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National Wind Technology Center Site Environmental Assessment: Bird and Bat Use and Fatalities—Final Report

Period of Performance: April 23, 2001 – December 31, 2002

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Executive Summary

Fatalities of birds and bats have been documented at wind power developments around the world. Particular attention has been given to deaths of raptors (hawks and eagles) in the United States because of a documented high rate of collisions of birds with wind turbines at the Altamont Pass Wind Resource Area in central California. State and federal laws prohibit unauthorized killing of raptors and most other birds, along with bats. Even a small number of deaths could have significant impacts on local bird and bat populations.

This study was conducted to ascertain actual and potential impacts on populations of birds and bats at the National Wind Technology Center (NWTC) in northern Jefferson County, Colorado. The NWTC, which is part of the U.S. Department of Energy's National Renewable Energy Laboratory (NREL), is located on a mesa dominated by ungrazed grassland with isolated patches of ponderosa pine. Similar lands to the north and west are part of the city of Boulder's "open space" system. Areas to the east and south are part of the Rocky Flats Environmental Technology Site.

NREL specified these core questions to be addressed in the study:

- What levels of bird and bat mortality are associated with the present NWTC facility, and how might this change with future expansions at the site, and with regional land use changes?
- How does the present NWTC facility affect abundance and movement patterns of birds and bats, both on the site and regionally?
- How might these abundance and movement patterns change in the future as the NWTC site is expanded, and as regional land use patterns change?

Field methods included fixed-distance point counts of both raptor and non-raptor species, and visual, acoustic, and capture surveys of bats, using plots both on and near the NWTC site. Behavioral responses of birds to wind turbines and other structures at the NWTC were recorded, as were general movement patterns of raptors. Finally, carcass searches were conducted and calibrated by tests of scavenging rates and searcher efficiencies to compare bird and bat mortality on and off the site. In this report, studies of diversity, status, and mortality of birds (Part I) and bats (Part II) are reported separately because of the differences in the biology of the study organisms, the techniques needed to study them, and the field personnel responsible.

Salient findings of the study were as follows:

- Abundances of individual raptor species on the NWTC site were similar to surrounding areas. However, the average number of species detected per count at the NWTC was nearly double that of surrounding areas in winter, the season when raptors are most abundant in the region. This difference is likely attributable to increased availability of perches at the site. Raptors flew and perched higher at the NWTC than in adjacent areas, again probably related to the wind turbines and other structures at the site.
- Only 1 of 46 bird species counted on grassland plots during this study differed in abundance between the NWTC and adjacent areas—the horned lark, which was about 16 times more common off site. This difference is attributable to cattle on Boulder Open Space creating low-stature grasslands preferred by this species.

- Bird abundance and variety on the site south of NWTC slated for future use were generally similar to the developed areas, except for the relative scarcity of raptors on the undeveloped site, which probably was due to a lack of perches.

- The NWTC does not support a large diversity or abundance of bat species (possibly six species of bats use the site), but an area on the northwest side of the site, with trees close to a rocky outcrop, provides foraging and perhaps roosting habitat.

- We found no raptor carcasses during our 12-month survey of the NWTC, except one American kestrel that had died before the study started. Bird mortality associated with the site appears to be minor. Approximate annual bird mortality attributable to the NWTC was 24 individuals, all songbirds (Passeriformes). Most of these deaths were probably the result of collisions with support wires for the meteorological towers rather than the turbines themselves. We found no evidence of bat fatalities at the site.

Part I: Avian Use and Fatalities at the National Wind Technology Center, May 2001–May 2002

Introduction

Background

With the current push to explore more sustainable energy resources, wind power is increasingly seen as a viable and desirable alternative to power generated by combustion of fossil fuels. However, questions have been raised about the impacts of wind turbine facilities, especially their effects on avian communities. For example, there has been significant mortality of raptor species at the Altamont Pass Wind Resource Area in California (Orloff and Flannery 1992; Thelander and Rugge 2000; Thelander, Smallwood, and Rugge publication pending). Similar studies have focused primarily on raptