the most abundant species observed (32 birds). Northern flicker and western meadowlark were the next most abundant, with 18 and 12 birds observed, respectively. The house finch was also the most widespread species, occurring at 15 survey points. Northern flicker and western meadowlark were the next most widespread, occurring at 12 and 8 survey points, respectively. These results are similar to Spring and Summer results. However, in Spring and Summer nine species were rare in abundance and distribution with only one bird observed at one survey point. In Fall, five species were rare in abundance and distribution: black-capped chickadee, Brewer's blackbird, red-breasted nuthatch, red-tailed hawk, and an unidentified warbler.

Habitat Types

At the habitat level, tall shrubland supported the highest bird abundance (all species) per survey point (**Table 2**). Although the short grass and mixed grass habitats had lower bird abundance per survey point, the highest total numbers of birds (46 and 39, respectively) were detected at these points during Fall surveys. These results are similar to what was recorded during the Spring and Summer surveys.

Table 2. Average Number of Birds Detected Per Survey Point for Habitat Types During Fall 2004 Surveys at the National Renewable Energy Laboratory, Golden, Colorado.

	Habitat Type					
Species	**Short Grass** n=7	**Mixed Grass** n=7	**Tall Shrubland** n=3	**Ravine Shrubland** n=1	**Disturbed/ Reclaimed** n=1	**Developed** n=1
American kestrel	0.29	0.29	0.00	0.00	0.00	0.00
American robin	0.00	0.86	0.00	0.00	0.00	0.00
Barn swallow	0.43	0.00	0.00	0.00	0.00	0.00
Black-billed magpie	0.00	0.14	0.33	0.00	0.00	0.00
Black-capped chickadee	0.00	0.00	0.33	0.00	0.00	0.00
Brewer's blackbird	0.00	0.14	0.00	0.00	0.00	0.00
European starling	0.00	0.00	2.00	0.00	0.00	0.00
Flycatcher sp.	0.00	0.00	0.67	0.00	0.00	0.00
House finch	1.57	1.71	1.67	2.00	0.00	2.00
House sparrow	0.00	0.57	0.00	0.00	0.00	0.00
Loggerhead shrike	0.29	0.00	0.00	0.00	0.00	0.00
Mourning dove	0.43	0.00	0.33	0.00	2.00	0.00
Northern flicker	1.43	0.43	1.00	2.00	0.00	0.00
Red-breasted nuthatch	0.00	0.14	0.00	0.00	0.00	0.00
Red-tailed hawk	0.14	0.00	0.00	0.00	0.00	0.00
Rock dove	0.00	0.14	0.00	0.00	3.00	0.00
Rock wren	0.14	0.14	0.00	0.00	0.00	0.00
Say's phoebe	0.29	0.00	0.00	0.00	0.00	0.00
Spotted towhee	0.14	0.29	0.67	1.00	0.00	0.00
Unidentified warbler	0.00	0.00	0.33	0.00	0.00	0.00
Vesper sparrow	0.29	0.14	0.00	0.00	0.00	0.00
Western kingbird	0.14	0.14	0.00	0.00	0.00	0.00
Western meadowlark	1.00	0.43	0.67	0.00	0.00	0.00
Average Number of Birds per Survey Point	**6.58**	**5.57**	**8.00**	**5.00**	**5.00**	**2.00**

n – Number of survey points

Upland Game Birds

No upland game birds were detected during Fall 2004 point transect surveys or during other site visits.

2.2 Raptor Surveys and Nest Searches

Surveys for raptors were conducted during raptor migration season on September 29 and October 4, 2004. The second survey, originally scheduled for September 30, was delayed due to weather. Six species of raptors were observed during surveys: Cooper's hawk, sharp-shinned hawk, northern harrier, red-tailed hawk, prairie falcon, and American kestrel. This was the first observation of the northern harrier on site, and it was observed hunting and catching prey on the mesa top. The Cooper's hawk was observed hunting (perching and then dropping to the ground) in the mixed grass habitat between the Solar Energy Research Facility (SERF) building and the Visitor's Center.

2.3 Predator Surveys

Similar to Summer predator surveys, only one predator species, the coyote, was detected during the Fall 2004 season at the scent stations. During the first Fall survey, no predators were detected at any of the stations; only deer and black-billed magpies were detected at the scent stations. Weather may have been a factor in not detecting any predators as it rained during the second and third nights of the survey. During the second Fall survey, coyote tracks were detected in P-6 after the first night. Other species that visited the scent stations during this survey period included mule deer and cottontail. Human and domestic dog tracks were detected at P-1 after the third night of the survey.

2.4 Small Mammal Surveys

In 400 trap nights (100 traps x 4 nights), a total of 191 small mammals were caught for a trapping success rate of 48 percent. Four species of small mammals were caught during the Fall 2004 season: deer mouse, western harvest mouse, Mexican woodrat, and prairie vole. The deer mouse was the most abundant species caught (142), with Mexican woodrat (36), prairie vole (12), and western harvest mouse (1) following (**Table 3**). Of the four habitat types represented, deer mice were the only species caught in all four habitat types. Prairie voles were trapped in two habitat types, short and mixed grass. Mexican woodrats, while also found in two habitat types, were found only in the drainages on the project site where shrubs are common. Five mortalities occurred during trapping: four deer mice and one prairie vole. Three traps were disturbed on transect F in Camp George West on the third night of trapping. Coyotes may have disturbed the traps because fresh coyote scat was observed next to one of the moved traps. Two of the traps were recovered.

Comparatively, in the Summer season, a total of 113 small mammals were caught, for a success rate of 28 percent. Western harvest mice were not captured and deer mice were the only species caught in all four habitat types during Summer surveys.

Table 3. Number of Small Mammals Caught Per Habitat Type During Fall 2004 Trapping Survey at the National Renewable Energy Laboratory, Golden, Colorado.

Species	Habitat Type				
	Short Grass (30 traps)	Mixed Grass (40 traps)	Short Shrubland (20 traps)	Ravine Shrubland (10 traps)	Total
Deer mouse	50	56	34	2	142
Mexican woodrat	0	0	21	15	36
Prairie vole	10	2	0	0	12
Western harvest mouse	0	1	0	0	2
Total	60	59	55	17	191

2.5 Large Mammal Surveys

During the Spring 2004 season, 100 pellet-group plots were established and all pellets were removed. In July, SAIC observed that two stakes (D-2-4 and D-4-3) representing pellet plots had been removed. These two pellet plots were re-established during the Fall 2004 season and were cleared of all pellets, but were not included in the Fall 2004 analysis. D-2-4 and D-4-3 will be included in the Spring 2005 analysis. SAIC also observed that t-post D-3 had been moved; SAIC returned this t-post to its original location and included this plot in the analysis. Due to Phase I construction of the SERF chiller room upgrade, pellet plot C-1-1 was removed. SAIC added a plot to transect G (G-0-7) to replace the plot C-1-1, although G-0-7 represents a different habitat type, and will include G-0-7 in the Spring 2005 analysis.

Due to the loss of three plots, a total of 97 pellet plots were checked for pellet groups during the Fall 2004 season. A pellet group was defined as consisting of five or more pellets of the same general size, shape, hardness and color (Bowden et al. 1969), with at least half of the group within the boundary of the plot. Pellet groups were found in 18 of the 97 plots, with a total of 27 pellet groups in the 18 plots. Only mule deer pellet groups were observed.

The greatest number of pellet groups was found in the mixed grass habitat, with eight pellet groups (**Table 4**). The mixed grass habitat had the highest number of plots (41) compared to all other habitats on site and is the second largest habitat on site. Short grass, the largest habitat on site, had the second highest number of pellet groups (six) along with tall shrubland habitat which also had six pellet groups. Only 12 plots were located in the tall shrubland habitat.

Table 4. The Distribution and Results of 97 Circular Pellet-Group Plots Among Habitats at the National Renewable Energy Laboratory, Golden, Colorado.

Habitat Type[a]	Surface Area		Plots		Number of Pellet Groups
	Acres[b]	Percent	Number	Percent	
Short Grass	140.46	41.0	32	33.0	6
Mixed Grass	113.08	33.0	41	42.3	8
Short Shrubland	17.53	4.9	3	3.1	2
Tall Shrubland	23.43	6.8	12	12.4	6
Ravine Shrubland	5.97	1.7	5	5.2	3
Disturbed/Reclaimed	32.07	9.4	6	6.2	2
Developed	27.37	8.0	1	1.0	0
Total	342.38	100	97	100	27

[a] Not all NREL habitats sampled.
[b] Acreage values from Plantae Consulting Services 2002. Total does not equal total acres of NREL site due to not all habitats being sampled.

2.6 Reptile/Amphibian Surveys

Reptile and amphibian species observed on site during the Fall 2004 season included western rattlesnake and tiger salamander. Rattlesnakes were observed in the grassland behind the SERF building, in the amphitheatre, and near the top of the mesa slope north of the Visitor's Center in the rocks. A rattlesnake den may be present on this part of the mesa slope as four rattlesnakes were observed within a few feet of each other, one in the open and three in a rock crevice. The tiger salamander was observed in the road near the Site Entrance Building and placed in the grass on the roadside, so as not to be struck by a vehicle.

3.0 DISCUSSION AND RECOMMENDATIONS FOR MITIGATION MEASURES

During Fall 2004, 17 new species were observed (Appendix A). The 17 new species included one amphibian, 13 birds, and three mammals. Two of the mammal species, long-tailed weasel and raccoon, were observed by NREL personnel. As the new bird species were not observed during Spring or Summer surveys, they may not breed on site, but use the site during migration. It is recommended to have the security personnel add to the current wildlife list as they observe new species.

To manage wildlife habitat and limit disturbance to wildlife species on site, SAIC recommends the following site-wide best management practices be considered.

- Avoid starting construction projects during breeding season for migratory birds (approximately April 15 – July 15). By starting construction outside of the breeding season, the potential for take of bird species and nests, as defined by the Migratory Bird Treaty Act, would be minimized.
- Conduct migratory bird surveys and nest searches and raptor surveys and nest searches 30 days prior to the start of construction if breeding season can not be avoided. Contact U.S. Fish and Wildlife Service if nests are found.
- Maintain movement corridors for larger wildlife (e.g., deer, coyotes).
- Develop and electronically integrate institutional controls, as part of NREL's Environmental Management System (EMS) and budgetary system, to ensure that future NREL projects: 1) budget for environmental compliance and 2) do not irreversibly commit agency resources or impact natural resources without first obtaining the appropriate internal and regulatory approvals and permits.
- Continue the integrated weed management component of the vegetation management program to prevent new weed infestations, eradicate small weed populations, manage existing weed populations, and monitor for new weed infestations as recommended in Plantae Consulting Services 2002. Eradication of weed species on site could be used to mitigate loss of habitat on site.

4.0 REFERENCES

Begon, M., J.L. Harper, and C.R. Townsend. 1990. *Ecology - Individuals, Populations and Communities.* Blackwell Scientific Pub. Cambridge, Mass. 945 p.

Bowden, D.C., A.E. Anderson, and D.E. Medin. 1969. Frequency Distributions of Mule Deer Fecal Group Counts. Journal of Wildlife Management 33(4):895-905.

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The FORUM Associates, Inc. 1987. Solar Energy Research Institute Wildlife Report. September 1987.

Appendix A

Wildlife Species Observed During Spring, Summer, and Fall 2004 at the National Renewable Energy Laboratory South Table Mountain Site, Golden, Colorado

Wildlife Species Observed During Spring, Summer, and Fall 2004 at the National Renewable Energy Laboratory South Table Mountain Site, Golden, Colorado.

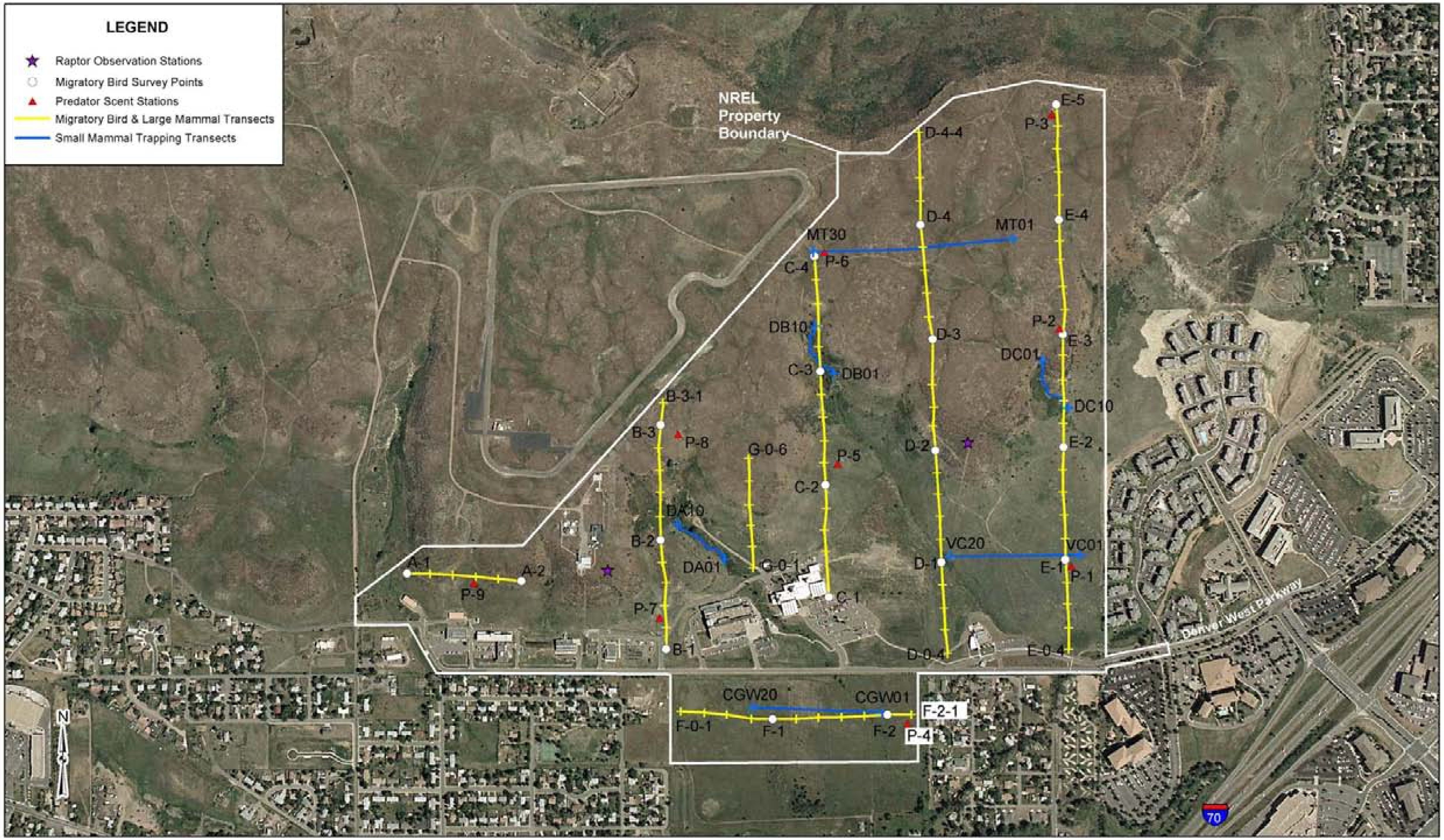
COMMON NAME	SCIENTIFIC NAME
Reptiles	
Plains garter snake	*Thamnophis radix*
Six-lined racerunner	*Cnemidophorus sexlineatus*
Tiger salamander*	*Ambystoma tigrinum*
Western rattlesnake	*Crotalus viridus*
Birds	
American crow	*Corvus brachyrhynchos*
American kestrel	*Falco sparverius*
American robin	*Turdus migratorius*
Barn swallow	*Hirundo rustica*
Black-billed magpie	*Pica pica*
Black-capped chickadee	*Poecile atricapilla*
Black-crowned night heron*	*Nycticorax nycticorax*
Blue jay*	*Cyanocitta cristata*
Brewer's blackbird	*Euphagus cyanocephalus*
Brown headed cowbird	*Molothrus ater*
Bullock's oriole	*Icterus bullockii*
California gull*	*Larus californicus*
Common nighthawk	*Chordeiles minor*
Common raven	*Corvus corax*
Cooper's hawk	*Accipiter cooperii*
Dark-eyed junco*	*Junco hyemalis*
Downy woodpecker*	*Picoides pubescens*
European starling	*Sturnus vulgaris*
Flycatcher*	*Empidonax sp.*
Golden eagle	*Aquila chrysaetos*
House finch	*Carpodacus mexicanus*
House sparrow	*Passer domesticus*
Killdeer	*Charadrius vociferous*
Loggerhead shrike*	*Lanius ludovicianus*
MacGillivray's warbler*	*Oporornis tolmiei*
Mallard	*Anas platyrhynchos*
Mountain bluebird*	*Sialia currucoides*
Mourning dove	*Zenaida macroura*
Northern flicker	*Colaptes auratus*
Northern harrier*	*Circus cyaneus*
Red-breasted nuthatch*	*Sitta canadensis*
Red-tailed hawk	*Buteo jamaicensis*
Rock dove	*Columba livia*
Rock wren*	*Salpinctes obsoletus*
Say's phoebe	*Sayornis saya*
Sharp-shinned hawk	*Accipiter striatus*
Spotted towhee	*Pipilo maculates*
Tree swallow	*Tachycineta bicolor*
Turkey vulture	*Cathartes aura*
Unidentified sparrow 1	-
Unidentified sparrow 2	-
Unidentified species	-
Unidentified warbler*	-

COMMON NAME	SCIENTIFIC NAME
Vesper sparrow	*Pooecetes gramineus*
Western kingbird	*Tyrannus verticalis*
Western meadowlark	*Sturnella neglecta*
White-crowned sparrow	*Zonotrichia leucophrys*
Mammals	
Coyote	*Canis latrans*
Deer mouse	*Peromyscus maniculatus*
Long-tailed weasel*	*Mustela frenata*
Mexican woodrat	*Neotoma mexicana*
Mountain cottontail	*Sylvilagus nuttalli*
Mule deer	*Odocoileus hemionus*
Prairie vole	*Microtus ochrogaster*
Raccoon*	*Procyon lotor*
Western harvest mouse*	*Reithrodontomys megalotis*

* Indicates new species observed in Fall 2004 season.

Appendix B

Figure 1



0 50 100 200 300 Meters

1" = 200 Meters

Date Plotted: 11/11/04

Figure 1
Transects and Sampling Station Locations
for Wildlife Surveys at the National Renewable Energy Laboratory,
Golden, Colorado.

TO: Maureen Jordan, NREL

FROM: Madeline Terry, SAIC

CC: Margaret Mortenson (NREL)
Robert Henke (SAIC)
Mark Deffley (SAIC)

DATE: February 18, 2004

SUBJECT: National Renewable Energy Laboratory Wildlife Surveys Project – Winter Letter Report (SAIC Project No. 01-0203-04-8269-xxx)

1.0 INTRODUCTION

A wildlife study of the National Renewable Energy Laboratory (NREL) South Table Mountain (STM) site in Golden, Colorado was conducted in 1987 by The FORUM Associates, Inc. The demographics of the area surrounding the STM site have changed and additional development of the STM site has occurred since that time. At the request of the NREL, Science Applications International Corporation (SAIC) began a four season wildlife study of the STM site in Spring 2004 to update the 1987 data and, at the end of the study, to compare the results of the 2004-2005 wildlife study with the 1987 study. During Spring and Summer 2004, survey protocols and stations were established on site as needed to survey for birds, raptors, predators, small mammals, large mammals, and reptiles and amphibians. This report summarizes the results of the Winter 2004-2005 season in which migratory bird, predator, and small mammal surveys were conducted. Reptiles and amphibians were surveyed for opportunistically during the season. Survey protocol were described in the Summer 2004 Letter Report (SAIC 2004). Scientific names are listed in Appendix A. A map of the site, with survey station locations, is in Appendix B.

2.0 DOCUMENTATION OF SURVEY RESULTS

2.1 Migratory Bird Surveys

The NREL STM site provides habitat for a diversity of bird species. Habitat types surveyed for migratory birds at the STM site include short grass, mixed grass, tall shrubland, ravine shrubland, disturbed/reclaimed, and developed as defined by Plantae Consulting Services (2002). A total of 49 bird species were observed on site during Spring, Summer, Fall 2004, and Winter 2004-2005 (Appendix A). Appendix A represents a work in progress that can be expanded as additional bird species are observed at NREL during the four season wildlife surveys.

Bird Community

Winter 2004-2005 was the fourth and final season for migratory bird surveys at the STM site. A total of 13 species and 58 birds were recorded during the Winter point transect surveys (**Table 1**). A majority of the observed birds were detected visually, as opposed to calling or singing. As expected, fewer species and fewer birds were detected during winter surveys than any other season.

Table 1. Number of Breeding Birds Detected During Winter 2004-2005 Surveys at the National Renewable Energy Laboratory South Table Mountain Site, Golden, Colorado.

Species	Number of Birds Detected	Number of Survey Points Observed (n = 20)
American crow	1	1
American kestrel	1	1
American tree sparrow	4	1
Common raven	2	1
Black-billed magpie	14	8
European starling	2	1
Dark-eyed junco	5	1
House finch	16	5
House sparrow	4	3
Northern flicker	2	2
Northern harrier	1	1
Red-tailed hawk	1	1
Rock dove	5	3
All Species Winter 2004-2005	58	-

Species diversity is an index of community diversity that takes into account both species richness and the relative abundance of species (Begon et al. 1990). Richness is the number of species found in a community. Simpson's index of diversity takes into account both the total number of species (richness) and how common or rare each species is. Thus, for a given evenness, diversity increases with species richness; similarly, for a given species richness, diversity will increase with evenness (Begon et al. 1990). Evenness is a function of the relative abundance of the species that occur in a community. The Simpson's index of evenness has a maximum value of one (even composition of each species), and lower values have a more disparate species composition with some species being more common and others being rare. Bird species diversity and evenness for the STM site in the Winter season, as measured by Simpson's index, were 6.1 and 0.47, respectively. Diversity was lower in winter surveys than any other season, although evenness was the highest of all seasonal surveys.

Target bird species for grassland habitats include greater roadrunner, mountain plover, upland sandpiper, burrowing owl, loggerhead shrike, Cassin's sparrow, and raptors (RMBO et al. 2000). Mountain shrubland habitat target species included sharp-tailed grouse. Target species observed during Winter surveys included American kestrel, northern harrier, and red-tailed hawk.

Individual Species

The house finch and the black-billed magpie were the most abundant species observed (16 and 14 birds, respectively) during Winter surveys. Rock dove and dark-eyed junco were the next most abundant, each with five birds observed. The black-billed magpie was also the most widespread species, occurring at eight survey points. House finch was the next most widespread, occurring at five survey points. The house finch was one of the most abundant species observed in three of the four seasons. Western meadowlark, either the most abundant or second most abundant species during the other three seasons was not observed at any survey point during Winter surveys. However, one western meadowlark was observed during Winter surveys between transects. Four species were rare in abundance and distribution with only one bird at one survey point, similar to Summer surveys. Two Colorado winter residents were observed, American tree sparrow and dark-eyed junco (Andrews and Righter 1992).

Habitat Types

At the habitat level, ravine shrubland supported the highest bird abundance (all species) per survey point (**Table 2**), similar to Spring surveys. Although the mixed grass and tall shrubland habitats had lower bird abundance per survey point, the highest total numbers of birds (30 and 10, respectively) were detected at these points during Winter surveys. Mixed grass and short grass habitats had the highest bird abundance for Spring, Summer, and Fall surveys.

Table 2. Average Number of Birds Detected Per Survey Point for Habitat Types During Winter 2004-2005 Surveys at the National Renewable Energy Laboratory South Table Mountain Site, Golden, Colorado.

Species	Habitat Type					
	Short Grass n=7	Mixed Grass n=7	Tall Shrubland n=3	Ravine Shrubland n=1	Disturbed/ Reclaimed n=1	Developed n=1
American crow	0.14	0.00	0.00	0.00	0.00	0.00
American kestrel	0.00	0.00	0.00	0.00	0.00	1.00
American tree sparrow	0.00	0.57	0.00	0.00	0.00	0.00
Common raven	0.00	0.00	0.67	0.00	0.00	0.00
Black-billed magpie	0.00	1.43	1.00	0.00	0.00	1.00
European starling	0.00	0.00	0.00	0.00	2.00	0.00
Dark-eyed junco	0.00	0.00	0.00	5.00	0.00	0.00
House finch	0.29	1.57	1.00	0.00	0.00	0.00
House sparrow	0.00	0.57	0.00	0.00	0.00	0.00
Northern flicker	0.00	0.14	0.33	0.00	0.00	0.00
Northern harrier	0.14	0.00	0.00	0.00	0.00	0.00
Red-tailed hawk	0.14	0.00	0.00	0.00	0.00	0.00
Rock dove	0.00	0.00	0.33	0.00	2.00	2.00
Average Number of Birds per Survey Point	0.71	4.29	3.33	5.00	4.00	4.00

n – Number of survey points

Upland Game Birds

No upland game birds were detected during Winter point transect surveys or during other site visits.

2.2 Predator Surveys

No predators were detected at the scent stations during the Winter surveys. During the first Winter survey, only mule deer, cottontail and domestic dog were detected at the scent stations. Prior to setting up the first survey, coyote scat was observed at two scent stations, P-8 and P-9. During the second Winter survey, black-billed magpie, mule deer, cottontail, and deer mouse tracks were observed at the scent stations. Weather may have been a factor during the second night of surveys as approximately two to three inches of snow fell, with the snow stopping around 10 am, prior to conducting surveys. Coyote tracks were observed in the snow on the mesa top.

2.3 Small Mammal Surveys

In 400 trap nights (100 traps x 4 nights), a total of 204 small mammals were caught for a trapping success rate of 51 percent. Three species of small mammals were caught during the Winter season: deer mouse, Mexican woodrat, and prairie vole. The deer mouse was the most abundant species caught (172), with Mexican woodrat (20), and prairie vole (12) following (**Table 3**). Of the four habitat types represented, deer mice were the only species caught in all four habitat types. Prairie voles were trapped in two habitat types, short and mixed grass.

Mexican woodrats, while also found in two habitat types, were found only in the drainages on the project site where shrubs are common. Three mortalities occurred during trapping: two deer mice and one prairie vole. On January 20, 2005, two traps were each found to have two deer mice inside.

Mild winter weather with daytime highs around 65 degrees Fahrenheit and nighttime lows in the 30s, may have contributed to the high trapping success rate and the highest number of individuals caught of the three seasons. Similar to Summer and Fall surveys, deer mice were the only species caught in all four habitat types.

Table 3. Number of Small Mammals Caught Per Habitat Type During Fall 2004 Trapping Survey at the National Renewable Energy Laboratory South Table Mountain Site, Golden, Colorado.

Species	Habitat Type				
	Short Grass (30 traps)	Mixed Grass (40 traps)	Short Shrubland (20 traps)	Ravine Shrubland (10 traps)	Total
Deer mouse	53	54	13	52	172
Mexican woodrat	0	0	10	10	20
Prairie vole	6	6	0	0	12
Total	59	60	23	62	204

2.4 Reptile/Amphibian Surveys

No reptile or amphibian species were observed on site during the Winter season.

3.0 DISCUSSION

During Winter surveys, three new species were observed, two birds and one mammal (Appendix A). The American tree sparrow is a winter resident in Colorado and breeds mainly in Canada. This species was observed in the shrubs adjacent to survey station D-1. Canada geese were only observed flying over the site, not actually on the site. One white-tailed jackrabbit was observed on the mesa top.

4.0 REFERENCES

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Appendix A

Wildlife Species Observed During Spring, Summer, Fall 2004, and Winter 2004-2005 at the National Renewable Energy Laboratory South Table Mountain Site, Golden, Colorado

Wildlife Species Observed During Spring, Summer, Fall 2004, and Winter 2004-2005 at the National Renewable Energy Laboratory South Table Mountain Site, Golden, Colorado.

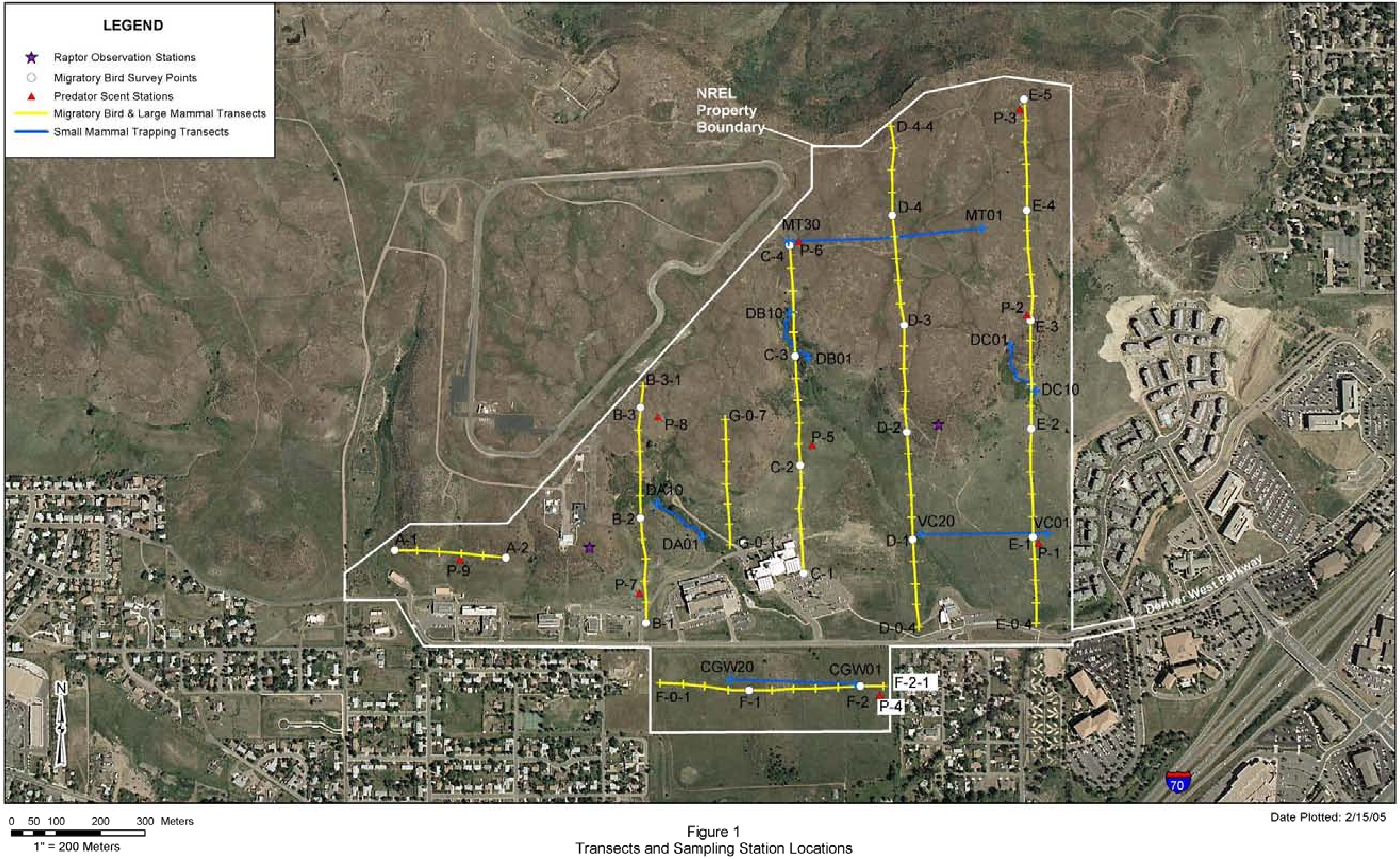
COMMON NAME	SCIENTIFIC NAME
Reptiles	
Plains garter snake	*Thamnophis radix*
Six-lined racerunner	*Cnemidophorus sexlineatus*
Tiger salamander	*Ambystoma tigrinum*
Western rattlesnake	*Crotalus viridus*
Birds	
American crow	*Corvus brachyrhynchos*
American kestrel	*Falco sparverius*
American robin	*Turdus migratorius*
American tree sparrow*	*Spizella arborea*
Barn swallow	*Hirundo rustica*
Black-billed magpie	*Pica pica*
Black-capped chickadee	*Poecile atricapilla*
Black-crowned night heron	*Nycticorax nycticorax*
Blue jay	*Cyanocitta cristata*
Brewer's blackbird	*Euphagus cyanocephalus*
Brown headed cowbird	*Molothrus ater*
Bullock's oriole	*Icterus bullockii*
California gull	*Larus californicus*
Canada goose*	*Branta canadensis*
Common nighthawk	*Chordeiles minor*
Common raven	*Corvus corax*
Cooper’s hawk	*Accipiter cooperii*
Dark-eyed junco	*Junco hyemalis*
Downy woodpecker	*Picoides pubescens*
European starling	*Sturnus vulgaris*
Flycatcher	*Empidonax sp.*
Golden eagle	*Aquila chrysaetos*
House finch	*Carpodacus mexicanus*
House sparrow	*Passer domesticus*
Killdeer	*Charadrius vociferous*
Loggerhead shrike	*Lanius ludovicianus*
MacGillivray’s warbler	*Oporornis tolmiei*
Mallard	*Anas platyrhynchos*
Mountain bluebird	*Sialia currucoides*
Mourning dove	*Zenaida macroura*
Northern flicker	*Colaptes auratus*
Northern harrier	*Circus cyaneus*
Red-breasted nuthatch	*Sitta canadensis*
Red-tailed hawk	*Buteo jamaicensis*
Rock dove	*Columba livia*
Rock wren	*Salpinctes obsoletus*
Say's phoebe	*Sayornis saya*
Sharp-shinned hawk	*Accipiter striatus*
Spotted towhee	*Pipilo maculates*
Tree swallow	*Tachycineta bicolor*
Turkey vulture	*Cathartes aura*
Unidentified sparrow 1	-
Unidentified sparrow 2	-

COMMON NAME	SCIENTIFIC NAME
Unidentified species	-
Unidentified warbler	-
Vesper sparrow	*Pooecetes gramineus*
Western kingbird	*Tyrannus verticalis*
Western meadowlark	*Sturnella neglecta*
White-crowned sparrow	*Zonotrichia leucophrys*
Mammals	
Coyote	*Canis latrans*
Deer mouse	*Peromyscus maniculatus*
Long-tailed weasel	*Mustela frenata*
Mexican woodrat	*Neotoma mexicana*
Mountain cottontail	*Sylvilagus nuttalli*
Mule deer	*Odocoileus hemionus*
Prairie vole	*Microtus ochrogaster*
Raccoon	*Procyon lotor*
Western harvest mouse	*Reithrodontomys megalotis*
White-tailed jackrabbit*	*Lepus townsendii*

* Indicates new species observed in Winter 2004-2005 season.

Appendix B

Figure 1



Date Plotted: 2/15/05

Figure 1
Transects and Sampling Station Locations
for Wildlife Surveys at the National Renewable Energy Laboratory,
Golden, Colorado.

Spring 2005 Wildlife Survey Results for the National Renewable Energy Laboratory South Table Mountain Site, Golden, Colorado

1.0 SPRING 2005 SURVEY RESULTS

The following wildlife surveys were conducted at the National Renewable Energy Laboratory South Table Mountain Site during Spring 2005 as part of a four season wildlife study: large mammals, predators, small mammals, and reptiles and amphibians. Results for each of these surveys are presented below.

1.1 Large Mammal Surveys

During the Spring 2004 season, 100 pellet-group plots were established and all pellets were removed. In July 2004, SAIC observed that two stakes (D-2-4 and D-4-3) representing pellet plots had been removed. These two pellet plots were re-established during the Fall 2004 season and were cleared of all pellets, but were not included in the Fall 2004 analysis. D-2-4 and D-4-3 were included in the Spring 2005 analysis. Due to Phase I construction of the SERF chiller room upgrade, pellet plot C-1-1 was removed. SAIC added a plot to transect G (G-0-7) to replace the plot C-1-1, although G-0-7 represented a different habitat type, and included G-0-7 in the Spring 2005 analysis. In March 2005, SAIC observed that pellet plot F-2-1 was removed due to road construction in Camp George West. This plot was not replaced and was not included in the Spring 2005 survey or analysis. During the Spring 2005 pellet plot survey, SAIC observed that two stakes (D-4-1 and E-3-4) had been removed. These two plots were not surveyed and were not included in the analysis.

Due to the loss of three plots (D-4-1, E-3-4, and F-2-1), a total of 97 pellet plots were checked for pellet groups during the Spring 2005 season. A pellet group was defined as consisting of five or more pellets of the same general size, shape, hardness and color (Bowden et al. 1969), with at least half of the group within the boundary of the plot. Pellet groups were found in 33 of the 97 plots, with a total of 49 pellet groups in the 33 plots. Only mule deer pellet groups were observed.

The greatest number of pellet groups was found in the short grass vegetation type, with 29 pellet groups (Table 2). The short grass vegetation type had the second highest number of plots (33) compared to all other vegetation types on site and exhibits the largest spatial coverage of all vegetation types on site. Mixed grass, exhibits the second largest spatial coverage on site, and had the second highest number of pellet groups (11). Tall shrubland, which had approximately the same number of plots as the ravine shrubland, disturbed/reclaimed, and developed vegetation types combined, had more than three times the number of pellet groups as those latter combined vegetation types.

Table 1. The Distribution of 97 Circular Pellet-Group Plots Among Vegetation Types and the Results of the Spring 2005 Pellet Plot Survey at the National Renewable Energy Laboratory South Table Mountain Site, Golden, Colorado.

Habitat Type[a]	Surface Area[b]		Plots		Number of Pellet Groups
	Acres	Percent	Number	Percent	
Short Grass	124	37.9	33	35.4	29
Mixed Grass	103	31.4	40	40.4	11
Short Shrubland	19	5.8	3	3.0	0
Tall Shrubland	16	4.9	11	11.1	7
Ravine Shrubland	5	1.5	3	3.0	2
Disturbed/Reclaimed	32	9.8	6	6.1	0
Developed	28	8.6	1	1.0	0
Total	327	99.9	97	100	49

[a] Not all NREL habitats sampled.
[b] Acreage values from SAIC 2003. Total and percent do not equal total acres of NREL site due to not all habitats being sampled.

1.2 Predator Surveys

Similar to all other seasonal predator surveys, only one predator species, the coyote, was detected during the Spring 2005 season at the scent stations. During the first Spring survey, coyote tracks were observed in one plot after the second night of surveys and in one plot after the third night of surveys. Other species detected at the plots included mule deer, cottontail, and deer mouse. During the second Spring survey, coyote tracks were detected in P-2, P-4, P-5, and P-7 after the first night; in P-2 after the second night; and in P-9 after the third night. Other species that visited the scent stations during this survey period included mule deer, cottontail, and deer mouse.

1.3 Small Mammal Surveys

In 400 trap nights (100 traps x 4 nights), a total of 140 small mammals were caught for a trapping success rate of 35 percent, the second lowest of the four seasons. Three species of small mammals were caught during the Spring 2005 season: deer mouse, Mexican woodrat, and prairie vole. The deer mouse was the most abundant species caught (108), with Mexican woodrat (21), and prairie vole (11) following (Table 3). Of the four vegetation types represented, deer mice were the only species caught in all four vegetation types. Prairie voles were trapped in two vegetation types, short and mixed grass. However, one dead juvenile prairie vole was observed in the amphitheater drainage next to trap DA-03. Mexican woodrats, while also found in two vegetation types, were found only in the drainages on the project site where shrubs are common. Two mortalities occurred during trapping: one deer mouse and one prairie vole.

Table 2. Number of Small Mammals Caught Per Vegetation Type During the Spring 2005 Trapping Survey at the National Renewable Energy Laboratory South Table Mountain Site, Golden, Colorado.

Species	Vegetation Type				
	Short Grass (30 traps)	**Mixed Grass (40 traps)**	**Short Shrubland (20 traps)**	**Ravine Shrubland (10 traps)**	**Total**
Deer mouse	30	33	8	37	108
Mexican woodrat	0	0	11	10	21
Prairie vole	7	4	0	0	11
TOTAL	37	37	19	47	140

1.4 Reptile and Amphibian Surveys

Reptile and amphibian species observed on site during the Spring 2005 season included western rattlesnake. Rattlesnakes were observed near the top of the mesa slope north of the Visitor's Center in the rocks. No other reptile or amphibian species were observed during site visits in Spring 2005.

APPENDIX B

Survey Protocols

1.	Migratory Birds	A. Point-Transect Protocol for Monitoring Colorado's Birds (RMBO et al. 2000) B. Handbook of Field Methods for Monitoring Landbirds (Ralph et al. 1993) – included pages on nest searches only.
2.	Large Mammals	The Pellet-Group Count Technique for Big Game Trend, Census, and Distribution: A Review (Neff 1968)
3.	Predators	Determining the Relative Abundance of Coyotes by Scent Station Lines (Linhart and Knowlton 1975)
4.	Small Mammals	Transect versus grid trapping arrangements for sampling small-mammal communities (Pearson and Ruggiero 2003)

Migratory Birds	A. Point-Transect Protocol for Monitoring Colorado’s Birds (RMBO et al. 2000)

Point-Transect Protocol for *Monitoring Colorado's Birds*

I. Project overview

Colorado Bird Observatory (CBO) in cooperation with Colorado Division of Wildlife, U.S. Forest Service, and Bureau of Land Management, has developed a program of point transects as the main technique in establishing a breeding-bird monitoring project for the state. The point count portion of this project is designed to be statistically rigorous and produce data for analysis of population trends of approximately ___ bird species that breed in Colorado (___% of the regular breeding avifauna). This document delineates the design and operation of our point-count program. It is intended to instruct our field workers on how to establish and run the program **and** for others to follow when establishing monitoring projects of their own, so that design and methods are comparable.

II. Transect design

In this program, the transects, not the individual points, are the data units. Since there are many species that normally occur in densities low enough to be rarely encountered on point counts, we are adding a line transect facet to the data collection in order to increase sample size on those species. Therefore, we will consider the inter-point intervals to be part of a long strip transect on which we will only record individuals of a short list of low-density target species (Fig. 1).

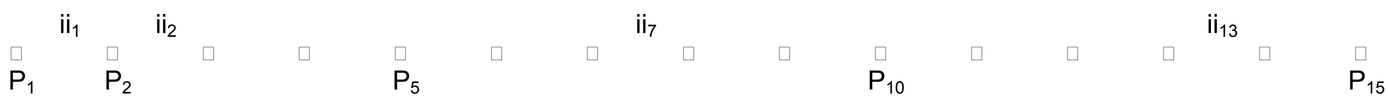


Fig.1. Depiction of point-count transect showing points (P*n*) and inter-point intervals (ii*n*). Point counts are conducted at points (all species are recorded). Only low-density target species are recorded along inter-point intervals. The inter-point interval distances are 250m.

We have randomly established 30 point transects within each of 14 habitats in the state (Lowland Riparian and Wetlands transects are conducted differently; see Appendix E). The access points for these transects will be randomly determined, but falling on a road running through or within one mile of the target habitat.

After a long and complex discussion about transect placement in relation to roads we have decided to avoid biasing transects toward roads, but also to avoid biasing them against roads (they *are* part of Colorado's landscape). Thus, our working assumptions for placing transects near roads are:

1) Colorado is mostly unroaded, therefore, transects should sample primarily unroaded areas,
2) The frequency of roads is variable by habitat,
3) Species have different size territories/home ranges and varying responses to roads, and
4) There are no studies demonstrating strong or consistent road effects (see Rotenberry and Knick 1995, Hutto *et al*. 1995, Keller and Fuller 1995 which show that, for most species, there are no differences between results of counts on roads and of counts away from roads).

Once an access point is chosen, the transect's first point will be placed 0-400 meters (randomly determined) from the access point within the habitat. Transects will run from the first point along a pre-selected, randomly-determined compass bearing. All transects will consist of 15 points each. All transects will have an inter-point interval of 250 meters.

Point counting provides ***samples*** of the local bird community; ***it is not intended to provide a census***. It is assumed that some of the birds present within the area of a point count will not be recorded by the observer--some will not vocalize or otherwise make their presence known to the observer during the length of the point count.

III. Materials

A. A timepiece with a countdown timer and a chime;
B. A clipboard;
C. At least two writing utensils - in case you lose one (pencil or indelible ink pen);
D. Binoculars;
E. Data forms sufficient for all the points planned for that morning;
F. A master list of four-letter codes taped to the clipboard for easy access;
G. A master list of codes to record cloud cover, wind speed, *etc*., also taped to the clipboard; and
H. Random number table, if points are not permanent and/or not already plotted.

IV. Establishing and conducting transects

If the transect which you will be running has already been established, simply follow the directions provided for that transect. If it is not or if you are not provided directions, then you will need to establish the transect. When establishing a new transect, and upon arriving at the pre-selected access point, determine whether the road on which that access point lies runs through the target habitat. If so, then follow the protocol in A below; if not, then follow the protocol in B below.

A. *Establishment of transects from roads that run* ***through*** *the target habitat*--From the access point on the road, pace off the pre-determined random distance (0-400m) on a bearing perpendicular to the road in a randomly-selected direction (right or left). In many (most?) stands, the orientation and shape of the stand may force you to select a bearing from a very small array of possibilities. The first point count and the beginning of the transect is reached at the end of that random distance. From the first point, follow the pre-selected, randomly-determined bearing to all succeeding points. In cases where the random bearing will obviously quickly (in the first 2-3 points) and permanently take the transect out of the target habitat, then you should select another bearing from a random numbers table. Repeat, if necessary.

In cases where you hit a habitat edge after initiating a transect and determine that the pre-selected bearing will not quickly re-enter the target habitat, you should backtrack to the last point conducted and randomly selecting (flip a coin) a right or left turn, then continue the transect perpendicular to the original bearing in the direction selected by the coin toss. If that won't work, run the transect in the other direction. With further direction choices at habitat edges, alternate right and left at those choices.

B. *Establishment of transects from roads that do NOT run through the target habitat*--Walk a bearing from the access point on the road that will reach the target habitat in the shortest distance. (If you cannot see the habitat from the access point, check with the habitat map to see where the target habitat is, then walk toward the habitat.) Upon reaching the target habitat, you are at the first point. From the first point, run the transect along the pre-selected bearing. Should that bearing take the transect out of the habitat, select another bearing from a random numbers table. Repeat, if necessary. Should you hit a habitat edge after initiating a transect, use the protocol for such a situation found in III.A., above.

C. *Transects in linear habitats*--Transects in linear habitats are established in the same manner as with other habitats. However, linear habitats, *e.g.* riparian habitats, provide particular problems in establishing those transects. If rivers ran straight, there would be no problem, but they don't. It is very important when laying out a riparian transect that no two points are closer together than the selected inter-point interval. An extreme example of the problems imposed by meandering linear habitats:

> From point 1 on a transect, you follow a stream that goes straight for 100 meters then turns right, goes 50 meters, turns right again, and then goes 100 meters. You will have walked 250 meters, but the distance between points number 1 and 2 is only 50 meters.

In these cases, it would probably be best to plot the points on a topographic map to ensure the correct inter-point intervals.

V. Methods

A. *Selecting random bearings*--A random numbers table from a statistics text is the best source of random numbers and one is provided to technicians. Field workers that will be establishing transects need to have one on hand. To select a bearing from the table, look at the first three digits on the table. If the number is less than 360, that is your bearing. If it is greater than 359, then subtract multiples of 360 from it until the result is less than 360, at which point that is your bearing. Once you've used a set of three digits from the table, cross them off and use the next three digits for the next bearing.

B. *Determining your pace for pacing distances*--Before pacing off distances, you should first determine the length of your pace. To do this, lay out a 100-meter tape measure in a straight line, preferably in habitat, and then walk that distance and count the number of steps it takes to cover it. You should walk at your normal speed, without trying to take steps larger than you normally do; your pace needs to be consistent and repeatable. Repeat this process in the opposite direction. If your two tries were very different, then try again (and again) until the two attempts are similar (within two paces of each other). Once you obtain two similar values then you should figure out the number of paces you need to cover the inter-point distance.To determine the number of paces needed for you to cover the inter-point interval, simply divide the inter-point interval by 100 meters (the distance you've already paced) and multiply the result by the number of paces you needed to cover 100 meters. (Example: If 250 meters is the inter-point distance and you did the 100 meters in 150 paces, then 250/100 = 2.5, and 2.5 x 150 paces = 375 paces for 250 meters.)

VI. Conducting counts

A. *Seasonal Timing*--Point counts should be performed after all migratory species have returned to the area and as early in the season as possible, but beware of performing them too early and potentially counting a lot of migrants that are not local breeders. Also, transects within a given habitat should all be performed in as short a period as possible--within three to four weeks; less time, if possible. Obviously, counts performed in Lowland Riparian in late May are not comparable to counts performed in the same habitat in mid-July, as most locally-breeding species have completed nesting and are much less vocal in July than they were in May. By limiting the period in which transects in given habitats are performed, we reduce the amount of seasonal variability in singing rates that we capture in our data.

B. *Conducting counts*--Point transects are conducted in two parts: 1) 15 5-minute point counts and 2) a transect count of target bird species conducted while traversing the area between the first and last points.

1) Point counts--Upon reaching a point, fill out all the data about the point (point number, weather data, time of start, *etc*.) on a pre-printed data form. **Do NOT begin counting until after this is done.** Doing this ***first*** is important for two reasons: it will ensure that you do not forget to write it down, as is possible if you wait until after the count is done and it will allow the local birds to "settle down" somewhat after the disturbance you created by your approach to the point. Pay particular attention to filling in the squares in the habitat block of the data form for each of the 15 points per transect upon arriving at each point. In the habitat block, if you enter Cliff/Rock, Rural/Agriculture, or Shore/Bank in a habitat block, do **not** enter a seral stage code. See Appendix C for a more detailed explanation of the field form.

The count duration is **5 minutes**. Count all birds seen and/or heard during that time. Estimate the distance to each individual bird recorded on the count and record on the data sheet. When performing a point count, it is important to have a timepiece that has a count-down timer and a chime that rings at the end of the period. This eliminates having to look at the timepiece to see how much time remains in the count, thus potentially missing birds.

After the general point data are recorded, activate your timepiece and begin counting the birds you see and/or hear. For each bird detected, record the ***correct*** 4-letter code (Appendix D; please, commit to memory those codes that you use frequently) and how it was **initially** detected (see details on codes in Appendix B). In the How column, enter "V" for visual, "C" for calling, or "S" for singing. In the Sex column, enter "F" for female, "M" for male, and U for unknown. Use whatever cues you can to determine the sex of each bird, even if you initially detected a bird by voice but sexed it visually. Thus, for a bird that is first detected calling, but then seen and sexed as a female, the how-detected code entered should be "C" and the sex code should be "F." Assume that singing and/or displaying birds are males (except for Spotted Sandpiper and Wilson's Phalarope). The wing whistle of Broad-tailed Hummingbirds and drumming of woodpeckers should be coded as singing, as it results in the same sex determination as singing. Then, estimate the **radial** distance to the individual at the point at which it was **first** detected (estimated in meters). For individuals of species that are low-density targets for the habitat in which you are counting, estimate both the radial distance **AND** the distance perpendicular to the transect line and enter the distances in the appropriate columns.

> Example 1: On point 1 of a Ponderosa Pine transect, you detect six individual birds: a male WISA that you see, a calling WISA that you do not see, a calling WBNU, a singing WETA, a singing CHSP, and a brown-plumaged CAFI. You should make estimates of radial distance for all six individuals and perpendicular distances for the two WISA and the CAFI. In order, the How column should be filled in with V, C, C, S, S, V and the Sex column should be filled in with M, U, U, M, M, U (male CAFI require two years to achieve adult plumage, thus a brown-plumaged bird cannot be sexed in the field).

When estimating distance, **do NOT round estimates** to the nearest 5 or 10 meters, particularly for birds that are close to you (<50m). Rounding distances causes heaping at popular values and makes analysis more difficult! For flyovers, enter the species code and an "F" in the how detected column and draw a short line through the distance column - do not estimate distance for fly-overs. For individuals of species that habitually hunt on the wing, record those individuals that appear to be foraging (*e.g*. Northern Harrier coursing over open country, swallows flying at relatively low altitudes and not flying purposefully in one direction) as on the point, **NOT** as flyovers. Provide distance estimates to those flying individuals that you record as on the point. Additionally, individuals that are first detected in flight, but that are simply flying from perch to perch within the habitat are counted as using the habitat. Thus, estimate distance to the point at which you first saw the bird(s) and record the best how-detected variable.

While conducting a count, be sure to look and listen in all directions, including up. It is best to slowly rotate in place while you are counting; making three complete turns in the five minutes is probably adequate. **Don't forget to look up!** It is very important to stay in one place while counting - *it is called a point count for a reason*. It is acceptable to take a step or two away from the point in order to identify a bird that you can detect from a point but cannot identify from the point, but ***ALWAYS*** return ASAP to the point. Do NOT chase birds during the count. After the five minutes are up, you may chase down a bird that you couldn't identify on the point in order to get an identification for the point, but do not leave the point during the five minutes and do NOT record birds for the point that were only found while chasing another bird. ***Remember: Consistency of methods and coverage is the key to useful data!*** Be aware of what is going on around you and realize that you will hear individual birds on multiple points. When at a point, **DO NOT** count an individual bird that you saw and/or heard on a previous point.

> Example 2: On a Grassland point you see an adult male NOHA quartering low over the habitat. You mark it down for that point, finish the point, and walk to the next point. After writing down the point information, you start the count. At some point you look in the direction of the previous point and see two NOHAs, one of which is an adult male. For the second point, you should only record one Northern Harrier, as you recorded the adult male on the previous point.

> Example 3: At the same point above, you hear two WEMEs singing, each bird on bearings perpendicular to the line of the transect and 180° from each other. When you start the next point,

you hear three WEMEs, two from back by the previous point on opposite sides of the transect and one in the opposite direction toward the third point. You would record only one WEME for the second point, as you had already recorded two of them on the first point.

2. *Transect counts*--Conduct transect counts between the first and last points of the transect. While pacing the distance from one point to the next, record individuals of target bird species that you see and/or hear on the transect between individual points. A list of target species for each habitat is given in Appendix C.

After completing the first point count, begin pacing the inter-point interval to the next point. Walk at a constant speed and spend as little time as possible looking down, so that you can scan the surroundings for target bird species. *However, you DO need to watch where you are going enough to follow the correct compass bearing and avoid hazards.* For each individual of a target species discovered while walking between points, record the species, the ***perpendicular*** distance (**not** radial distance), and How code, and enter "99" for the point number. If you detect target species as flyovers, enter the species code and "F" in the how detected column, but do not estimate distance to the bird(s). ***Individual birds that are first encountered on points may NOT be counted on transects, nor may individual birds first encountered on transects be counted on points.***

VII. Potential problems when conducting point counts

A. *Window species*--This is "listening through" (not detecting) a particular common species because you are habituated to it (Mourning Dove is a common window species).
B. *Looking/listening everywhere*--Be sure to look up regularly, particularly in taller forest types and, particularly if you are wearing a hat. Be sure to look AND listen in all directions (try to look and listen in all directions about equally).
C. *Stand at points*--Do **not** sit or kneel as this can reduce the number of individuals recorded, by decreasing visibility and audibility.
D. *Recording data*--Do not use a second person as scribe; this can enable the observer to record more birds (or fewer, if the scribe detracts), therefore those points are not comparable to points that were conducted by one person.
E. *NO pishing*--Do not attract birds to you. Pishing is permissible after the count in order to attempt to identify an individual that was not identifiable on the count, but do not add other individuals that were otherwise not counted.
F. *Airplane (and other) noise*--If audibility of birds is reduced by mechanical noise, interrupt count, restart when noise abates, and add time to the end to make a five-minute count. Obviously, a timepiece that permits stopping and restarting from the stop point is of great value in this instance.
G. *Guessing*--Never guess on the identity of a bird. Instead, use an unknown code (*e.g.* unidentified sparrow - UNSP) for those individuals about which you're not sure. However, recording a lot of unidentified birds is an indication that you need to learn/practice more before performing point counts.
H. *Practice*--PRACTICE **IN** habitat before counting for real and be familiar with the songs and calls of all species found in the habitat.

VIII. Literature Cited

All literature cited is from:
Ralph, C.J., J.R. Sauer, and S. Droege, eds. 1995. Monitoring Bird Populations by Point Counts. Gen. Tech. Rep. PSW-GTR-149. Albany, CA: Pacific Southwest Research Station, Forest Service, USDA. 187 pp.

Hutto, R.L., S.J. Hejl, J.F. Kelly, and S.M. Pletschet. 1995. A comparison of bird detection rates derived from on-road vs. off-road point counts in northern Montana. Pp 103-110.
Keller, C.M.E. and M.R. Fuller. 1995. Comparison of birds detected from roadside and off-road point counts in the Shenandoah National Park. Pp 103-110.
Ralph, C.J., S. Droege, and J.R. Sauer. 1995. Managing and monitoring birds using point counts:

Standards and applications. Pp 161-168.
Rotenberry, J.T. and S.T. Knick. 1995. Evaluation of bias in roadside point count surveys of passerines in shrubsteppe and grassland habitats in southwestern Idaho. Pp 111-116.

Appendix A. Field form, Page 1.

Appendix A. Field form, subsequent page(s).

Appendix B. Explanation of field form and codes for its use.

Transect #: Enter the four-character transect number

Stand #: Enter the five-digit stand number (for stands with fewer digits, enter leading zeroes)

Habitat: Enter two-letter habitat code of the habitat at which the transect is targeted

AT=Alpine Tundra	*MC=Mixed Conifer Forest*	*SA=Sage Shrubland*
AS=Aspen	*MS=Mountain Shrubland*	*SE=Semidesert Shrubland (east)*
CR=Cliff/Rock	*LP=Lodgepole Pine*	*SB=Shore/Bank*
GR=Grassland	*PJ=Piñon-Juniper*	*SF=Spruce/Fir*
HR=High-elevation Riparian	*PP=Ponderosa Pine*	*SW=Semidesert Shrubland (west)*
LR=Lowland Riparian	*RA=Rural/Agriculture*	*WE=Wetlands*

Observer: Enter your first two initials and your last name

Directions to access point: Provide **explicit** directions (if not already available) from some nearby town or geographical feature readily found on a DeLorme atlas to the access point. If there are already directions, enter "Used previous directions" in this box, unless you modify the directions in some way. Also, be explicit about the exact location of the access point (e.g. "the right post of the gate" or "the NE corner of the bridge").

Transect description: Provide the distance and bearing from the access point to the first point (do not provide bearing from first point to the access point)

Transect data

Date: Enter the date in the format MM-DD-YY

Time: Enter start and stop times for entire transect (not individual points) using 24-hour clock

Sky (start and end): Enter one-digit codes at beginning and end of transect (not at points)

0=0-15% cloud cover	*1=16-50% cloud cover*	*2=51-75% cloud cover*
3=76-100% cloud cover	*4=fog*	*6=drizzle*

You shouldn't conduct counts in any other conditions!

Wind (start and end): Enter one-digit codes at beginning and end of transect

0=Less than 1 mph; smoke rises vertically
1=1-3 mph; smoke drift shows wind direction
2=4-7 mph; leaves rustle, wind is felt on face
3=8-12 mph; leaves, small twigs in constant motion; light flag extended
4=13-18 mph; raises dust, leaves, loose paper; small branches in motion

You shouldn't conduct counts in any other conditions!

Appendix B. Continued.

Temperature (start and end): Enter in °F (no thermometer?, estimate to nearest 5°)

Transect notes: Enter information relevant to the stand, good camp sites, cool scenery, or other tidbits that either don't really fit in other places or that future surveyors might find interesting

UTM data: Enter the UTM coordinates (using the NAD27 CONUS datum in navigation setup) for each point. For LR transects, enter the beginning UTM in the point 1 spot and the ending UTM in the point 15 spot. For WE transects, simply enter the starting point UTM in the point 1 spot.

Habitat data

Within 100m of road (Y/N): Enter "Y" for yes and "N" for no for **EACH** point

On private land (Y/N): Enter "Y" for yes and "N" for no for **EACH** point

Best habitat classification: Enter two-letter code of habitat that BEST describes the habitat at the point (see habitat codes above in transect data explanation)

Best habitat seral stage: Enter one-digit code of seral stage of habitat used in best habitat classification
1=grass-forb stage *2=shrub-seedling stage* *3=sapling-pole stage*
4=mature stage *5=old growth stage*

Next-best habitat classification: Enter two-letter code of habitat that NEXT best describes the habitat at the point

Next-best habitat seral stage: Enter one-digit code of seral stage of habitat used in next-best habitat classification

Primary understory classification: Enter two-letter code of understory vegetation type that best describes the understory types within 50m of the point (this is to be used only for forested habitats - AS,LP,MC,MR,PJ,PP,SF):
BG=bare ground *GO=Gambel's oak* *GF=grass/forb*
MM=mountain mahogany/serviceberry *NS=not sage or willow*
SA=sage *SN=snowberry* *WI=willow*

Primary understory percentage: Enter one-digit code of percentage cover within 50m radius of point:
0=0-20%, 1=21-40%, 2=41-60%, 3=61-80%, 4=81-100%

Secondary understory classification: Enter two-letter code of understory type that NEXT best describes the understory within a 50m radius of the point, as above

Secondary understory percentage: Enter one-digit code of percentage cover within 50m radius of point, as above

Appendix B. Continued.

Point data

Point #: Enter number of point (1-15) on the transect; **NOTE --** for entries for target species between points (see protocol text on target species), enter “99" here

Species: Enter **CORRECT** four-letter code for birds (see Appendix D); PLEASE, PLEASE use correct codes, as it makes data entry and analysis easier. Species that cause particular problems for observers include: **Northern Shoveler** (NSHO, not NOSH), **Blue Grouse** (BGRU, not BLGR), **Mountain Plover** (MOUP, not MOPL), **Broad-tailed Hummingbird** (BTLH, not BTHU), **Western Scrub-Jay** (WESJ, not SCJA), **Tree Swallow** (TRES, not TRSW), **Bank Swallow** (BANS, not BASW), **Barn Swallow** (BARS, not BASW), **Yellow Warbler** (YWAR, not YEWA), **Yellow-rumped Warbler** (AUWA - for Audubon’s Warbler, not YRWA), **Lark Bunting** (LARB, not LABU), **Sage Sparrow** (SAGS, not SASP), **Savannah Sparrow** (SAVS, not SASP), **Lazuli Bunting** (LAZB, not LABU) and **Red-winged Blackbird** (RWBL, not RWBB).

Radial distance: Estimate radial distance (that is, direct distance from point to bird) to each bird in one-meter units (**DO NOT** round off to five- or ten-meter units) -- if beyond a kilometer (1000 meters) fit number in the three spaces provided as best you can

Perpendicular distance: Estimate the distance to the bird perpendicular to the transect line, not the distance from the point to the bird

How: Enter code for how each individual was detected: C=calling; S=singing; VF=visual - female; VM=visual - male; VU=visual - unknown; F=flyover

VERY IMPORTANT: Skip a line between entries for individual points and/or individual legs of the transect. That is, all individual birds on a particular point (or transect leg) should be bunched together on the form, then you should leave a blank line before starting entries for the next transect leg (or point).

Don’t forget to enter transect and page numbers at the bottom of EACH page!

Appendix C. Low-density target species by habitat. **NOTE: All raptors, galliforms, and woodpeckers (except for RSFL) should be treated as target species in all habitats.**

Habitat	Low-density target species
Alpine Tundra	White-tailed Ptarmigan, Brewer's/Timberline Sparrow, Brown-capped Rosy-Finch
Aspen	Red-naped Sapsucker, Olive-sided Flycatcher, Hammond's Flycatcher
Grassland	Greater Roadrunner, Mountain Plover, Upland Sandpiper, Burrowing Owl, Loggerhead Shrike, Cassin's Sparrow
High-elev. Riparian	Belted Kingfisher, Red-naped Sapsucker, Willow Flycatcher, Cordilleran Flycatcher, American Dipper, Veery, Swainson's Thrush, Fox Sparrow
Mixed Conifer	Olive-sided Flycatcher, Hammond's Flycatcher, Clark's Nutcracker, Brown Creeper, Cassin's Finch, Evening Grosbeak
Mountain Shrubland	Sharp-tailed Grouse
Pinyon/Juniper	Black-chinned Hummingbird, Gray Flycatcher, Say's Phoebe, Gray Vireo, Pinyon Jay
Ponderosa Pine	Olive-sided Flycatcher, Hammond's Flycatcher, Clark's Nutcracker, Brown Creeper, Cassin's Finch
Sagebrush Shrubland	Northern Sage-Grouse, Gunnison Sage-Grouse, Sage Sparrow
Semidesert Shrubland	Scaled Quail, Greater Roadrunner, Say's Phoebe, Curve-billed Thrasher, Canyon Towhee, Black-throated Sparrow
Spruce/Fir	Olive-sided Flycatcher, Hammond's Flycatcher, Clark's Nutcracker, Brown Creeper, Golden-crowned Kinglet, Cassin's Finch, Pine Grosbeak, Evening Grosbeak

Appendix D. Key to four-letter bird name codes (alphabetical by species name).

Code	Species	Code	Species	Code	Species
AMAV	American Avocet	BHGR	Black-headed Grosbeak	CAEG	Cattle Egret
AMBI	American Bittern	BNST	Black-necked Stilt	CEDW	Cedar Waxwing
AMCO	American Coot	BTYW	Black-throated Gray Warbler	CCLO	Chestnut-collared Longspur
AMCR	American Crow	BTSP	Black-throated Sparrow	CHRA	Chihuahuan Raven
AMDI	American Dipper	BLGR	Blue Grosbeak	CHSW	Chimney Swift
AMGO	American Goldfinch	BGRU	Blue Grouse	CHSP	Chipping Sparrow
AMKE	American Kestrel	BLJA	Blue Jay	CHUK	Chukar
AMPI	American Pipit	BGGN	Blue-gray Gnatcatcher	CITE	Cinnamon Teal
AMRO	American Robin	BWTE	Blue-winged Teal	CLGR	Clark's Grebe
AWPE	American White Pelican	BOBO	Bobolink	CLNU	Clark's Nutcracker
AMWI	American Wigeon	BOOW	Boreal Owl	CLSW	Cliff Swallow
ATFL	Ash-throated Flycatcher	BRBL	Brewer's Blackbird	COGR	Common Grackle
BAEA	Bald Eagle	BRSP	Brewer's Sparrow	COME	Common Merganser
BAOR	Baltimore Oriole	BTLH	Broad-tailed Hummingbird	CONI	Common Nighthawk
BTPI	Band-tailed Pigeon	BRCR	Brown Creeper	COPO	Common Poorwill
BANS	Bank Swallow	BRTH	Brown Thrasher	CORA	Common Raven
BNOW	Barn Owl	BCRF	Brown-capped Rosy-Finch	COSN	Common Snipe
BARS	Barn Swallow	BHCO	Brown-headed Cowbird	COYE	Common Yellowthroat
BEVI	Bell's Vireo	BUOR	Bullock's Oriole	COHA	Cooper's Hawk
BEKI	Belted Kingfisher	BUOW	Burrowing Owl	COFL	Cordilleran Flycatcher
BEWR	Bewick's Wren	BUSH	Bushtit	CBTH	Curve-billed Thrasher
BLPH	Black Phoebe	CAGU	California Gull	GHJU	Dark-eyed Junco
BLSW	Black Swift	CAGO	Canada Goose	DICK	Dickcissel
BLTE	Black Tern	CANV	Canvasback	DCCO	Double-crested Cormorant
BBCU	Black-billed Cuckoo	CANT	Canyon Towhee	DOWO	Downy Woodpecker
BBMA	Black-billed Magpie	CANW	Canyon Wren	DUFL	Dusky Flycatcher
BCCH	Black-capped Chickadee	CAFI	Cassin's Finch	EAGR	Eared Grebe
BCHU	Black-chinned Hummingbird	CAKI	Cassin's Kingbird	EABL	Eastern Bluebird
BCNH	Black-crowned Night-Heron	CASP	Cassin's Sparrow	EAKI	Eastern Kingbird

EAME	Eastern Meadowlark
EAPH	Eastern Phoebe
EASO	Eastern Screech-Owl
EUCD	Eurasian Collared-Dove
EUST	European Starling
EVGR	Evening Grosbeak
FEHA	Ferruginous Hawk
FISP	Field Sparrow
FLOW	Flammulated Owl
FOTE	Forster's Tern
FOSP	Fox Sparrow
FRGU	Franklin's Gull
GADW	Gadwall
GAQU	Gambel's Quail
GOEA	Golden Eagle
GCKI	Golden-crowned Kinglet
GRWA	Grace's Warbler
GRSP	Grasshopper Sparrow
GRCA	Gray Catbird
GRFL	Gray Flycatcher
GRAJ	Gray Jay
GRVI	Gray Vireo
GBHE	Great Blue Heron
GCFL	Great Crested Flycatcher
GHOW	Great Horned Owl
GTGR	Great-tailed Grackle
GRPC	Greater Prairie-Chicken
GRRO	Greater Roadrunner
GRHE	Green Heron
GTTO	Green-tailed Towhee
AGWT	Green-winged Teal
GUSG	Gunnison Sage-Grouse
HAWO	Hairy Woodpecker
HAFL	Hammond's Flycatcher
HETH	Hermit Thrush
HOGR	Horned Grebe
HOLA	Horned Lark
HOFI	House Finch
HOSP	House Sparrow
HOWR	House Wren
INBU	Indigo Bunting
JUTI	Juniper Titmouse
KILL	Killdeer
LBWO	Ladder-backed Woodpecker
LARB	Lark Bunting
LASP	Lark Sparrow
LAZB	Lazuli Bunting
LEBI	Least Bittern
LETE	Least Tern
LEGO	Lesser Goldfinch
LEPC	Lesser Prairie-Chicken
LESC	Lesser Scaup
LEWO	Lewis's Woodpecker
LISP	Lincoln's Sparrow
LOSH	Loggerhead Shrike
LBCU	Long-billed Curlew
LEOW	Long-eared Owl
MGWA	MacGillivray's Warbler
MALL	Mallard
MAWR	Marsh Wren
MCLO	McCown's Longspur
MIKI	Mississippi Kite
MOBL	Mountain Bluebird
MOCH	Mountain Chickadee
MOUP	Mountain Plover
MODO	Mourning Dove
NOBO	Northern Bobwhite
RSFL	Northern Flicker
NOGO	Northern Goshawk
NOHA	Northern Harrier
NOMO	Northern Mockingbird
NOPI	Northern Pintail
NOPO	Northern Pygmy-Owl
NRWS	Northern Rough-winged Swallow
NOSG	Northern Sage-Grouse
NSWO	Northern Saw-whet Owl
NSHO	Northern Shoveler
OSFL	Olive-sided Flycatcher
OCWA	Orange-crowned Warbler
OROR	Orchard Oriole
OSPR	Osprey
PEFA	Peregrine Falcon
PBGR	Pied-billed Grebe
PIGR	Pine Grosbeak
PISI	Pine Siskin
PIJA	Pinyon Jay
PLVI	Plumbeous Vireo
PRFA	Prairie Falcon
PUMA	Purple Martin
PYNU	Pygmy Nuthatch
RECR	Red Crossbill
RBWO	Red-bellied Woodpecker
RBNU	Red-breasted Nuthatch
RHWO	Red-headed Woodpecker
RNSA	Red-naped Sapsucker
RTHA	Red-tailed Hawk
RWBL	Red-winged Blackbird
REDH	Redhead
RNDU	Ring-necked Duck
RINP	Ring-necked Pheasant
RODO	Rock Dove
ROWR	Rock Wren
RCKI	Ruby-crowned Kinglet
RUDU	Ruddy Duck
RUHU	Rufous Hummingbird
RCSP	Rufous-crowned Sparrow
SAGS	Sage Sparrow
SATH	Sage Thrasher
SACR	Sandhill Crane
SAVS	Savannah Sparrow
SAPH	Say's Phoebe

SCQU	Scaled Quail
STFL	Scissor-tailed Flycatcher
SCOR	Scott's Oriole
SSHA	Sharp-shinned Hawk
STGR	Sharp-tailed Grouse
SEOW	Short-eared Owl
SNEG	Snowy Egret
SNPL	Snowy Plover
SOSP	Song Sparrow
SORA	Sora
SPSA	Spotted Sandpiper
SPTO	Spotted Towhee
STJA	Steller's Jay
SWHA	Swainson's Hawk
SWTH	Swainson's Thrush
TTWO	Three-toed Woodpecker
TOSO	Townsend's Solitaire
TRES	Tree Swallow
TUVU	Turkey Vulture
UPSA	Upland Sandpiper
VEER	Veery
VESP	Vesper Sparrow
VGSW	Violet-green Swallow
VIRA	Virginia Rail
VIWA	Virginia's Warbler
WAVI	Warbling Vireo
WEBL	Western Bluebird
WEGR	Western Grebe
WEKI	Western Kingbird
WEME	Western Meadowlark
WESO	Western Screech-Owl
WESJ	Western Scrub-Jay
WETA	Western Tanager
WEWP	Western Wood-Pewee
WBNU	White-breasted Nuthatch
MWCS	White-crowned Sparrow
WFIB	White-faced Ibis
WTPT	White-tailed Ptarmigan
WTSW	White-throated Swift
WWCR	White-winged Crossbill
WITU	Wild Turkey
WILL	Willet
WISA	Williamson's Sapsucker
WIFL	Willow Flycatcher
WIPH	Wilson's Phalarope
WIWA	Wilson's Warbler
WODU	Wood Duck
YWAR	Yellow Warbler
YBCU	Yellow-billed Cuckoo
YBCH	Yellow-breasted Chat
YHBL	Yellow-headed Blackbird
AUWA	Yellow-rumped Warbler

Appendix E. Design of Lowland Riparian and Wetlands transects.

Lowland Riparian – We will determine the number of navigable river miles below 6000 feet elevation (the approximate beginning level of changeover from low-elevation to high-elevation species of cottonwood) in Colorado. From that selection pool, we will randomly select 30 one-mile stretches of river. On the selected stretches, two-person teams (an observer and a canoer) will run the transects by canoe, utilizing true transect methodology and estimating the perpendicular (from the river) distance to each bird detected. In other respects, methodology will not differ.

Wetlands – After randomly selecting 30 wetlands, we will use true transect methodology to sample this habitat. Individual observers will conduct transects of 300 meters length, estimating the perpendicular (from the transect line) distance to each bird detected. In other respects, methodology will not differ.

Migratory Birds	B. Handbook of Field Methods for Monitoring Landbirds (Ralph et al. 1993) – included pages on nest searches only.

United States
Department
of Agriculture

Forest Service

**Pacific Southwest
Research Station**

General Technical
Report PSW-GTR-144-www

Handbook of Field Methods for Monitoring Landbirds

C. John Ralph
Geoffrey R. Geupel
Peter Pyle
Thomas E. Martin
David F. DeSante

Ralph, C. John; Geupel, Geoffrey R.; Pyle, Peter; Martin, Thomas E.; DeSante, David F. 1993. **Handbook of field methods for monitoring landbirds.** Gen. Tech. Rep. PSW-GTR-144-www. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 41 p.

This handbook is a compilation of methods that can be used to assay population size, demographics, and status of many species of birds occurring in a wide variety of habitats. The handbook will prove useful to field biologists, managers, and scientists anywhere in the New World from the arctic through the tropics. The methods include four types of censuses for determining population size and trends, mist-netting and nest searches to determine demographic parameters, and other methods that will be useful in operating a monitoring station, including habitat and weather observations, and suggestions for training personnel and possibilities for detailed studies. Suggestions of specific methods and data forms are included.

Retrieval Terms: bird populations, census, mist-nets, monitoring, nesting birds

Acknowledgments:

The late L. Richard Mewaldt was the first among equals in setting high standards and maintenance of accurate records. His contributions are detailed by Ralph (1992). We take great pleasure in dedicating this handbook to him.

This handbook is a direct outgrowth of the landbird program started more than 25 years ago at the Point Reyes Bird Observatory to monitor landbird populations in coastal California, and much of this handbook is the result of the methods developed and adapted there. Over this period, many people contributed to the development of this landbird monitoring program.

The handbook benefitted greatly from discussions and correspondence by Bruce Bingham, Grant Ballard, Danny Bystrak, Barbara Carlson, Brenda Dale, Sam Droege, John Faaborg, Kevin J. Gutzwiller, Denise Hardesty, Kimberly Hollinger, Bill Howe, David W. Johnston, Stephanie Jones, Cherry Keller, Kathy Klimkiewicz, Rolf R. Koford, Karin Kozie, Borja Milá, Sherri Miller, Michael Morrison, Barry R. Noon, Nadav Nur, Raymond J. O'Connor, Will Peach, Carol Pearson Ralph, Martin Raphael, Dan Reinking, Christopher C. Rimmer, Sharon Ritter, John T. Rotenberry, John R. Sauer, Tom Sherry, Sue Sniado, John Tautin, Jared Verner, Dennis Vroman, George E. Wallace, Dan Welsh, and Joseph M. Wunderle, Jr.

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May 1993

Sources of Equipment[1]

Advertisements for supplies and good articles on capture techniques can be found in the publication "North American Bird Bander." Persons doing mist netting or banding should join their regional Association and receive this, the joint publication of the Western Bird Banding Association (BBA), 1158 Beechwood St., Camarillo, CA 93010 (Colorado and west); Eastern BBA, R.D. #2, Box 436A, Hellertown, PA 18055 (Appalachians and east); or the Inland BBA, 81 Woodshire Drive, Ottawa, IA 52501.

Mist Nets

Nets can be purchased in the United States at the following:

Association of Field Ornithologists, c/o Manomet Bird Observatory, Box 936, Manomet, MA 02345 [telephone (508) 224-6521]. A wide assortment of nets.

Avinet, P.O. Box 1103, Dryden, NY 13053 [telephone and FAX: (607) 844-3277]. They have a wide selection of nets, banding tools, scales, poles, color bands, and other material.

Eastern Bird-Banding Association, Gale W. Smith, R.D. #2, Box 131, Kempton, PA 19529. An assortment of nets.

Color Bands

The only source of split-ring plastic color bands for landbirds that we have found is A.C. Hughes, Ltd., 1 High Street, Hampton Hill, Middlesex TW12 1NA, England. Avinet (see above) carries a limited supply of Hughes' bands.

The best bands for most species are the "Plastic Split Rings" in solid colors. We have found their five most visible and separable colors are Red, Yellow, Light Blue, Dark Blue, and Orange. If more colors are needed, some investigators have found White reasonably separable from the standard aluminum band, and the Black and the Dark Green separable from the Dark Blue. Hughes' sizes (and their Fish and Wildlife Service approximate equivalents) are: XF (0), XCS (1), XCL (1B), XB (1A), and X3 (2).

Optical Device for Skulling

An excellent one is OptiVisor, a binocular magnifier available in 2.5, 2.75 and 3.5 powers. Available from the manufacturer Donegan Optical Company Incorporated, P.O. Box 14308, Lenexa, Kansas 66285-4308, or call them at (913) 492-2500 for a distributor near you.

Wing Rulers

Rigid tempered steel rules with a stop at the end are very good for measuring wings. Sizes are 15 cm, 30 cm, and 60 cm. Available from Chris N. Rose, 98 Lopez Rd., Cedar Grove, NJ 07009.

[1]The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

Banding Pliers

The best have holes in jaws to fit standard U.S. band sizes, with a split pin on top for even band opening. Three pliers are available: one will open all of band sizes 0, 1, 1B, and 1A; another for sizes 2 and 3; and one for sizes 3B, 3A, and 4. These are available from Roger N. MacDonald, 850 Main St., Lynnfield, MA 01940, (617) 334-3448.

Scales for Weighing

Electronic scales are widely available for under $300, and Pesola scales and a spring balance field scale are available through Avinet (see above). A good general purpose one has a capacity of 300 g and a readability of 0.1 g. The Ohaus C-Series costs under $200 and Acculab has one under $150. With a capacity for most birds, Acculab has a pocket balance with 80 g capacity for under $100. These are available from many scientific supply houses, such as Markson, P.O. Box 3944, Houston, Texas 77253 (800-528-5114).

Bags for Holding Birds

Washable bags can be made, or cotton mailing bags can be purchased. An ideal size for most small birds is 6 by 9 inches, or somewhat larger. U.S. Government agencies can purchase excellent cotton mailing bags from the General Services Administration.

Bird Banding Laboratory and Office

All capture work must be done under very strict regulations and permits. Permit applications in the United States can be obtained from the Bird Banding Laboratory, U.S. Fish and Wildlife Service, Laurel, Maryland 20708. In Canada, the address is Canadian Bird Banding Office, Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3. Special permits are also needed from most states and provinces, and the above offices can supply information on them. Many Latin American countries also require permits.

The Bird Banding Laboratory and Office provide excellent support for all activities relating to capture, and permittees receive bands at no cost. However, they have limited resources for supporting banding work and cannot honor all requests for permits. Applicants for permits must show evidence of qualifications and must have a well-justified need to band. Permittees are expected to provide accurate and timely reports of birds banded.

Nest Searches

Nest searches provide the most direct measurement of nest success in specific habitats. They also allow identification of important habitat features associated with successful nests and insight into habitat requirements and species coexistence. Knowledge of the appropriate cues and techniques for finding nests allows large numbers to be found, thereby providing vital information about many species. Nest searches have an advantage over constant-effort mist netting, in that the measures of success are direct and habitat-specific. However, they are more limited as to the area surveyed and do not measure individual survivorship. Mist nets sample birds from a larger area, and the data derived may therefore have wider applicability, but are not habitat specific.

In this section we describe aids and standardized techniques for locating and monitoring success of nests, adapted from Martin and Geupel (in press).

Nest Sites

Nest finding is labor intensive (DeSante and Geupel 1987, Ricklefs and Bloom 1977), but most observers can improve their ability to locate nests in a matter of days with training and practice.

The behavioral observations and clues described below work effectively for a variety of species. However, our experience includes a small subset of species and habitats and, in particular, is largely restricted to forest and shrub habitats. Other methods may be more effective in other habitats. For example, cable-dragging (Higgins and others 1969) and rope-dragging (Labisky 1957) may be more effective for many grassland species. In particular, all species, and even some individuals, differ in nest placement and behaviors near the nest. The patience and alertness of observers, and their familiarity with the habitat and behavior of individual species, are the most important influences on effectively locating nests.

Nest finding can be a frustrating task; patience is an important asset. It is a good idea to set a goal of finding at least one nest daily. More than one nest will be found on many days, but if at least one nest can be consistently found every day, the numbers of nests over the season will rapidly accumulate.

Methods

The particulars of plot sizes and numbers will vary according to the purpose of the study or activity, the habitat involved, and the density of birds. As a general guideline, we recommend that two study plots be established for each person that searches for nests. The searchers should work alternating days on these two plots for the entire nesting season. This provides consistent monitoring and allows the person to become familiar with the plot. In general, eight plots, each 40-50 ha, would usually be necessary to be established in forest habitat to find sufficient numbers of nests (ca. 20 nests per species) for the range of species typically found in any given forest, but smaller plots (ca. 10 ha) can be established in areas with higher densities.

In general, one should try to develop as quickly as possible a search image for the nests of various species. T. Sherry (pers. comm.) notes that he routinely finds 25-50 percent of his nests by constantly scanning appropriate potential nest locations in the vicinity of an active female.

During Nest Construction

Ideally, nests should be located during construction to provide the best estimates of nest success. This is also usually the easiest time to find nests because of the high level of activity and, in some areas, forests are not leafed out, making the task of following the female much simpler (T. Sherry, pers. comm.). We advise biologists to spend the maximum amount of time early in the season when the finding rate is maximum. Nest building begins by May in most areas of North America, although permanent residents and some ground-nesting species will begin earlier. Only the female constructs the nest and incubates the eggs for most small terrestrial birds (Kendeigh 1952, Silver and others 1985). Exceptions include woodpeckers, vireos, and wrens. Thus, the most effective way of finding most nests is by locating and following females, although males may provide some cues. Some nests in the shrub layer can be found by random search. Ground nests in forests are usually the most difficult to find. It is best to watch the female as she is gathering nesting material without using binoculars, because when she flies, she can be followed more easily with the naked eye.

Females tend to be extremely furtive during nest building. A mated female can be recognized by copulations or by her movements around the territory unharassed by the male. Females should always be checked with binoculars, especially during and after long, direct flights, to determine whether nesting material is being carried. Many birds will carry very fine material, not obvious upon casual inspection, such as spider webbing and hair for lining nests.

Sitting near sources of nesting material (e.g., failed nests, thistles) or open areas with a good view of the territory can help detection of nest-building females. Observers should use different paths across plots to increase the probability of randomly encountering females near undiscovered nests.

Follow a bird with nesting material from a distance to avoid disturbance. Do not interrupt a long flight. If the bird disappears in a patch of vegetation, begin to scan for potential nest sites. Be patient and wait for another visit by the bird. If the area where the female disappears is near the nest, the female will spend time in the area. At the same time, be aware that the female may move out of the back side of the patch to another patch that contains the nest.

Some individuals tolerate nearby observers and behave normally, but most species are very wary of observers. If the observer is too close to the nest, the bird often will sit on a perch somewhere near the nest site until the observer leaves. Eventually the bird will drop the nesting material if the observer does not move away. Thus, such behavior is an indication that the observer is too near the nest and should move quickly away. Obtain a new position at some distance (ca. 15 m) hidden by vegetation. Observe the female arrive with nest material and leave without it from the same location several times. Be aware that a female can skulk into one patch of vegetation and leave unobserved to move to a different patch, then return the same way, to give the appearance of nesting in the first patch. Some species such as MacGillivray's Warbler, Hooded Warblers, and Sage Sparrows will walk on the ground for several meters to approach the nest secretly. Birds can often be detected by watching for movement of the vegetation where they are otherwise hidden. Where the vegetation stops moving is usually the nest site.

Mapping the male's position as he sings around the territory can often reveal a center of activity from which the male can often see the nest (T. Sherry, pers. comm.). The observer then can scan appropriate nest sites nearby, or at least increase the chance of catching a glimpse of a wary female.

Once the suspected nest site has been identified, back away quickly. Verify the status and location a few hours later, being careful that the female is absent. Do not approach the nest while the female is watching; disturbance at this early stage can cause abandonment. After quick verification, the area should be left and not visited for four days.

During Egg-Laying

This is the most difficult stage for finding nests because the female may visit the nest only when she lays an egg, and most species lay one egg per day. The female will sometimes sit on the nest during egg-laying when weather is particularly harsh. Nest visitation becomes more frequent with more eggs in the nest (Kendeigh 1952).

Behavioral cues are useful at this stage. When either parent gets near the nest, they will look at it. If an egg-laying female detects a predator in the area, such as an observer following her, she will sometimes check the nest. Another good cue is a female staying in an area without actively feeding. She will often look at the nest site repeatedly, aiding location of the nest.

Finally, copulatory behavior can be used during both nest-building and egg-laying. Copulation often occurs in the same tree above a nest, on the same branch, or in the next tree. Examine carefully the area immediately adjacent to copulatory activity.

During Incubation

The beginning of incubation can be estimated as when females suddenly "vanish," and males increase singing. Some behavioral cues can help locate nests. Females start foraging faste during the incubation and nestling stages, probably because their time is more limited. Females that are making rapid hops, quick short flights, and rapid wing flicks will probably return to the nest soon. On average, most passerine females are off the nest for 6-10 minutes and on for 20-30 minutes (e.g., Zerba and Morton 1983).

Observers can find females by alertly moving through the study plot, but sitting down in a spot for 20-30 minutes is also useful. A female leaving a nearby nest can thereby be detected. Females can also be detected by call notes, although species differ in the types of sounds. Females of many taxa (e.g., gnatcatchers, warblers, Emberizine finches) chip or call just before leaving, or just after leaving, the nest. This behavior seems to be a communication note to the mate. Females of other species use other vocal signals, e.g., thrushes give a chuck or mew sound; tanagers often give a characteristic sound near the nest or during copulation; and some taxa (e.g., Emberizine finches and icterines) have a nest departure call (McDonald and Greenberg 1991), often answered by the male. If you detect, follow, but then lose a vocalizing female, immediately return to the original location where she was detected, and you may often find her again before she returns to the nest.

Males can also be of some help. When the female is off the nest, some males quietly guard the nest or follow her (for example, the Gray Catbird) (Slack 1976). A quiet male may indicate presence of a foraging female or a nest nearby. In many species, especially cavity-nesters, males will feed incubating females (e.g., Lyon and Montgomerie 1987; Martin and Geupel, unpubl. data; Silver and others 1985). Males of some species (e.g., Chestnut-sided Warbler) use singing perches that are in direct view of the nest. Males sitting on a perch, looking towards the same spot, may indicate a nest.

Males can sing anywhere in the territory while a female is incubating, but he can become silent when the female is about to leave, or has left, the nest (T. Sherry, pers. comm.). When this occurs, he will often make a long flight over to where the female is starting to forage (and sometimes will incite her to leave the nest). Sherry suggests being alert to these flights because they provide valuable clues to where the nest vicinity is, and can also help the observer detect females, which are often difficult to find considering how long they stay motionless during incubation.

A female foraging off the nest is fairly tolerant of people, but observers should be inconspicuous. As she returns to the nest, she is more cautious. This can be used to an observer's advantage. First, a relatively long flight after foraging is probably a return to the nest, and is often along the same route. Quickly running in her direction for about 25 m may often result in a resighting, because the disturbance will keep her from returning to the nest, giving more time to relocate her. If she is near the nest, but cautious about approaching, she will bounce between a few branches, and may also forage rapidly. Eventually, she will start to move down toward the nest several times and then suddenly fly back up, apparently indecisive. If the observer is too close to the nest, the bird will continue to bounce, and will sometimes fly off, only to return within a few minutes. The observer should then back off and watch. If it is cold, do not keep her off the nest for too long. If the female has been followed for more than 30 minutes without results, then she probably is not on a nest, unless both sexes incubate.

If a female disappears into a tree or shrub, the nest is probably in or next to it. Memorize the area where the female disappeared and choose potential nesting sites before approaching. Moving quietly, begin tapping potential nest shrubs with a stick. Listen for the flush of the female off the nest. If unsuccessful, the site can be revisited for careful searches.

In many species, nest site preference seems to be an evolutionarily conservative trait (Martin 1992). Some birds greatly prefer their nest to be in or under certain plant species, or in particular patch types (Martin and Roper 1988, Martin unpubl. data). Describe and visit nest sites from previous years to aid new observers in finding nests.

During the Nestling Stage

Finding nests during the nestling period is the easiest, because both males and females commonly bring food and remove fecal sacs. Males are normally the easiest to follow, as they tend to be less cautious. Nests can usually be found from a distance using binoculars because of the constant activity of the parents.

In some species a singing male can indicate the nest location. He may sing, for example, less and less as he starts to gather food to carry to the nest, become silent when he is about to approach the nest, and then resume loud song immediately after leaving the nest (T. Sherry, pers. comm.). Additionally, Sherry notes that birds will often become reticent to go to a nest with a human nearby, so that if a bird becomes relatively inactive (hopping around, not taking long flights) in a particular area, or dropping prey, then the nest is probably nearby. In this case, the observer should either search intensively in the vicinity, if likely nest spots are nearby, or back away to give the bird a chance to become calm and go to the nest.

Knowledge of the nesting cycle allows an observer to anticipate when to start looking for a new nest. Most species will renest after a nesting failure, although this varies among and within species (Geupel and DeSante 1990a, Martin and Li 1992). Reconstruction usually begins within 10 days, and the earlier in the nesting cycle that failure occurred, the farther apart the nests are likely to be (citations in Martin 1992). Multi-brooded species may renest in as little as 8 days after fledging. Sometimes the female will begin nesting while the male is still tending the fledglings of the previous brood (Burley 1980).

Nest Monitoring

Each nest found needs to be checked every 3 to 4 days to determine its status. Careful attention to checking nests is critical for data quality, because the number of days that nests have eggs or young is used to calculate daily mortality rates, the most effective measure of nest success (Mayfield 1961, 1975). Nests should be checked from a distance the day before expected fledging, and every other day thereafter. A chart showing nests as they are found and the expected date of fledging is extremely helpful. If nestlings appear ready to fledge before the next scheduled visit, then the next visit should be sooner. Calculations of nest success should terminate with the last day that young were observed in the nest. Nests should also be checked more frequently about the time of hatching, if the length of the incubation period is desired.

With canopy nests, mirrors attached to telescoping aluminum poles can check contents of nests. These are available from stores stocking swimming pool supplies, and are commonly up to 4-5 m. A window-washing pole to 12 m is also available (Tucker Manufacturing Company, 613 Second Ave. S.E., Cedar Rapids, Iowa 52406; 319 363-3591). T. Sherry (pers. comm.) suggests a convex mirror to allow views from a variety of angles from the ground. Mounting a small flashlight next to the mirror can illuminate the nest contents in cloudy or rainy weather. Often binoculars must be used to view the nest in the mirror.

Careful and detailed observations should be recorded if a nest predation event is observed. If the nest appears inactive from a distance, it should be approached to verify. If the eggs or young appear to be gone, then check the nest structure and immediate area, perhaps up to 6-10 m (T. Sherry, pers. comm.) for evidence. Any evidence (e.g., shell fragments, hole in nest, nest torn up) should be fastidiously noted. When the young fledge, they commonly perch on the edge, flattening it, and leave fecal droppings in (or on the edge of) the nest. These would indicate possible successful fledging. Observers should try to verify success by seeing fledglings or by hearing adult alarm calls or begging calls of the young. Fledglings normally do not move very far in the first couple of days, although some, such as Rufous-sided Towhee, may move 100 m in a few hours. Some species or individuals may carry food up to 24 hours or longer after predation of their nest, including to unrelated fledglings from neighboring territories.

Nestlings may be banded when the primaries first break sheath. Banding may provide valuable information on juvenile survival and dispersal. Always have an assistant with you to record data, and be careful the nestlings do not jump out as you try to remove them (use two hands). Avoid banding in the morning or during cold or wet periods.

Filling Out the Forms

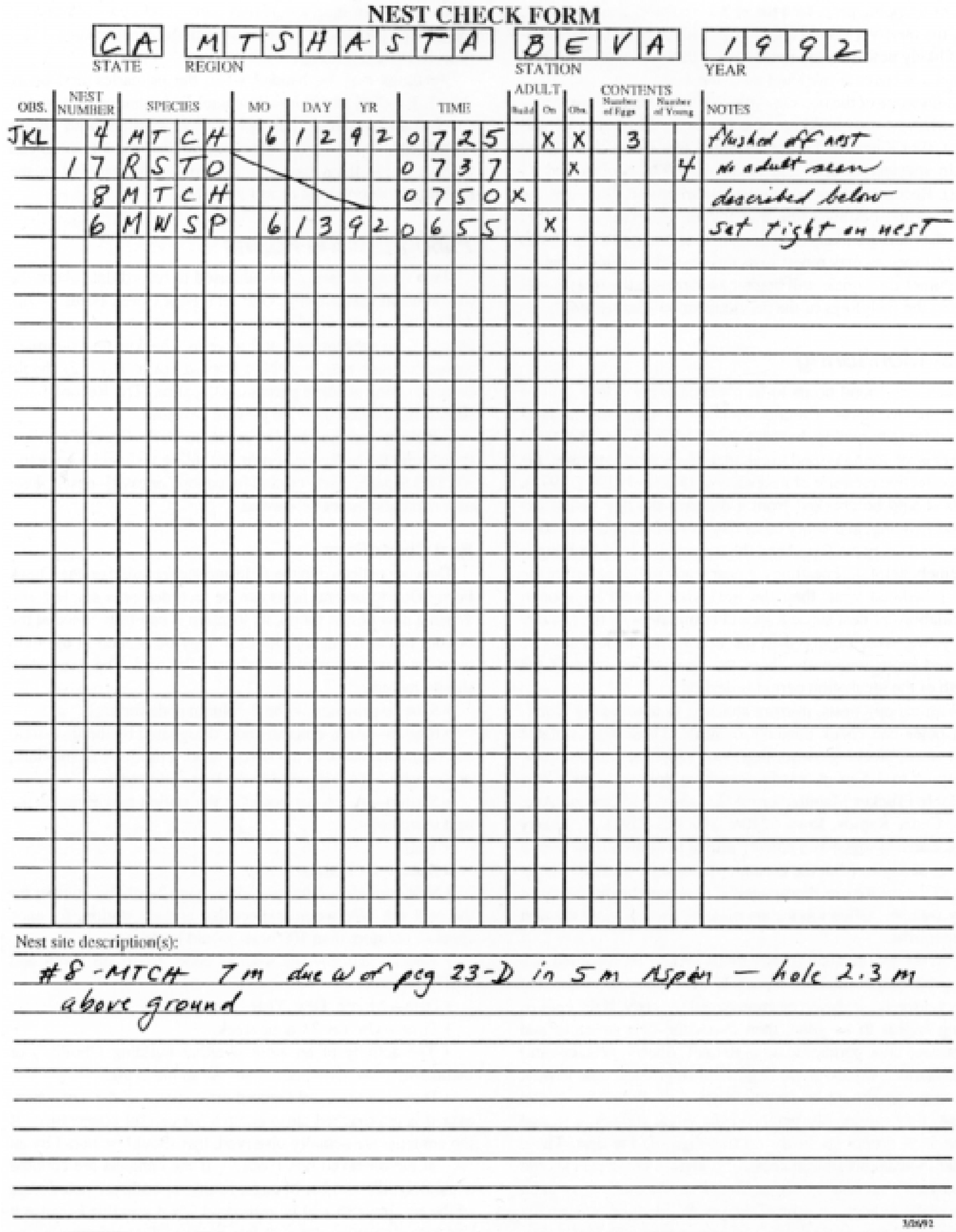
Two types of data sheets are used to record data about the nest site and nest activity. One set ("Nest Check Form"—*fig. 11)* is used in the field to record information when nests are checked. To prevent loss, and serve as a backup and summary record for each nest, the "Nest Record Form" *(fig. 12)* should be maintained at some permanent location. The Record Form should be updated daily, to prevent data loss.

All observations should be recorded on the Check Form and transferred to the Record Form, including visits with no activity. This is particularly critical for canopy or cavity-nests where nest contents cannot be viewed.

Nest Check Form

Data are collected in the field and are recorded on the Check Form. One to several nests can be recorded on a single form. When a new nest is found, its location is carefully noted at the bottom of the form, and the form may be needed in the field over the next few visits to relocate the nest. The data taken should include:

- State or province—The 2-column code for each.
- Region—An 8-column code, designated by the investigator. Often, the name of the USGS quad, a prominent landmark, or a nearby town will provide the best code name.
- Station—A 4-letter code for the station that contains the nest search plot.
- Year.
- Observer's initials.
- Nest number—A unique, identifying 2-column number for the nest site. We would expect that at each station, for each species, no more than 100 nests would be found.



NEST CHECK FORM

STATE	REGION	STATION	YEAR
CA	MTSHASTA	BEVA	1992

OBS.	NEST NUMBER	SPECIES	MO	DAY	YR	TIME	ADULT Build	ADULT On	ADULT Obs	CONTENTS Number of Eggs	CONTENTS Number of Young	NOTES
JKL	4	MTCH	6	12	92	0725		X	X	3		Flushed off nest
	17	RSTO				0737			X		4	no adult seen
	8	MTCH				0750	X					described below
	6	MWSP	6	13	92	0655		X				sat tight on nest

Nest site description(s):

#8-MTCH 7 m due W of peg 23-D in 5 m Aspen — hole 2.3 m above ground

3/26/92

Figure 11—An example of a Nest Check Form for recording in the field the status of nests and information on where the nest is located.

NEST RECORD FORM

1.

STATE	REGION	STATION	SPECIES	YEAR	NEST NO.	ATTEMPT
CA	MTSHASTA	BEVA	MTCH	1992	4	2

2. NEST CHECKS

DATE: Month	Day	Build-ing	Adult on	observed	CONTENTS: Number of eggs	Number of young	COMMENTS
6	6	X					entering hole
6	9	X		X			3/4? built
6	12		X	X	3	0	flushed off nest
6	15			X	3	0	
6	18			X	0	0	empty

DATE: Month	Day	Build-ing	Adult on	observed	CONTENTS: Number of eggs	Number of young	COMMENTS

3. DATES and PERIOD

	Month	Day	Contents / Number
Found	6	6	start of nest
1st egg	6	9	
Clutch completion	6	12	3 eggs
Hatched			nestl.
Fledged or failure			fledg.
Last date active	6	15	

Outcome: predation - jay?

Cause of failure: PE

Period	Number of days observed	Success
Egg laying	4	S
Incubation	3	D
Nestling	0	

4. NEST SITE Measurements in cm unless otherwise designated

Plant common name: Alder

Genus: ALNUS

Plant height	530	Nest height above ground	2.70
Plant dbh	45	Nest dist. from edge	32
Canopy cover (denso.)	60	Nest dist. from center/stem	0
Number support branches	0	Diameter support branches	
Concealment from above		from below	
Concealment from side N		S / E / W	
Compass direction		Total % cover nest substrate	

Band numbers of young

3/10/92

Figure 12—An example of a Nest Record Form that is kept at a permanent location for recording data from the Nest Check Form, as well as the nest site and characteristics data.

• Species name—The 4-letter code, based on CWS and USFWS (1991).

• Date—Month, Day, Year.

• Time—Use the 24-hour clock.

• The activity of an adult if either building ("build.") or incubating ("on"), by putting an "X" in the blank.

• The observer should record the contents of the nest whenever it is approached close enough for careful observation. If the contents are actually observed, this should be noted by an "X" in the observed box ("obs."). If the contents are counted accurately, the number of eggs, young, or both, are noted. Age of the nestlings should be estimated when possible because it can help determine the nest fate by providing information on length of time that nests were active. Age estimates should be recorded in Notes.

The form also includes space for a description of one or more nest sites that the observer finds on this day. The description should be sufficiently detailed to allow anyone to locate the nest. Take compass readings from a fixed point (e.g., a stake or grid point) to establish a reference location.

Nest Record Form

This form is filled out each day upon return from the field, and should contain the following data:

• Header data
  State or Province
  Region
  Species code
  Year
  Nest number

The number of attempts at nesting that this record represents for that pair for that season.

• Nest Checks. These are the data transcribed from the Check Form, and are the same as for that form.

• Dates and Period

The following dates should be tabulated, as they become available: date of finding of nest (and contents when found), date of first egg laid, date of clutch completion (and number of eggs laid in final clutch), date of hatching of last egg (and number of nestlings produced), date of fledging (and the number of fledglings), or nest failure, and date when last active.

Outcome, a written description of the fate of the nest.

Cause of failure (codes: UN = unknown because not revisited; FY = **f**ledged, with at least one **y**oung seen leaving or in vicinity of nest; FP = **f**ledged young, as determined by **p**arents behaving as if dependent fledgling(s) nearby, FU = Suspected **f**ledging of at least one young, but **u**ncertain (e.g., no adult behavior observed); FC = **f**ledged at least one host young with **c**owbird parasitism; PO = **p**redation **o**bserved; PE = probable **p**redation, nest **e**mpty and intact; PD = **p**redation, **d**amage to nest structure; AB = nest **ab**andoned prior to eggs; DE = **de**serted with egg(s) or young; CO = failure due to **co**wbirds; WE = failure due to **we**ather; HA = failure due to **h**uman **a**ctivities; and OT = **ot**her).

Period = the number of days nest was observed for the following: days during the egg laying, incubation, and nestling period.

Success = for each period, based on the following codes: S = **S**uccessful, D = **D**epredated, N = status unknown/ nest **n**ot occupied, U = status **U**nknown/nest occupied fate unknown, M = **M**ortality other than predation, A = **A**bandoned, F = **F**emale died, Z = abandoned, no (**z**ero) eggs laid.

Predation Risk from Monitoring

Locating and monitoring nests have potential to increase predation (Major 1989, Picozzi 1975, Westmoreland and Best 1985). With proper precautions, such biases can be eliminated or minimized (Gottfried and Thompson 1978, Willis 1973). Finding the nest normally creates the most distress to adults and disturbance to the nest site because subsequent visits are brief. Some evidence suggests that predation rates are higher on the first or early visits than subsequent visits (Bart 1977, but see Bart and Robson 1982).

Therefore, we suggest the following when locating nests:

• Minimize distress calls by adults; never allow them to continue for more than five minutes;

• Do not approach a nest when any potential nest predators, particularly visually-oriented predators (e.g., corvids), are present;

• Minimize disturbance to the area around the nest; and

• Do not get close to nests during nest building, as birds will abandon if disturbed before egg-laying, particularly during the early part of a season.

To lower the probability of predation or brood parasitism from checks, we recommend that you

• Check from as great a distance as possible, using binoculars to look into the nest or climb up to look from above;

• Approach nests on different paths on subsequent visits, using paths that are quick, quiet, and that minimize vegetation disturbance;

• Never leave a dead-end trail to the nest, but continue walking in a different direction;

• If avian predators are common, check other bushes without nests, and always assume a predator is watching;

• Be quick and accurate during nest checks and nestling banding;

• Minimize the number of observers;

• Use a pen or stick to check nests to prevent human scent from being left on or near a nest.

Vegetation Measurement

We suggest two methods of vegetation measurement: (1) the nest and the plant containing it; and (2) the nest site and random points in the plot. The entire plot should be measured with a series of points, as outlined in the section "Methods of habitat assessment" below.

Large Mammals	The Pellet-Group Count Technique for Big Game Trend, Census, and Distribution: A Review (Neff 1968)

SPECIAL ARTICLE

THE PELLET-GROUP COUNT TECHNIQUE FOR BIG GAME TREND, CENSUS, AND DISTRIBUTION: A REVIEW[1]

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Abstract: Systematic pellet-group counts for big game trend, census, and distribution originated in the late 1930's and have since been used for a variety of research and management objectives. Their chief advantage is that pellet groups can be sampled by standard field plot techniques. Most pellet-group plots have been circles or long narrow rectangles, usually distributed in some form of stratified-random design. Sample plot layout can often be planned to minimize variance between plots or groups of plots. Sampling technique will depend upon local objectives, but some guidelines have been recognized. Sampling is generally more efficient in areas of higher pellet-group density. If pellet groups are distributed uniformly, a large area may require no more plots for adequate sampling than a small area. Pellet groups generally are deposited in a clumped pattern. Sampling intensity estimates can be made on the basis of the mean and variance derived from preliminary sample counts. Daily defecation rate is needed for computing deer-days use or total numbers of deer. Available data on defecation rate for wild native North American ruminants is tabulated, with some information on livestock and one exotic, the Barbary sheep. High defecation rate in deer has been observed to accompany high feed intake, high forage moisture content, high percentage of young in the herd, change in diet from roughage to concentrates, and the psychological impact of captivity. Observer bias arises mainly from differences in interpretation and from missed groups. Because of missed groups most counts will underestimate actual pellet-group density. Missed groups error is influenced by plot size and shape, type and density of understory vegetation, and observer fatigue and inherent visual acuity. Sources of interpretational differences include decisions concerning peripheral groups, scattered groups, and the minimum number of pellets to be counted as a group. Common practice requires use of permanently marked plots which are periodically cleared. Temporary plots are sometimes used where the deposition period can be dated by reference to leaf-fall, by deformation of pellets due to emergence of succulent feed, or by estimation of the period of herd occupancy of seasonal range. Such dating schemes introduce an additional source of observer bias. Pellet group counts have been unworkable at times because of rapid loss of pellets by insect attack or heavy rains, because of difficulties in identifying pellets of different species, or because of extremely dense vegetation. In a few cases the pellet group count has been tested against known numbers of deer in fenced areas, or against other census techniques. Reasonable accuracy of estimate has been obtained in many cases.

Pellet-group counting is the process of estimating by fecal pellet-group counts the actual or relative numbers of big game animals, or their days of use, in a given area. According to Riney (1957) such counts provide an objective measure of substantial population fluctuations, and also aid in determining preferred habitat types and seasonal use patterns. Systematic use of big game pellet-group counts was first described in print by Bennett et al. (1940). Numerous refinements have made the technique a useful research and management tool. Although various difficulties are involved, the method has the distinct advantage that pellet groups are an inert kind of evidence which can be subjected to field plot sampling and statistical analysis.

The volume of reports involving pellet-group counts is now sufficiently large and complex that a review of the subject seems warranted. This review seeks to make generally available a mass of widely scattered information, much of it in obscure references available only in large libraries seldom inhabited by wildlife managers. The material reviewed consists both of general principles as tested and evaluated by researchers, and of the results obtained and problems encountered in numerous field tests. Few hard and fast rules have been

[1] A contribution of Arizona Federal Aid Project W-78-R.

listed here, primarily because conditions in the field are infinitely varied and each field worker must decide on his own set of rules.

In establishing a pellet-group sampling system the basic questions of procedure include what kind of plot and how big, how the plots are to be distributed, and how many plots are needed. No clear-cut best answers can be given, but some guidelines are offered, based on both theoretical and empirical considerations. The single most vexing problem is, without doubt, observer bias. This is partly a characteristic of the individual worker, but also is affected by various elements of the sampling system. Daily defecation rate under various conditions varies widely and, in the case of deer, has received considerable research attention. Other problems are discussed which can be critical in some circumstances, for instance, the loss of pellet groups by washing rains and insect attack. Finally, a number of more or less controlled tests of census by pellet-group counts are reviewed.

Acknowledgment is made of the invaluable assistance of Donald R. Thompson, Allen E. Anderson, O. C. Wallmo, Clay Y. McCulloch, and Ronald H. Smith, all of whom took the time to make detailed criticisms of the manuscript. Steve Gallizioli and other members of the Research Division, Arizona Game and Fish Department, provided both field and editorial assistance.

SIZE AND SHAPE OF SAMPLE PLOT

The relative efficiency of various types and sizes of field sample plots is a universal problem. A considerable body of theoretical and practical knowledge has been developed on the subject, much of which can be applied to pellet-group counting.

Users of the pellet-group count technique have reported an amazing array of different plot sizes but only two basic shapes: circles and long narrow rectangles or belts. The belt transects have ranged from 66–2,000 ft in length and 3–20 ft in width. Popular sizes of circular plots include 0.001 acre, 100 square ft, 0.01 acre, and 0.02 acre.

According to Pechanec and Stewart (1940) many small sampling units are usually more efficient than fewer large units. (That is, less total area is required in the sample for the same sampling accuracy.) The larger number of sample units provides a smaller estimated variance. It is generally agreed that long narrow plots are superior to shorter wider plots or squares of the same total area, and also that segments of a long narrow plot (or belt transect) can be systematically omitted without proportionately reducing the efficiency of the sampling unit (Robinette et al. 1958). This amounts to a series of plots spaced at intervals along a line (line-plots). Pechanec and Stewart (1940) reported that their large line-plots were only half as efficient as small line-plots for forage production sampling, but were twice as efficient as square plots of the same total area, and appreciably more efficient than rectangular plots of the same total area.

Robinette et al. (1958) tested these principles in relation to pellet-group counts in Utah sagebrush–juniper winter range. They found that 0.001-acre circular line-plots were substantially more efficient than the larger 100-square-ft (0.0023-acre) plots. Similar results were obtained by Harris (1959), Neff (1960), Smith (1964), and Smith (1968). However, at the Three Bar area, near Roosevelt Lake in Arizona, McCulloch (1955) compared 0.01-acre circular plots and 0.1-acre (6.6 ft by 1 chain) belt transects on a small chaparral watershed and found no difference in statistical efficiency.

It should be noted that there is generally less chance of overlooking pellet groups on the smaller plots, and thus degree of observer error is confounded with statistical efficiency of plot sizes and shapes (Smith 1968).

One criterion for choice of appropriate plot size is the density of pellet groups in the sample area. Smith (1964:443) calculated the appropriate plot sizes at various levels of deer use. He found that 400-square-ft circular plots might average one pellet group each where use was as low as 10 deer-days per acre. With the 100-square-ft circular plot, density will not average one pellet group per plot until deer use reaches 40 deer-days per acre.

In terms of man-hours, the plot size requiring the smallest area of ground sampled is not always the best plot size. For instance, much less effort might be required to establish and maintain 10 transects of 0.01-acre circular plots than 20 transects of the smaller 100-square-ft plots, even though the total plot area is twice as large. Travel between plots and transects usually takes more time than the actual searching of the plots. However, if the sample system can be designed for an increased number of smaller plots without greatly increasing travel time, a marked increase in efficiency may result (Smith 1968).

One of the most important considerations in choice of plots for pellet-group sampling is the effect of plot size and shape on observer error. One source of error is the interpretation of groups partly in and partly out of the plot. The boundaries of circular plots are much easier to delineate accurately than are those of belt transects. Reports of pellet-group counts have often stressed the errors arising from missed groups. Generally, the smaller the sample area and the more accurate its delineation, the smaller the error. Because of the importance of the problem of observer bias a full section of this review is devoted to it.

DISTRIBUTION OF SAMPLE UNITS

The sample unit may be a single circular plot or belt transect. More likely the unit will be a series of circular plots spaced along a line transect, or a cluster of plots or belts in a systematic pattern around a reference point.

The area to be sampled is chosen on the basis of local research or management goals and on prior knowledge of animal use patterns in relation to topography and vegetation. The chosen sampling area must satisfy biological data requirements and must also be practicable in terms of available manpower. Getting maximum results for time expended involves the statistical efficiency of various combinations of plot size and shape and the sample unit layout in the field.

Sampling units may be distributed by subjective, random, or systematic selection. Various combinations of these elements are possible. Plots within transects or clusters usually are arranged systematically. Sampling units placed strictly at random usually are difficult to establish and relocate in the field. The most advantageous system in most cases is restricted random sampling, which insures adequate distribution of sampling units over the whole sample area, yet satisfies statistical requirements for randomness.

Few pellet-group sampling systems have employed a completely random distribution. Dasmann and Taber (1955) placed 50 circular plots at random on a 400-acre study area in the northern California chaparral. Brown (1961) used 14 belt transects randomly distributed in a 36,000-acre tree farm in western Washington.

One report of distributing sampling units by subjective selection is that of Leopold et al. (1951:95) whose best estimate of deer numbers on the Jawbone winter deer range in the Sierras was obtained from 95 miles of belt transects. These transects apparently followed trails or ridgetops.

If sample units are distributed on a restricted random basis, some form of subdivision, or stratification, of the sample area is required. On large-scale pellet-group surveys, strata based on section and township have been used for deer (Hanson 1954, Bever 1955, Bennett 1964, Ryel and Bennett 1964), and for Barbary sheep and deer (Ogren 1964). Stratification of this type insures that sample units will be more or less evenly distributed. However, stratification based on biological properties can have the additional effect of increasing the homogeneity of the population to be sampled. Thus, strata based on soils, topography, and elevation were used by Wallmo (1958) in the Black Gap area of western Texas. Van Etten (1959) divided the 647-acre Cusino deer enclosure in Michigan into four strata on the basis of well-known patterns of deer use, which presumably arose from patterns of topography and vegetation.

The multiple-random-start system (Krefting and Shiue 1960) represents an unusual combination of random and systematic elements. In this system the sample area was divided into small square blocks within which five plot locations were chosen by random coordinates. The same pattern of five plots was repeated on each of the blocks. Pellet-group counts were totaled for corresponding plots from all blocks, and five mean pellet-group densities were calculated. From these mean values an overall mean and confidence limits for the whole area were obtained.

A variation of the multiple-random-start system was adopted for experimental watersheds at Beaver Creek, Arizona (Wallmo 1964). On each watershed a baseline was established from the weir to the head of the drainage. Transects of circular plots were then oriented at right angles to this baseline, spaced at random intervals in groups of four transects each. The same series of randomly chosen intervals was repeated in each group of transects.

In rough country it is often necessary to locate transects in relation to the roads, trails, or washes which provide access to them. Exact location of sampling points may be accomplished by random or systematic choice of distances along the road from an arbitrary starting point. Transects may be laid out perpendicular to the road or on a chosen azimuth. The use of roads and trails as a basis for distribution of sampling introduces a certain amount of bias, since areas farther from the nearest road or trail than the length of the sample transect will have no chance of being sampled (Schultz and Muncy 1957). On the 310,000-acre Interstate deer herd winter range in northern California, McCain (1948) employed belt transects oriented at right angles to the roads at 1-mile intervals. Similar road-oriented systems were used by Gallizioli (1958), Hanson (1954), and Wallmo (1958).

In many cases sample plots have been arranged in clusters. For white-tailed deer movement studies in the Chiricahua Mountains, Welch (1959) used five very large clusters, each 70 by 20 chains with 48 circular plots arranged systematically in eight transects. Eberhardt and Van Etten (1956) used clusters of two or three circular plots at the Cusino deer enclosure in Michigan. Van Etten (1959) later used courses of belt transects, three per course, in the Cusino enclosure. Jantzen (1957) employed similar courses of belt transects at the Grapevine study area in northern Arizona. Smith (1964) recommended the use of clusters of four circular plots (0.0025 acre) which provide a sample area equal to one 0.01-acre plot, but are subject to less observer error and may provide less variability per unit than the single large plot. Shaw (1962) used a radial pattern based on sample points chosen at random within vegetative strata in the Hatter Creek enclosure in northern Idaho. Eight transects radiated from a center stake, with the azimuth of the first line chosen at random and the other lines at 45 degree angles. On each transect four circular plots were established at regular intervals. This radial system permits easy relocation of permanent plots, but does not provide even distribution of sample plots over the area (Greig-Smith 1957:22).

Where general coverage of an area is desired, a series of transects of circular plots traversing the entire width of the study area may be the best solution. Distance between transects may be either systematic or restricted random, and intervals between plots along each transect may or may not be uniform for the whole system. Robinette et al. (1958) surveyed Utah winter deer ranges with parallel line-plot transects running diagonally across the stream drainages from the lower to the upper edge. The diagonal orientation was designed to include maximum variability within each transect, with minimum variability between transects. Calculations of various sampling intensities required for various plot intervals indicated that the most efficient system statistically was one in which the interval between plots along the transect was about equal to the interval between adjacent transects. However, it was noted that the most efficient system from the standpoint of time and effort involved a smaller interval between plots than between transects.

Webb (1959) estimated deer populations on the Three Bar study area in central Arizona with a series of 15 line-plot transects running due north and south. Transects averaged ¼ mile apart on a restricted random basis and 45 circular plots were spaced at 4-chain intervals along each transect.

Harris (1959) divided the Cedar Ridge mule deer winter range study area in Middle Park, Colorado, into 18 transverse blocks and randomly located one transect of 25 circular plots within each block. Because of irregular boundaries the transects varied from ¼ mile to over 2 miles in length, with the 25 plots evenly distributed over the transect length. This resulted in a much greater sampling intensity on the shorter sections, but was said to be justified on the basis of simplified data analysis.

In a few cases where deer were confined to fenced enclosures or where the sample site was small, a complete count of the entire area was attempted (Wing 1962, Neff 1964, Smith 1964, McKean 1965). This type of count is possible only on areas no larger than a few acres, with sparse ground cover.

SAMPLING INTENSITY

The term *sampling intensity* refers to the percentage of the study area which must be included in the sample plots to obtain the desired statistical confidence level. There is no definite answer to the question of sampling adequacy: "It is dependent upon many variables such as pellet group density, size of the area to be sampled, size, shape and distributional pattern of the sampling unit, pellet group distribution and sampling accuracy desired" (Robinette et al. 1958: 412). Robinette and his associates examined these variables as they applied to pellet-group counts. The ensuing discussion depends heavily upon their work.

Pellet-Group Density

Other factors being equal, the requisite sampling intensity varies inversely with pellet-group density. At the Little Hills, Colorado, experimental deer pastures the sample plot area needed for comparable precision was more than five times as great for a pasture with 109 pellet groups per acre as for a pasture with 538 groups per acre (Robinette et al. 1958:413). In another study at Little Hills it was found that doubling the stocking rate (from 10 to 20 deer-days per acre) reduced the required sample area by as much as 70 percent (Rogers et al. 1958:197). Smith (1964: Fig. 2) plotted his calculations of sampling intensity for various levels of deer use from 10 to 80 deer-days per acre. At the lowest levels of pellet-group density, anywhere from 900 to 2,300 100-square-ft plots were required to achieve the desired accuracy. At the highest pellet-group densities only 200 to 300 plots were necessary. The same rule held true for pellet-group counts on roadside transects of circular plots in central Arizona chaparral (Neff 1960). With a decline from 525 to 127 pellet groups per acre, the number of units required rose from 20 transects to 141 transects.

In short, pellet-group sampling is more efficient in areas of high pellet-group density. Winter ranges or other deer concentration areas should be chosen for herd census or trend studies whenever possible. Preliminary surveys on temporary plots are a necessary step in the preparation of a pellet-group sampling program. Survey counts provide the necessary estimates of mean pellet-group density and variance as well as some idea of pellet-group distribution.

Pellet-Group Distribution

Population distribution patterns may be random, regular, or contagious (clumped), with all possible intergradations. Indications are that pellet groups tend toward the contagious distribution. Thus, a plot that has one group on it has higher probability of having more than one group than would be the case if the distribution were random. It is assumed that pellet groups are deposited most heavily in those places in which the deer spend the greater part of their time. Thus pellet-group density will usually vary considerably between south and north slopes (Bever 1955) and between different vegetation types (Van Etten 1959). If the line-plot transect or belt transect is to be the unit of sampling analysis, then as much as possible of this variation must be included within each transect, and as little as possible between transects. One way that this has been accomplished is by running transects diagonally across the drainage pattern so that all slope exposures will be sampled by each transect (Robinette et al. 1958).

Area of Range Unit to be Sampled

Robinette et al. (1958:413) found an inverse relationship between percent of an area to be sampled to attain the desired confidence limits and the total area of the range unit. This relationship is illustrated by data from four Colorado and Utah deer ranges ranging in size from 100 acres in a pasture at Little Hills to over 8,000 acres at Ephraim, Utah. Required sampling intensity dropped from about 0.8 percent of the total area at Little Hills to less than 0.1 percent at Ephraim.

This principle is based on the fact that the precision of the estimate of mean pellet-group density remains about the same on a large area as on a small area, *if* the pellet-group density and pattern remain roughly the same for the whole area. However, the careless inclusion of large areas of highly variable deer use into one block for sampling will increase the variance of the data and a larger sample size will be required.

Sampling Accuracy Desired

Other factors being equal, the sampling intensity required varies directly with the degree of sampling accuracy desired. For each sampling area and for each sampling objective a decision must be made as to how accurate an estimate of mean pellet-group density is desired. No standard value has yet been established in wildlife management which can be generally applied.

For determining sample size needed to produce a desired degree of sampling accuracy, Grieb (1958:63) offers the following formula:

$$N = \frac{(t_{0.10})^2 s^2}{(0.20 \times \bar{x})^2}.$$

where N = number of plots required
s^2 = variance of the preliminary sample data
$\bar{x}$ = mean of the preliminary sample data
0.20 = selected risk of error (*e.g.*, if the estimate is expected to fall within 20 percent of the mean 95 times out of 100, use 0.20 times the mean)
$t_{0.10}$ = tabular value for the selected level of probability.

DEFECATION RATE

Pellet-group density estimates may be used directly as indicators of population trend between years or between areas without consideration of defecation rate (assuming that defecation rates are similar in all years and areas). However, the number of groups deposited per animal per day is a necessary factor in computing either total deer-days use, or total number of animals present. Published information on defecation rate for deer and other animals is summarized in Table 1.

Factors which are believed to cause higher defecation rates include:

1. Good range condition and relatively high feed intake (Rogers et al. 1958).
2. High moisture content in forage (Longhurst 1954).
3. An abrupt change in diet from native range forage to concentrates (Smith 1964).
4. High percentage of fawns. Fawns after weaning show higher rates than adults. Therefore a high percentage of fawns in a winter herd would tend to raise the mean rate (Smith 1964).
5. Psychological effects of captivity. Nervous hyperactivity in a penned wild buck in one study resulted in numerous small groups and a high mean rate (Neff 1964).

In regard to the defecation rates of young deer, Smith (1964:438) reported that two young fawns averaged about 5 groups per day in July, increased to 7.5 and 9.0 groups per day in August, 12.6 for each in September, and reached a peak of 22.2 and 28.0 in October before dropping back to 20.6 and 23.9 in November.

Smith (1964:442) suggested that 12.7 groups per day, the standard figure first derived by McCain (1948) from the data of Rasmussen and Doman (1943), is too low. Smith's data indicated that a mean rate of 13 to 14 groups per day would be more realistic.

Rogers et al. (1958) reached similar conclusions. They recommended that 15 groups per day be used as the standard rate for winter deer herds on good range, but that 13 per day would probably be more accurate on depleted ranges where variety and volume of forage were restricted.

Because of missed groups error, field counts almost invariably will produce an underestimate of the mean pellet-group density. The effect of raising the defecation rate factor will be to lower the estimated total numbers of deer or deer-days use, reinforcing the tendency to underestimate deer numbers.

OBSERVER BIAS

Human error in pellet-group counts involves personal factors such as fatigue,

Table 1. A summary of determinations of defecation rate for deer and other ruminants.

Reference	Species and Location	Size of Test Area	Sample Period	Number of Animals	Animal-Days Use	Type of Feed	Mean Defecation Rate per Animal per Day
Rasmussen and Doman 1943	Mule deer (*Odocoileus h. hemionus*) UTAH	741 acres	Aug., Sept., Oct.	172	15,824	Depleted winter range	Not published
McCain 1948	Mule deer	Calculations based on Rasmussen and Doman data.					Mean = 12.7
Julander et al. 1963	Mule deer	Calculations based on Rasmussen and Doman data.					Aug. = 11.1 Sept. = 13.1 Oct. = 13.5 Mean = 12.6
Rogers et al. 1958	Mule deer COLORADO	90–160 acres per pasture	Over-winter	3–40 deer per pasture	402–5,457 per pasture	Winter browse	All plots (15 est.) 12.8–20.5 Mean = 15.2 Cleared plots (8 est.) 11.3–20.1 Mean = 14.9
Smith 1964	Mule deer	Calculations based on Rogers et al. data. Reweighted pasture data: Data adjusted to agree with Smith's methods:					Mean = 15.0 Mean = 14.3
Smith 1964	Mule deer UTAH	Pens	Various	30	165 278 446 889	Native forage	Fawns 16.9 Yearlings 12.6 Adults 12.2 Mean 13.2
					621 545 1,012 2,178	Native + conc.	Fawns 18.2 Yearlings 13.2 Adults 13.4 Mean 14.7
		3 acres	Summer Winter		205 201	Aspen–forb range	10.0 11.2
		8–11 acres	Summer Winter		2,730 645		8.0 13.2
		11 acres	Winter Winter Winter		1959—266 1960—314 1961— 65	Oak–sagebrush	13.0 14.1 9.7
Neff 1964	Mule deer ARIZONA	5 acres	Feb.	1 adult	7.0–7.5	Dormant browse	13.0–13.9
			April	1 yearling	7.0–7.5	Spring greens	14.8–15.9
			July	1 adult	9.3	Summer drouth	22.2
McKean 1965	Mule deer COLORADO	2 acres 2 acres 2 acres 2 acres 4 acres	3 winters 3 winters 3 winters 3 winters 3 winters	6 4 3 2 2	120 80 60 40 20	Pine–juniper range	12.5 13.3 12.0 15.0 13.1
				Total	320		Mean 13.2
Eberhardt and Van Etten 1956	White-tailed deer (*Odocoileus virginianus*) MICHIGAN	Pens	Feb.–March	36	36 (18 fawns, 18 adults)		*Fawns* / *Adults*
						Cafeteria	13.5 / 14.6
						Swamp conifers	12.3 / 13.2
						Swamp hardwoods	12.6 / 13.0
						Hemlock–hardwoods	10.8 / 12.8
						Fire succession	11.8 / 12.7
						Mixed conifer–hardwood	11.5 / 13.2
						Mean, all diets	12.1 / 13.3
						Mean, all deer	12.0 ± 0.3

Table 1. Continued

Reference	Species and Location	Size of Test Area	Sample Period	Number of Animals	Animal-Days Use	Type of Feed	Mean Defecation Rate per Animal per Day
Van Etten 1959	White-tailed deer MICHIGAN	Pens	Jan. 13–Apr. 23	2 does	26.7	Good 5.09 lb/day	11.8
				2 does	29.1	Poor 3.52 lb/day	11.5
				4 fawns	44.8	Good 3.28 lb/day	13.4
				4 fawns	40.9	Poor 2.69 lb/day	12.7
				2 bucks	21.3	Good 6.51 lb/day	17.9
			Totals	14	162.8		Mean = 13.2
Hines 1963	Black-tailed deer (*Odocoileus h. columbianus*) OREGON	340 acres	Yearlong	43		Native forbs, grasses, browse	23.1
			Dec.–May	15			18.5
Morris (in Julander et al. 1962)	Rocky Mountain elk (*Cervus canadensis*) MONTANA		3 days	5 cows and 5 calves	30		Mean = 11.0
Neff et al. 1965	Rocky Mountain elk ARIZONA	217 acres	Feb. 14–June 5	4–10	598	Native forbs, grasses, browse	Mean = 12.52 ± 1.38
Edwards (reported by Julander et al. 1963)	Moose (*Alces a. andersoni*) BRITISH COLUMBIA						13.[illegible]
Ogren 1959	Barbary sheep (*Ammotragus lervia*) NEW MEXICO	Pen	4 days	10 adults	40	Zoo maintenance ration	12.7
Longhurst 1954	Domestic sheep CALIFORNIA	3 acres	20 days	32 wethers	640	Grain stubble, hay	13.3
		Pens	1 day	2 ewes	2	Green grass	15.0–16.0
Julander 1955	Beef cattle UTAH	100 acres			1,401 1,062	Crested wheatgrass	11.2 11.6

boredom, visual acuity, and experience, which are difficult to evaluate. More easily tested are such factors as type and density of ground cover, and size and shape of plots. Observer error has been found to arise principally from missed groups, but differences in interpreting what constitutes a group and in methods of dealing with peripheral groups are also important.

Influence of Size and Shape of Sample Plot

To test observer efficiency, several tests have been conducted with concentric circular plots of various sizes. Robinette et al. (1958) found when they counted concentric 100-square-ft and 0.01-acre plots that the smaller plot usually gave a higher estimate of pellet-group density. Concluding that this was due to increased error in missed groups on the larger plots, they were able to correct the error by counting 0.01-acre plots in two 6-ft bands rather than counting the whole 11.78-ft radius in one sweep. Two counts, clockwise and counterclockwise, were made on each plot. Similar results have been reported by Eberhardt and Van Etten (1956), Harris (1959), Neff (1960), Smith (1964), and Smith (1968).

Belt transects appear to be relatively more subject to missed-groups error than are circular plots. Studies in the Black Hills reported by Bever (1955) and by Hart (1958) showed that the efficiency of the field crews on 10-ft × 2,000-ft belt transects fell off 25 percent in the second 1,000-ft section as compared to the first section. Recounts of four transects gave a correction factor of 1.97, indicating that on the first count almost as many groups were missed as were found. The following year the belts were reduced to 8 ft × 1,000 ft and counts were made more thoroughly, resulting in a correction factor of only 1.18.

Observer comparisons were conducted on three different occasions at the Three Bar game management unit in central Arizona (Neff 1962, 1963). In December, 1961, a group of 18 observers from the Arizona Game and Fish Department counted pellet groups on a series of 80 circular 100-square-ft plots in desert shrub vegetation. No consensus was reached in the field but at least 67 pellet groups were present. Observers' counts varied from 41 to 85 pellet groups. Counts of research personnel regularly involved in pellet-group counting ranged from 47 to 70 pellet groups. Indications were that the primary source of error was missed groups, but that differences in interpretation were significant.

In February, 1962, a second test on the same 80 plots was conducted with eight observers. On this occasion a field review of all plots established a consensus total of 81 pellet groups. Observer totals varied from 64 to 81. Again missed groups error was of major concern but interpretational differences still remained. During the field review, agreement was reached on several major points of difference.

A third test on the same 80 plots was held in December, 1962. In this case the first 40 plots were cleared of old scattered pellets and were totaled separately from the last 40 plots. Observer totals ranged from 38 to 47 on the clean plots with a consensus total of 48 pellet groups. On the last 40 plots observer totals ranged from 19 to 28 with a consensus of 32 groups.

Several conclusions seem justified from these tests:

1. Because of missed groups, pellet-group density estimates will almost always be less than true density.

2. Greater observer error will occur on temporary plots with an accumulation of old scattered and bleached groups than on permanent plots which are cleared regularly.

3. While observers in the Three Bar tests tended to maintain relative rankings, they were not sufficiently constant that a personal correction factor could be applied with any confidence.

4. Standards for interpretation of pellet-group identity should be carefully adhered to by all observers.

5. Experience is no guarantee of accuracy. A well-briefed beginner may be more alert than an old-timer.

Because of the artificialities involved in the transect used in the first three tests, one trial was made on an actual pellet-group sampling system. This test was conducted by eight observers on Watershed C at the Three Bar game management unit in March, 1964. Vegetation on this watershed consisted of chaparral regrowth from a 1959 wildfire, suppressed by herbicides. Ground cover in some areas was dense, including dried stems of trailing vines and new growth of red brome (*Bromus rubens*). No field consensus could be obtained, but an approach to a consensus was made by comparing the notes of each observer on each plot. The differences between observer counts and "correct" totals for the transects counted ranged from –55 percent to –24 percent. Watershed C approximates the worst pellet-group counting conditions to be expected in Arizona: extremely rough terrain, dense ground cover, and high observer fatigue.

If relative pellet-group density between areas or between years is the primary purpose of the pellet-group counts, the observer error can be avoided by using the same observers in both areas or both years. However, if observers change with time and area, or if pellet-group density per acre is important, then the time and effort involved in developing approximate observer correction factors may be well spent. The "confidence limits" on such correction factors will necessarily be wide, and periodic rechecks will be needed.

Sources of Interpretational Error

The problem of how to count groups which are only partly in the plot can be a major source of error. Strewn-out or scattered groups present a difficult problem in this regard. Robinette et al. (1958) recommended tallying fractions of strewn-out groups, or tallying those groups in which the midpoint of the group falls within the plot. In the Three Bar tests (Neff 1962) an edge group was counted if half or more of the pellets were within the plot. No fractions were tallied. However, failure to locate all the pellets of the group in dense vegetation would prevent the accurate determination of either the midpoint or the fraction lying within the plot.

The minimum number of pellets to be counted as a group caused much debate at the Three Bar. The final decision was made arbitrarily that 30 pellets or more must be present to count as a group. In some studies, even one pellet has been counted as a group if it was isolated (Bennett et al. 1940, Steinhoff 1947:29). This does not seem realistic in relation to defecation rate determinations or to the numbers of pellets counted in well-defined groups (Smith 1964, Ferguson 1955).

Another source of observer error at the Three Bar tests was the finding of several groups close together, consisting of pellets similar in size, shape, and color. In one test nine separate fresh groups were planted on one plot as a joke. The "lumpers" counted only three to five groups, while the "splitters" got seven to nine. After much debate the decision was made that adjacent groups of very similar appearance should be counted separately unless they were definitely connected by scattered pellets. The tendency of pellet groups to be deposited in bunches rather than at random can contribute to low pellet-group density estimates by observers who tend to be "lumpers."

In Michigan, plots are not cleared of pellets during the spring surveys. Instead, observers count only those groups deposited after the leaf fall of the previous autumn. Errors in dating groups are thus an additional source of interpretational error. According to Van Etten and Bennett (1965), missed groups and dating errors were both major problems. The two observers employed in their experiment differed significantly in their counts and the percent error of one observer appeared to be influenced by pellet-group density.

OTHER SOURCES OF ERROR

Various problems exist which may apply in general or which apply only to specific pellet-group sampling situations.

Period of Deposition

On permanently established pellet-group sampling systems the period of deposition is the elapsed time since the previous pellet-group count. All pellet groups counted are usually cleared completely from the plot, but may be marked with paint (Bever 1955, Hart 1958, McKean 1965). Clearing takes time but provides complete protection against counting the same pellet group twice. Clearing the plot also prevents the accumulation of old scattered pellets which make interpretation errors more likely. According to the tests made by Kufeld (1968), painting pellet groups could lead to considerable error because of the rapid deterioration of paint marks.

On some deer ranges temporary plots may be used with confidence for annual trend and census data because of circumstances which permit the accurate dating of the period of deposition.

In the Rocky Mountain and Intermountain regions of the West the period of occupation of the winter range by mule deer can be estimated within reasonable limits (McCain 1948, Robinette et al. 1958, Harris 1959, Smith 1964). During early spring counts there is little confusion between the depositions of the current winter and those of the year previous, except when pellets are wet. To calculate mean number of days spent by the herd on the winter range, periodic estimates were made of the percentage of the herd occupying the area (Robinette et al. 1958). High precision is not necessary since an error of a week in the estimated period of occupation in a 140-day winter range period would result in only a 5-percent error in population estimates. If the spring pellet-group count can be made before the herd leaves the winter range, only the beginning date of winter range use must be estimated.

Harris (1959:245) tested this method of determining the winter range use period in Colorado, and agreed that the error was not critical. Each day of herd occupancy accounted for a change of only 2.54 deer in the estimate of total deer numbers on Cedar Ridge in 1959. Thus, an error of 2 weeks (about 10 percent of the 150-day winter season) would result in an error of 35 deer out of an estimated total number of 381, or less than 10-percent error.

In eastern deciduous forests the period of winter use begins with leaf fall, and temporary plots may be used if precautions are taken to count only those groups deposited on top of the leaf litter. This technique does not apply to cedar swamps and other coniferous types, of course. Additional difficulties arise from the continuous light fall of oak leaves all winter, shifting of dead leaves by wind in fall and spring, and the lack of sufficient leaf cover in openings (Eberhardt and Van Etten 1956, Van Etten 1959).

Various investigators have suggested using pellet shape and color as correlated with the seasonal changes in diet, such as from winter browse to spring greenery, as a means of determining age of groups on temporary plots (Eberhardt and Van Etten 1956, Robinette, personal communication 1959). On the Black Gap desert shrub and chaparral ranges of western Texas the dramatically sudden appearance of deformed deer pellet groups was observed to accompany the abrupt development of green herbaceous forage. However, it was not a dependable phenomenon which could be regularly used in dating perods of deposition (O. C. Wallmo, personal communication 1965). In Arizona few deformed deer pellet groups are found at any season of the year.

Map Acreage vs. Acreage on the Ground

Estimates of pellet-group density have been found to be conservative when study area acreages were obtained from aerial photos or maps, while plots were measured on the slope (Leopold et al. 1951, Harris 1959). This results in considerable difference where the terrain is steep (a 33 percent error in plot acreage on a 30 degree slope). The error can easily be avoided if the observer keeps his radius rod or line horizontal when measuring the plot boundaries. Where very steep slopes are encountered, a plumb bob may be needed to determine the boundaries accurately. A pebble dropped from the end of the horizontal rod will serve in lieu of a plumb bob.

Loss of Pellet Groups by Washing and Insect Attack

Ferguson (1955) found that loss of groups by erosion was unimportant except when ground cover was very sparse, and that litter and vegetation held the pellets even on slopes of 60 to 80 percent. However, two pellet group deterioration tests in central Utah suffered considerable loss to dung beetles, with up to 14 percent of the groups being completely buried in a few weeks in the spring (Robinette et al. 1958). J. B. Low (1959, unpublished report, Utah Coop. Wildl. Research Unit) made further observations of Ferguson's marked groups, with the following conclusions:

1. Groups under maple overstory seldom persist more than a year because of concealment by leaf fall, lack of herbaceous ground cover to hold pellets, and attack by fungi in the damp soil.

2. Groups under sagebrush usually persist for about 2 years, after which they are either covered by grass litter or washed away.

3. Groups under juniper generally remain for 3 years or more because the groups are held by the litter, while further accumulation of litter is slow.

4. Groups on steep slopes without ground cover usually wash within 1 or 2 years.

5. A total of 58 groups were observed for 5 years:

   96.5 percent were recognizable after 1 year
   93.1 percent were recognizable after 2 years
   93.1 percent were recognizable after 3 years
   65.5 percent were recognizable after 4 years
   24.1 percent were recognizable after 5 years.

Van Etten and Bennett (1965) reported on the persistence of pre- and post-leaf-fall pellet groups under various cover and soil moisture conditions in Michigan. They found a few groups still present after 5 years, and a few 2-year-old groups which appeared to be fresh. In the chaparral and pine types in central Arizona, washing by summer rains and concealment by litter, respectively, were the chief agents of pellet-group loss. Neither type of loss was sufficiently large to cause problems with annual or semiannual pellet-group counts (Neff 1962).

Pellet-group losses in some cases have been great enough to prevent use of the technique, at least in some seasons. In western Texas 38 percent of 53 marked pellet groups were lost in less than 2 months, and 91 percent in 4 months, because of heavy washing rains (Wallmo et al. 1962:52). Because of this high degree of loss, pellet-group counts were subsequently conducted only during rain-free periods, usually in November through March. In southwest Georgia, dung beetle activity resulted in estimates of deer numbers only 20 to 25 percent of the known deer population (Downing et al. 1965). Experiments with various insecticides failed to solve the problem.

Species Identification of Pellet Groups

On ranges where more than one pellet-forming ruminant is present, pellet-group

Table 2. Comparison of pellet-group count estimates with known deer populations in the Cusino and George Reserve enclosures, Michigan (Eberhardt and Van Etten 1956:71).

Year	Estimates from Pellet Counts	Approx. 95% Confidence Limits on Estimates	Average Known Population
Cusino—647 acres			
1953	40.8	29.4–52.2	28.8
1954	25.5	18.0–33.0	25.0
1955	22.2	13.4–30.9	28.1
George Reserve—1,200 acres			
1953	30.7	23.2–38.2	32.7
1954	28.4	20.6–36.2	36.1
1955	17.3	12.5–22.1	37.2

Table 3. Comparison of pellet-group count estimates with known deer populations in the George Reserve enclosure, Michigan. (Data modified from Ryel 1959.)

Year	No. of Plots	Total Pellet Groups	Estimated Deer per Square Mile*	Known Deer Numbers
1953	243	533	30.9 (23.6–38.2)	33.1
1954	235	483	28.5 (20.9–36.1)	38.5
1955	241	285	17.3† (13.5–21.1)	39.6
1956	221	769	54.1 (43.6–64.6)	32.3
1957	249	649	38.9 (24.7–53.0)	41.4
1958	268	598	33.6 (21.9–45.3)	33.0

* Confidence limits of two standard errors.
† Recheck of 1955 plots gave estimate of 37.6 deer per square mile.

counts may not be feasible (Murie 1954: 255–256).

Smith (1954:96) expressed doubt that pellet-group counts would be workable for Idaho bighorn because of confusion between bighorn, mountain goats, and deer. Welles and Welles (1961:175–176) found it difficult to distinguish between deer and desert bighorn tracks and pellets. They showed that pellet size, shape, and color are not reliable indicators of desert bighorn sex or age. However, Ogren (1964) was able to distinguish between the pellets of mule deer and Barbary sheep by their shape and length–diameter relationships. Murie (1954: 272) warned that in ". . . joint elk–moose country some puzzling samples will be found. . . ." But Van Wormer (personal communication 1967) found that he could identify winter moose and elk pellets in northeastern Utah, and that in moose the sexes could be separated on the basis of winter pellet shape. In Arizona few problems have been encountered in differentiating between elk and deer. However, on some pinyon–juniper ranges in north-central Arizona, both deer and pronghorn pellet groups are found. This problem was solved by Howard (1967) in New Mexico with the discovery that the pellets of mule deer and pronghorn differed markedly in pH.

EXPERIMENTAL EVALUATION OF PELLET-GROUP COUNTS

On several occasions the opportunity has been available to test the pellet-group count technique against known numbers of animals in a fenced enclosure, or to compare it with other census techniques on the open range.

Comparison With Known Deer Populations

Eberhardt and Van Etten (1956) made pellet-group counts in the Cusino and George Reserve enclosures in Michigan and checked their results against drive counts. Their estimates in deer per square mile are shown in Table 2. In these surveys the counting of 200 to 400 circular 0.02-acre plots gave estimates ranging from 2 to 53 percent in actual error, primarily observer error of various kinds. In 1953 at Cusino some pellets dropped prior to leaf fall probably were included, and the 1955 counts at George Reserve are known to have involved a high degree of missed groups error. A controlled test of observer error at Cusino confirmed that missed groups and errors in dating pellet-group deposition were the chief problems (Van Etten and Bennett 1965).

In another report from Michigan (Ryel

Table 4. Estimates of winter deer populations on Cedar Ridge, Middle Park, Colorado, 1958 and 1959 (Harris 1959: 242).

Method	Estimates of Deer Numbers and Their Confidence Limits	
	1958	1959
Ground drives		
February	396	566
April	366	—
Aerial survey		
(helicopter)	—	511 as adjusted
(fixed wing)	—	545 as adjusted
Pellet-group counts		
100-square-ft plots	371 ± 94	—
0.01-acre plots	305 ± 70	381 ± 74

1959, as reported by Julander et al. 1963), reasonable estimates of deer numbers were obtained 4 years out of 6 in the George Reserve enclosure (Table 3). The sample covered a total of 4.4 acres in 0.02-acre circular plots.

Downing et al. (1965) tested pellet-group counts and other techniques on a known number of deer in a 746-acre enclosure in southwest Georgia. Pellet-group counts gave estimates of less than 25 percent of the known numbers of deer, primarily because of rapid destruction of pellets by dung beetles.

Comparison With Other Census Techniques

Harris (1959) compared pellet-group counts with ground drives and aerial surveys in mule deer winter range in Middle Park, Colorado, during two different winters (Table 4). The ground drive was

Table 6. Comparison of three deer census techniques, Missoula Hills, Montana (White 1960:122).

Year	Total Count	Lincoln Index	Pellet Group
1957	27	21	21
1958	20	14	26

regarded as giving the most accurate available estimate of deer numbers. The 1958 pellet-group count estimates are very close to the two ground-drive estimates and well within acceptable confidence limits for management purposes. In 1959 the two methods did not agree so well, the pellet-group count estimate dropping to 67 percent of the ground-drive figure. The pellet-group data reflected an increased population in 1959; however, the ground-drive estimate increased by 43 percent while the pellet-group density estimate increased by only 25 percent.

Dasmann and Taber (1955) compared the Lincoln index, the pellet-group count, the sample-area count, and the total deer count techniques on a 400-acre area of northern California chaparral (Table 5). Their pellet-group counts were made on 50 circular 100-square-ft plots located at random. Since the period of apparent over-estimate of deer density by pellet-group counts coincided with a period of lush green forage, the authors postulated an increased defecation rate during that period. They suggested a rate of 10 pellet groups per deer per day on sprouting brush, 13 on dormant brush, and 17 on green herbaceous feed.

Table 5. Comparison of four deer census techniques in northern California chaparral (Dasmann and Taber 1955:227).

Period	Total Count	Lincoln Index	Sample-Area Count	Pellet-Group Count
Jan.–May, 1952	78	—	79	79
June–Nov., 1952	103	109	100	93
Nov., 1952–March, 1953	94	86	83	120

White (1960) compared pellet-group counts, total deer count, and Lincoln index in the Missoula Hills, Montana, during the 150-day summer range period (Table 6). A total of 419 circular 100-square-ft plots were gridded over the 400-acre study area. Estimates of total deer numbers by the three methods differed by a large percentage (roughly ± 30 percent in 1958), but agreement was reasonably good considering the small actual numbers of deer present on the area. White also used pellet-group distribution to classify deer use in eight vegetation subtypes. Distribution of pellet groups by subtype compared closely with direct observation of deer activity patterns.

CONCLUSION

Two important subjects related to pellet-group counts have not been included in this review. First, the statistical details of field-plot sampling and analysis of data need comprehensive study and review by a biometrician. Secondly, the material presented here has been taken almost entirely from research studies of various kinds. The experiences of Michigan, Wisconsin, Utah, New Mexico, and other states in statewide pellet-group counting for deer and elk management would provide plentiful material for another review article.

The problems of designing, establishing, and operating pellet-group sampling systems have been thoroughly explored by numerous workers in numerous habitats. No insuperable technical difficulties have been encountered. Only the rapid destruction of pellets or their concealment by extremely dense vegetation has prevented the use of the technique in some areas. Probably the thorniest problem in most cases is human error, or observer bias. Careful standardization of procedures and rigorous adherence to standards are a necessity. Particularly is this true in management programs involving large numbers of observers. Because of the high degree of observer error that has sometimes been detected, pellet-group count sampling systems must be designed to minimize this form of error: that is, plots must be well defined, of the smallest size consistent with pellet group density, and the sampling system must be designed for efficient field location and access.

A major problem requiring future research attention concerns the use of pellet-group distribution pattern as an index to habitat preferences. Pellet-group counts are widely used for this purpose, yet the relationship between defecation and other animal activities remains conjectural. It is commonly assumed that the number of pellet groups counted in an area is closely related to the number of animal-hours or days spent in the area, or that the pellet-group count is an indicator of the importance of the sample plot site to the well-being of the animal population. Neither assumption appears entirely trustworthy, but in few cases (White 1960, Welles and Welles 1961) has it been possible to directly observe animal activity in corroboration or contradiction of pellet-group distribution.

In view of the many pitfalls and hazards detailed in this review it seems obvious that pellet-group counts are not a panacea or a short cut to big game population data. However, it does appear that the method is valid, and that it can be made to yield reliable data under most field conditions.

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Predators

Determining the Relative Abundance of Coyotes by Scent Station Lines (Linhart and Knowlton 1975)

DETERMINING THE RELATIVE ABUNDANCE OF COYOTES BY SCENT STATION LINES

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Abstract: In an attempt to determine the relative abundance of coyotes (*Canis latrans*), we have been checking several hundred scent station lines (about one line per 5,000 miles) each year in 17 western states. Each line consists of 50 scent stations located at 0.3-mile intervals along a continuous 14.7-mile route; each station is a perforated-plastic capsule containing a fermented-egg attractant placed in the center of a 1-yard circle of sifted dirt. Animal visits (based on tracks) are recorded for each station daily for 5 consecutive days during September to provide an index by which coyote population trends can be compared between states, regions, and years.

The present concern over predator control in the western United States has prompted a number of studies aimed at learning more about the ecology and behavior of coyotes, their economic impact, and methods of reducing their depredations on livestock. Determining the status and trends of coyote populations is essential to this research. The U.S. Fish and Wildlife Service (FWS) has investigated methods of making such measurements, within limited geographic areas, for many years. However, only recently did a search begin for a survey technique that (1) would provide annual indices of coyote abundance over extensive areas throughout the western United States, (2) could be checked at the same time and in exactly the same way from region to region and year to year, and (3) would provide as reliable an estimate of abundance as possible within limits of available funds and trained manpower.

Many wild-mammal censusing problems are compounded with wild canids, which are highly mobile, intelligent, and wary. Without unlimited resources or severe restrictions on sample-area size, it is a practical impossibility to obtain actual counts, so one must resort to some index of relative abundance. However, indices (like most direct counting methods) are subject to such variables as the characteristic non-random distribution of wild canids, varying seasonal or regional movement and behavior patterns, and other factors including age, sex, weather, food supply, and the influence of habitat. These factors become increasingly difficult to minimize when the survey is conducted over large areas. One can only select a technique as insensitive to these variables as possible and recognize that some variation in canid response is inevitable.

Wood (1959), Lord (1961), Overton and Davis (1969), Lewis (1970), Clark (1972), Knowlton (1972), Linhart and Robinson (1972), and Wolfe (1973) have reviewed most of the census techniques used to estimate densities of wild canids. Although varying in details, nearly all fall into five basic categories: (1) direct counts or catch, mark, release, and recapture (Lincoln Index); (2) counts of dens, tracks, or droppings; (3) questionnaires and bounty payments; (4) catch per unit of effort (trap nights, coyote-getter nights, etc.); and (5) elicited responses, such as frequency of visitation to man-made scent stations and howl responses to sirens.

Of these techniques, we felt that the

scent station method in which animal visits (tracks) are counted (Cook 1949, Richards and Hine 1953, Wood 1959, Pimlott et al. 1969) seemed the most likely to elicit reliable, easily counted responses from coyotes. For uniformity, economy, ease of operation with limited manpower, and use over large areas, we combined scent stations with a modification of the procedure used by Knowlton (1972) in Texas to measure coyote densities by coyote-getter or M-44 lines. Knowlton spaced 50 coyote-getter stations at 0.3-mile intervals on 15-mile routes along ranch roads and checked each station daily for 10 days. We chose the same spacing, but reduced the data collection period to 5 days. We considered laying out each line with 5 segments of 10 stations each with random distance intervals between segments—statistically advantageous because it would have permitted us to calculate variances for individual lines. However, since most individuals scheduled to run the lines were poorly acquainted with the need for randomization, we concluded that this refinement would unduly complicate the instructions.

September was chosen as the best survey month in the western states, where snow can be heavy from October through May, denning and summer heat may reduce coyote movement through August, and wind often obliterates tracks during winter and spring. Initial field tests of the scent station technique were conducted in Arizona in 1966 using cotton balls soaked with coyote urine as a coyote attractant. Although urine was satisfactory in this instance, it has obvious disadvantages in a large-scale program where uniformity and manpower costs are important. Later field tests in Colorado, Texas, and Nevada showed that a commercial fermented-egg product was only slightly less attractive than coyote urine. These factors, as well as a good response from many other carnivore species, resulted in the selection of the egg product for our survey.

We are grateful to personnel of the Divisions of Wildlife Services, Refuges, and Research, U.S. FWS, for help in undertaking the survey and to F. R. Henderson, Extension Specialist, Kansas State Extension Service, who was instrumental in initiating the Kansas survey. Cooperators from Washington and South Dakota state fish and game departments also assisted. Help and suggestions of D. S. Balser, R. D. Nass, J. R. Tigner, C. J. Carley, R. B. Finley, H. M. Wight, J. D. Roberts, and G. J. Dasch, all of the U.S. FWS, and J. Hodges and W. S. Overton, Oregon State University, are also gratefully acknowledged. The fermented-egg attractant was supplied by J. B. Moore, McLaughlin Gormley King Company,[1] Minneapolis, Minnesota 55414.

METHODS

Annual fall surveys were begun when 328 scent station lines were established and run in 17 western states in September and early October, 1972 (Fig. 1). Nearly all these lines plus 26 new ones were run in September, 1973, and are scheduled for future years. Manpower considerations limited us to establishing approximately one survey line for each 5,000 square miles. For example, we attempted to establish 20 survey lines throughout Wyoming (97,914 square miles). Sampling locations within each state were selected according to the following criteria: (1) physiographic and biotic regions of each state, (2) availability and location of field personnel who could run survey lines, and (3) probability of access to the sampling points in future years.

Most survey lines were run by field

[1] Reference to trade names does not imply U.S. Government endorsement of commercial products.

Fig. 1. Distribution of predator survey lines run in 1972.

personnel of the Division of Wildlife Services; the remaining few were run by personnel of the Divisions of Research and Refuges and by state and university cooperators. In nearly all cases, each man ran two lines. Because we could not visit potential line sites before the 1972 survey began, we mapped 75- × 75-mile quadrants in most cases to indicate the approximate location of each man's two lines. The individual assigned to the area was told to locate his lines through what was, in his opinion, typical coyote habitat containing average coyote densities. Most individuals were familiar with their assigned areas and already had some qualitative estimate of coyote abundance. Surveyors were also instructed to locate lines at least 20 miles apart on unpaved secondary or ranch roads along which coyotes would normally travel and to indicate the route locations on a topographic or county map for future reference.

Each survey line consisted of 50 scent stations, located at 0.3-mile intervals along a continuous 14.7-mile route. Occasionally,

Fig. 2. Coyote at a scent station (photo by F. R. Henderson).

it was necessary to "break" the line for a short distance when no suitable continuous section of road was available. Each scent station consisted of a circle of sifted earth or sand 1 yard in diameter. A small, perforated-plastic tissue capsule filled with about 0.035 ounce (1 gm) of the granular fermented-egg attractant was supported 1 inch above the ground with a wooden applicator stick placed in the center of the circle (Fig. 2). Capsules were consecutively numbered, and stations were located alternately on the left and the right side of the road to reduce the influence of changing winds. Scent stations were placed immediately adjacent to the road edge so that they could be observed from a vehicle. Capsules that were carried off by animals, destroyed (e.g., by cattle), or clogged with blowing dirt were replaced as required.

Each man was given a standard data-recording form for each line and asked to record topography, principal land uses, major vegetative characteristics, and whether or not predators were controlled in the area; if so, a qualitative estimate of control intensity and the extent to which predator depredations were reduced was also requested. Beginning the day after the scent stations were set up, the line was checked for 5 consecutive days and daily weather conditions, number of inoperative stations (disturbed by livestock, human interference, or weather), and species of carnivores and other larger mammals that visited each operative station (based on tracks within the 1-yard circle) were recorded. The surveyor was asked to simply indicate, for example, "coyote visit," "red fox visit," "no visit," etc., because it was usually impossible to determine from tracks alone whether more than one individual of a species had visited a station on a given day (or whether the same animal had visited more than one station). At stations visited or disturbed by larger mammals, the ground was smoothed so that new tracks could be distinguished on later days. On the final day, the surveyor removed the capsule from each station as he checked the line.

Since we could only review these procedures with Wildlife Services supervisory personnel, who in turn relayed the instructions to their field men, we felt it desirable to check some survey lines to ensure that procedures and data recording were understood. During 1972 we checked the lines of 17 men (about 10 percent of the total field force of 175) in 7 states and found few deviations from our written instructions and a generally positive attitude toward the survey. We subsequently learned that many routes had been selected more for their travel distance from home, availability of suitable roads, and access than because they represented typical coyote habitat. Thus, it is uncertain how closely the survey lines sampled what might be considered "average" coyote densities, but we believe that a fairly good distribution of lines was obtained nonetheless (Fig. 1).

The 1972 field data sheets were sent to the Denver Wildlife Research Center for tabulation. Under a contractual agreement, the 1973 data sheets were sent to Oregon State University where all survey data were punched onto cards for computer analysis.

The data from each survey line were tabulated by subtracting the number of instances when scent stations were inoperative from the total of 250 station-nights (50 stations × 5 nights) to give the total number of "operative station-nights." The total number of visits recorded for each species during the 5 nights was then used to calculate an index of relative abundance as follows:

$$\frac{\text{Total animal visits}}{\text{Total operative station-nights}} \times 1{,}000 = \text{index.}$$

For example, a line with 30 coyote visits and 235 operative scent station-nights would have an index for coyotes of 128 (30/235 × 1,000). These data were then tabulated by state, and state and regional maps were prepared indicating the location of survey lines, their carnivore index values, and the mean index values for each state.

RESULTS AND DISCUSSION

The coyote indices obtained ranged from zero in several areas to over 500 in south Texas, where coyotes visited about half the 50 stations on several lines all 5 nights. Fig. 3 shows coyote data from 316 *operative* survey lines that were run *both* in 1972 and 1973 as an example of the type of information that may be obtained by using scent station lines. Obviously, appropriate statistical tests should be used to determine significant year-to-year trend increases or decreases.

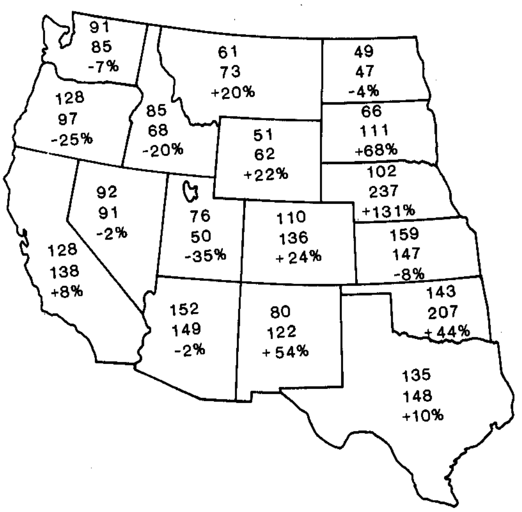

Fig. 3. Example of predator survey data showing an annual change in coyote indices by state. In each listing, the first figure is the mean 1972 state index, the second is the mean 1973 state index, and the third is the percent change between the 2 years.

In addition to coyotes, the surveys have recorded the presence of domestic dogs, red wolves (*Canis niger*), red fox (*Vulpes vulpes*), kit fox (*V. macrotis*), swift fox (*V. velox*), gray fox (*Urocyon cinereoargenteus*), and a variety of noncanid carnivores—black bears (*Ursus americanus*), raccoons (*Procyon lotor*), ringtail cats (*Bassariscus astutus*), weasels (*Mustela* sp.), mink (*M. vison*), skunks (*Mephitis mephitis*), badgers (*Taxidea taxus*), domestic cats, mountain lions (*Felis concolor*), lynx (*Lynx canadensis*), and bobcats (*L. rufus*). Some of these data, particularly for the noncanid species, are of questionable value as many survey lines were located primarily in coyote habitat and would not necessarily record the presence of other carnivores in the general area. The survey technique (location of lines, spacing of stations, etc.) would probably have to be modified to measure the relative abundance of such species reliably.

As with any technique that attempts to measure relative abundance over large areas, certain problems arose. Weather was the major one; wind and rain obliterated tracks and necessitated resifting of scent stations and occasional renewal of the attractant. In many of the western states, weather conditions make the scent station technique unsuitable at certain times of the year.

Coyote movement and distribution are dictated in part by topography, vegetative cover, and food, and thus may vary from area to area. For example, coyotes are generally distributed more uniformly in flat, short-grass areas than in more broken habitat, where they move primarily along washes or ridge tops. Thus, relative indices for different areas are probably less comparable than are annual trend data from the same area. We have also received occasional reports of coyotes ignoring scent stations and of single coyotes visiting a series of adjacent stations. Hopefully, such instances occur at about the same frequency among areas and years so that they do not introduce bias.

At present we have no way to relate these indices with the actual number of coyotes present in a given area; future studies will seek to clarify this relationship. Despite its limitations, we believe that the scent station technique is one of the better methods currently available for extensive measurement of relative coyote abundance.

The large volume of data resulting from the 1972 and 1973 surveys, as well as data to be obtained in future annual surveys, requires handling and analysis by computer. Analyses currently in progress will determine the precision and sensitivity of the technique and will perform the appropriate statistical tests to determine significant differences in relative abundance among areas and years. They should also indicate the minimum number of days the survey lines should be run, day-to-day differences in the behavioral response of coyotes to scent stations, and relationships between relative coyote densities and control efforts, physiography, vegetation, and land-use patterns, if such exist. These analyses will be published later.

It may take several years, but the results of these annual surveys hopefully will provide wildlife managers and researchers with the first set of data that relate coyote densities to management practices and to environmental factors regulating the abundance of this controversial species.

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CURRENT STATUS OF MANUSCRIPTS SUBMITTED TO THE WILDLIFE SOCIETY BULLETIN

As of July 1, 1975, 165 manuscripts had been submitted for consideration for publication in the *Bulletin*: 20 in 1972, 43 in 1973, 66 in 1974, and 33 in the first 6 months of 1975. Status of these papers as of July 1 was as follows. (George V. Burger, *Editor*)

Status	Number	Percent
Published (including 3[3])	57	34.5
Rejected	34	20.6
"Dead file"[1]	22	13.3
Other inactive	3	1.8
Referred to J. Wildl. Manage.	7	4.3
With referees	10	6.1
With authors; revision requested	29	17.6
With editor for action	3	1.8
Total	165	100.0

[1] Major revisions required; elapsed time or other reasons indicate further action unlikely.

Small Mammals	Transect versus grid trapping arrangements for sampling small-mammal communities (Pearson and Ruggiero 2003)

Transect versus grid trapping arrangements for sampling small-mammal communities

Dean E. Pearson and Leonard F. Ruggiero

Abstract We compared transect and grid trapping arrangements for assessing small-mammal community composition and relative abundance for 2 years in 2 forest cover types in west-central Montana, USA. Transect arrangements yielded more total captures, more individual captures, and more species than grid arrangements in both cover types in both years. Differences between the 2 methods tended to be greatest when small mammals were least abundant, suggesting that advantages of transect arrangements for obtaining basic community information may be greatest when sampling returns are poorest. Our results suggest that transect arrangements are more efficient than grids for small-mammal surveys and studies of small-mammal community composition because transects provide better resolution of community structure for a given effort.

Key words community composition, relative abundance, sampling methods, small mammals, species richness

Trapping methods employed in small-mammal research can affect conclusions regarding community composition. For example, trap types can vary greatly in capture efficiency by species and habitat (Beacham and Krebs 1980, Slade et al. 1993, Shore et al. 1995, Whittaker et al. 1998). As a result, indices such as relative abundance and species richness commonly used to assess the effects of human impacts on habitat quality for small mammals (Morrison and Anthony 1989, Trnka et al. 1990, Sullivan and Boateng 1996, Pearson et al. 2000) can be sensitive to sampling method.

Although a great deal of emphasis has been placed on the effects of trap type, relatively little effort has been expended to understand the equally important influence of trap arrangement (Stickel 1948*a*, Petticrew and Sadleir 1970, Steele et al. 1984, Read et al. 1988). Two spatial designs are primarily used to deploy traps in the field: grids and transects. Differences in geometry between methods can result in differences in effective sampling area that affects number of animals and species trapped. For instance, if we assume that each trap effectively samples the unit it lies within plus any adjacent unit, then 25 traps placed in a line will sample 65% more area than 25 traps placed in a grid (Figure 1). This is due to redundancies in sampling that result from greater overlap in effective sampling area of traps set in grid arrangements. This difference will decrease as trap spacing increases until there is no overlap among traps and transect and grid arrangements converge on the same effective sampling area. However, even when traps are independently spaced, transect arrangements may sample more unique microhabitats and more small-mammal home ranges due to similar effects of geometry as they relate to small-mammal and habitat dispersion. Therefore, a transect arrangement equal in trap number and interval to a grid may sample more small-mammal home ranges and microhabitats, resulting in more individuals and species of small mammals being captured.

The notion that transect arrangements should capture more individual animals and provide a better

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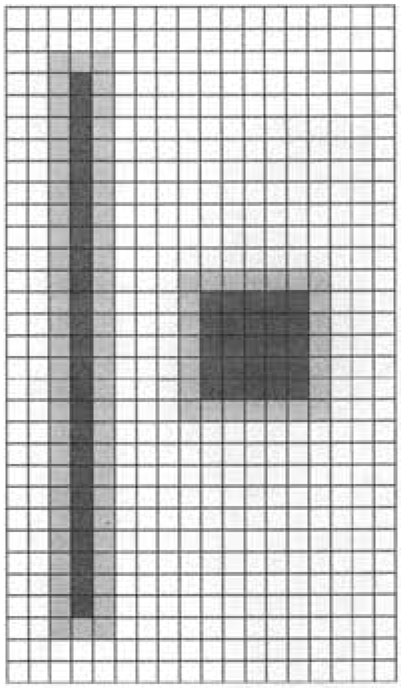

Figure 1. Schematic showing effective trapping area sampled by transect and grid arrangements of equal trap number and spacing where it is assumed that each trap effectively samples the cell it lies within and any adjacent cell. Dark-colored cells indicate those with traps, and light-colored cells indicate adjacent cells also sampled by the trap.

tool than grids for surveying small-mammal communities seems intuitive. Yet, literature reviews by Read et al. (1988) and Steele et al. (1984) indicate that grids are used more often than transects, even in cases where the objective is to survey small-mammal communities. We suggest that this situation results from a lack of consensus among studies comparing trapping arrangements for sampling small-mammal communities. For example, Stickel (1948*a*) and Bujalska (1989) concluded that transects ineffectively sampled small-mammal populations compared to grids, whereas Read et al. (1988) and Steele et al. (1984) determined that transects generated indices of higher species richness and greater diversity of small mammals than grids. Additional research is needed to determine costs and benefits associated with different trapping arrangements so researchers can select methods that maximize sampling returns for a given set of study objectives. Our objective was to compare grid and transect arrangements to determine whether population and community indices such as total captures, number of individuals captured, and species richness differed between methods.

Methods

The study area consisted of 9 forest stands located across west-central Montana, USA. Five stands were dominated by old-growth ponderosa pine (*Pinus ponderosa*) and 4 stands by mature western larch (*Larix occidentalis*). Stand boundaries were determined from aerial photographs. Stands included a variety of microhabitats, especially within ponderosa pine, where seeps and ravines provided mesic sites within the generally xeric habitat and large openings resulted in bunchgrass-dominated patches. Western larch stands were more homogeneous but also contained topographic relief that resulted in a mixture of shady, mesic microsites and dry ridges.

We placed 3 transects and 3 grids of 25 trap stations in each forest stand by randomly selecting starting points and randomly orienting the grid or transect to a cardinal direction. Trap spacing was 10 m, resulting in 40 × 40-m grids and 240-m transects. We used Sherman live traps (approximately 8 × 9 × 23 cm) and Tomahawk # 201 wire-mesh live traps (Tomahawk Live Trap Company, Tomahawk, Wis.) to survey a range of small-mammal species. We placed Sherman traps at all stations except where Tomahawk traps were placed. We set Tomahawks at the 4 corners of each grid (40-m interval) and at 40-m intervals along transects, beginning with trap station 1 and extending for 120 m (4 Tomahawk traps). Due to limited availability of Tomahawk traps, only 2 of 3 grids and transects on each site included these traps.

We baited all traps with a mixture of peanut butter and whole oats and ran traps for 8 consecutive days. We also baited Tomahawk traps with strawberry jam to target northern flying squirrels (*Glaucomys sabrinus*). We trapped grids and transects concurrently in each stand. We checked traps each morning and ear-tagged captured small mammals with #1005-1 monel ear tags (National Band and Tag Company, Newport, Ky.). We identified small mammals to species and determined age, mass, sex, and reproductive condition before animals were released at the trap station. Animal handling followed guidelines set forth by the American Society of Mammalogists (American Society of Mammalogists, Animal Care and Use Committee 1998), except that bedding material was not provided. The purpose of using no bedding was to reduce contact with rodent excreta as a safety precaution against hantavirus infection. We trapped stands in 1997 and 1998 from May through July.

We assessed the relative effectiveness of trapping arrangements using capture indices: total number of captures, total number of individuals marked, and total number of species captured. We used generalized linear models that assumed a Poisson distribution of the data using SAS PROC MIXED with the GLIMMIXED macro (SAS Institute 1990) to determine whether transects differed from grids with regard to the 3 indices. We treated cover type, sampling method (i.e., transect or grid), and year as fixed factors, and study site (forest stand) as a random factor within cover type.

Results

In 22,752 trap nights at 54 sampling locations (27 transects and 27 grids), we captured 2,007 individuals of 16 species 4,311 times over 2 years. Transects generated 2,459 captures of 1,170 individuals and 15 small-mammal species, and grids produced 1,852 captures of 837 individuals and 15 species. Deer mice (*Peromyscus maniculatus*), southern red-backed voles (*Clethrionomys gapperi*), and red-tailed chipmunks (*Tamias ruficaudus*) were the 3 most common species captured in descending order of abundance (Figure 2). Seven species—northern flying squirrel, Columbian ground squirrel (*Spermophilus columbianus*), western jumping mouse (*Zapus princeps*), bushy-tailed woodrat (*Neotoma cinerea*), cinereus shrew (*Sorex cinereus*), long-tailed vole (*Microtus longicaudus*), and montane vole (*M. montanus*)—were considered rare, with ≤12 individuals captured for transects and grids combined.

Generalized linear model results indicated that transects captured more total small mammals (F=7.76; df=1, 7; P=0.027), more individuals (F=14.74; df=1, 7; P=0.006), and more species (F=6.87; df=1, 7; P=0.034) on average than grids after controlling for cover type and year (Figure 3). Cover type did not differ for total captures (F=3.14; df=1, 7;

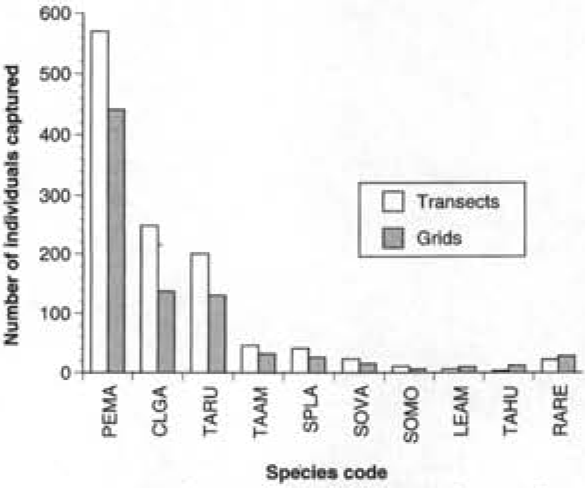

Figure 2. Capture frequencies for small-mammal species from 27 grids and 27 transects in western Montana 1996–1997. (PEMA = *Peromyscus maniculatus*; CLGA = *Clethrionomys gapperi*; TARU = *Tamias ruficaudus*; TAAM = *T. amoenus*; SPLA = *Spermophilus lateralis*; SOVA = *Sorex vagrans*; SOMO = *S. monticolus*; LEAM = *Lepus americanus*; TAHU = *Tamiasciurus hudsonicus*. RARE = 7 species with ≤12 individuals captured).

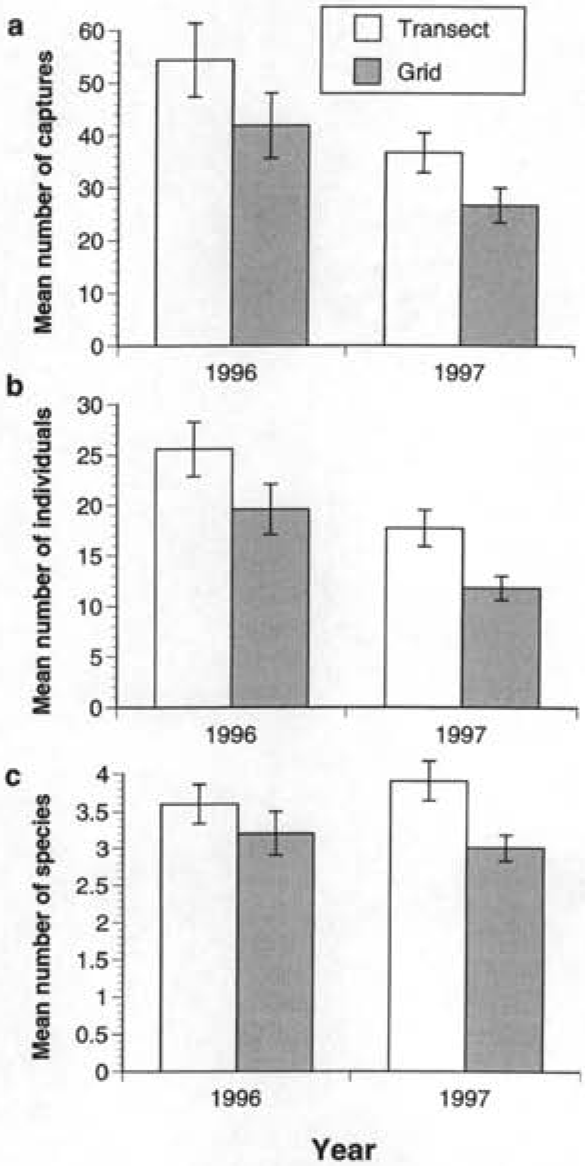

Figure 3. Means and standard errors for (a) total number of small mammals captured, (b) number of individual small mammals captured , and (c) number of small-mammal species captured using 27 grids and 27 transects in western Montana 1996–1997.

P=0.118), number of individuals captured (F=2.70; df=1, 7; P=0.144), or number of species captured (F=2.16; df=1, 7; P=0.185). However, year differed, with more individuals captured (F=27.85; df=1, 14; P<0.001) and higher total captures (F=16.11; df=1, 14; P=0.001) in 1996 than in 1997, though number of species captured did not differ between years (F=0.00; df=1, 14; P=0.988). Interactions were significant at the P=0.05 level for cover type and year for all analyses, but interactions were not significant between method and cover type, method and year, or method and year and cover type for any of the analyses.

Discussion

Although numerous studies have examined the effects of trap type (Beacham and Krebs 1980, Slade et al. 1993, Shore et al. 1995, Whittaker et al. 1998), trapping period (Gentry et al. 1968, Olsen 1975, Steele et al. 1984), and trap bait (Stickel 1948*b*, Fitch 1954, Fowle and Edwards 1954, Hansson 1972) on small-mammal trapping results, relatively little work has addressed the effect of trap arrangement on small-mammal community sampling. Moreover, literature published on this subject indicates a lack of consensus among studies addressing this question. Our results suggest that this lack of consensus is more a function of differing study designs than variability in outcomes resulting from effects of trap arrangement.

For example, Stickel (1948*a*) and Bujalska (1989) concluded that transects provided poor population indices when compared to grids. However, both authors superimposed transects onto large grids that differed in number of traps, trap spacing, and times the sites were trapped, rendering these studies inappropriate comparisons of transect versus grid trapping. Steele et al. (1984) compared transects and grids while controlling for trap number and spacing. They determined that for arrangements of 25 traps at 15-m intervals, transects were more effective than grids for estimating small-mammal species richness, but both methods produced similar results for abundance indices. Like Stickel (1948*a*) and Bujalska (1989), Steele et al. (1984) compared their smaller "sample" transects and grids to a large baseline grid. This approach assumes that the large baseline grid provides the true population and community parameters. In truth, data from the baseline grid are also samples, and since the baseline data come from a grid arrangement, this design potentially instills a grid-bias into such comparisons. Brant (1962) and Petticrew and Sadleir (1970) concluded that transects generated abundance indices comparable to grids, but both studies used fewer traps on transects and trapping was not concurrent between the different methods. From an intensive study in Australia that directly compared transects with grids while controlling for trap number and spacing, Read et al. (1988) determined that transects of 7.5-, 10-, and 20-m trap spacing produced better estimates for 4 diversity indices than grids of 7.5-, 10-, and 20-m spacing, but that concentrated grids of 5-m intervals were comparable to transects of the same trap spacing. They also concluded that results from transects were less sensitive to trap spacing than results from grids.

Our results are consistent with the hypothesis that transects sample more individuals and more species of small mammals than grids of equal trap number and spacing due to differences in geometry that result in a larger effective trapping area for transects. We found that transects generated more total captures of small mammals, more individuals of abundant species, and greater species richness compared to concurrently trapped grids of equal trap number and spacing. This outcome held for western larch- and ponderosa pine-dominated cover types and for years that differed greatly in small-mammal abundance. In fact, in 1997, when the number of individual small mammals captured was significantly lower than the previous year, differences between sampling methods tended to be more pronounced, though the interactions were not significant (Figure 3). These data suggest that the advantages of transects over grids for obtaining basic community information may be greatest when sampling returns are poorest.

Our results are consistent with Read et al.'s (1988) conclusion that diversity was higher for transects than grids, and Steele et al.'s (1984) findings that species richness was higher for transects. Our results also corroborate observations by Brant (1962) and Petticrew and Sadleir (1970) where transects produced relative abundance indices comparable to grids, even when trapping effort was substantially higher for grids. We contend the assertions made by Stickel (1948*a*) and Bujalska (1989) that transects ineffectively sample small-mammal populations compared to grids are incorrect and are the product of uncontrolled study designs.

Choice of trapping arrangement will involve a tradeoff between the relative benefits of grids versus transects. Grids provide better spatial resolution for estimating population density, depicting home ranges, and determining small-mammal dispersion. However, transects better reflect community composition and provide better samples for examining demographic attributes such as age and sex ratios and habitat relationships due to greater numbers of captures, individuals captured, and species captured. Transects also will likely encompass greater microhabitat diversity, and habitat data likely will exhibit less autocorrelation than data from grids for conducting microhabitat selection studies. Moreover, despite the spatial limitations of transects, methods have been developed for estimating small-mammal density on transects (O'Farrell et al. 1977), and some aspects of dispersion can be studied with transects. For example, Brant (1962) and Petticrew and Sadleir (1970) found that transects produced relative abundance estimates comparable to grids with substantially less trapping effort, and Pearson et al. (2001) used transects to identify habitat partitioning between male and female deer mice that resulted from differential dispersion of the sexes across microhabitats.

Studies comparing transect and grid trapping arrangements provide conflicting results regarding which method is more effective for obtaining various population and community indices. Although it seems intuitive that transects would perform better than grids for studies of community composition, literature reviews (Steele et al. 1984, Read et al. 1988) indicate that grids are used more often than transects, even when the study objective is to survey small-mammal communities. Whereas grids are arguably the optimal arrangement for studies of dispersion, home-range use, and population estimation, our results clearly indicate that transects provide greater trapping returns for a given effort in terms of total captures, individual animals captured, and species richness.

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Associate editor: *Whittaker*

APPENDIX C

Common and Scientific Names of Wildlife Species Observed During Wildlife Surveys at the National Renewable Energy Laboratory South Table Mountain Site, Golden, Colorado

Wildlife Species Observed at the National Renewable Energy Laboratory
South Table Mountain Site, Golden, Colorado.

COMMON NAME	SCIENTIFIC NAME
Reptiles	
Bull snake[1]	*Pituophis catenifer*
Plains garter snake	*Thamnophis radix*
Six-lined racerunner	*Cnemidophorus sexlineatus*
Tiger salamander	*Ambystoma tigrinum*
Western rattlesnake	*Crotalus viridus*
Birds	
American crow	*Corvus brachyrhynchos*
American kestrel	*Falco sparverius*
American robin	*Turdus migratorius*
American tree sparrow	*Spizella arborea*
Barn swallow	*Hirundo rustica*
Black-billed magpie	*Pica pica*
Black-capped chickadee	*Poecile atricapilla*
Black-crowned night heron	*Nycticorax nycticorax*
Blue jay	*Cyanocitta cristata*
Brewer's blackbird	*Euphagus cyanocephalus*
Brown headed cowbird	*Molothrus ater*
Bullock's oriole	*Icterus bullockii*
California gull	*Larus californicus*
Canada goose	*Branta canadensis*
Common nighthawk	*Chordeiles minor*
Common raven	*Corvus corax*
Common snipe	*Gallinago gallinago*
Cooper’s hawk	*Accipiter cooperii*
Dark-eyed junco	*Junco hyemalis*
Downy woodpecker	*Picoides pubescens*
European starling	*Sturnus vulgaris*
Flycatcher	*Empidonax sp.*
Golden eagle	*Aquila chrysaetos*
Great blue heron	*Ardea herodias*
Horned lark[1]	*Eremophila alpestris*
House finch	*Carpodacus mexicanus*
House sparrow	*Passer domesticus*
Killdeer	*Charadrius vociferous*
Lark bunting	*Calamospiza melanocorys*
Loggerhead shrike	*Lanius ludovicianus*
MacGillivray’s warbler	*Oporornis tolmiei*
Mallard	*Anas platyrhynchos*
Mountain bluebird	*Sialia currucoides*
Mourning dove	*Zenaida macroura*
Northern flicker	*Colaptes auratus*
Northern harrier	*Circus cyaneus*
Osprey	*Pandion haliaetus*

COMMON NAME	SCIENTIFIC NAME
Prairie falcon	*Falco mexicanus*
Red-breasted nuthatch	*Sitta canadensis*
Red-tailed hawk	*Buteo jamaicensis*
Red-winged blackbird	*Agelaius phoeniceus*
Rock dove	*Columba livia*
Rock wren	*Salpinctes obsoletus*
Say's phoebe	*Sayornis saya*
Sharp-shinned hawk	*Accipiter striatus*
Spotted towhee	*Pipilo maculates*
Swainson's hawk	*Buteo swainsoni*
Tree swallow	*Tachycineta bicolor*
Turkey vulture	*Cathartes aura*
Unidentified sparrow 1	-
Unidentified sparrow 2	-
Unidentified species	-
Unidentified warbler	-
Vesper sparrow	*Pooecetes gramineus*
Western kingbird	*Tyrannus verticalis*
Western meadowlark	*Sturnella neglecta*
Western scrub jay	*Aphelocoma californica*
White-crowned sparrow	*Zonotrichia leucophrys*
Mammals	
Black-tailed jackrabbit[1]	*Lepus californicus*
Bushy-tailed woodrat[1]	*Neotoma cinerea*
Coyote	*Canis latrans*
Deer mouse	*Peromyscus maniculatus*
Fox squirrel	*Sciurus niger*
Long-tailed weasel	*Mustela frenata*
Mexican woodrat	*Neotoma mexicana*
Mountain cottontail	*Sylvilagus nuttalli*
Mule deer	*Odocoileus hemionus*
Prairie vole	*Microtus ochrogaster*
Raccoon	*Procyon lotor*
Red fox	*Vulpes vulpes*
Western harvest mouse	*Reithrodontomys megalotis*
White-tailed jackrabbit	*Lepus townsendii*
Yellow-bellied marmot[1]	*Marmota flaviventris*

[1] Species observed during the 1987 survey, but not during the 2004-2005 surveys.

APPENDIX D

Photographs

Photo 1. Short grass vegetation type on mesa top. National Renewable Energy Laboratory, Golden, Colorado. May 2002.

Photo 2. Mixed grass vegetation type north of Visitor's Center (located on left side of photo). National Renewable Energy Laboratory, Golden, Colorado. May 2002.

Photo 3. Tall shrubland vegetation type on slope of hill. National Renewable Energy Laboratory, Golden, Colorado. May 2002.

Photo 4. Ravine shrubland vegetation type in center of photo. National Renewable Energy Laboratory, Golden, Colorado. May 2002.

Photo 5. Disturbed/Reclaimed vegetation type shown in foreground; developed vegetation type (building/parking lot) shown in background. National Renewable Energy Laboratory, Golden, Colorado. May 2002.

Photo 6. Coyote (*Canis latrans*) on the mesa top. National Renewable Energy Laboratory, Golden, Colorado. April 2005.

Photo 7. Mexican woodrat (*Neotoma mexicana*). National Renewable Energy Laboratory, Golden, Colorado. June 2004.

Photo 8. Mule deer (*Odocoileus hemionus*) on mesa top. National Renewable Energy Laboratory, Golden, Colorado. June 2004.

Photo 9. Tiger salamander (*Ambystoma tigrinum*). National Renewable Energy Laboratory, Golden, Colorado. September 30, 2004.

Photo 10. Western rattlesnake (*Crotalus viridus*). National Renewable Energy Laboratory, Golden, Colorado. September 29, 2004.

Photo 11. Mule deer at National Renewable Energy Laboratory, Golden, Colorado. Spring 2005.

Photo 12. Deer mouse (*Peromyscus maniculatus*). National Renewable Energy Laboratory, Golden, Colorado. June 2004.

Photo 13. Prairie vole (*Microtus ochrogaster*). National Renewable Energy Laboratory, Golden, Colorado. January 2005.

Photo 14. Coyote tracks in scent station. National Renewable Energy Laboratory, Golden, Colorado. Fall 2004.

Photo 15. Example of a large mammal pellet group plot. National Renewable Energy Laboratory, Golden, Colorado. April 2005.

Photo 16. Red-tailed hawk (*Buteo jamaicensis*) on power pole. National Renewable Energy Laboratory, Golden, Colorado. Fall 2004.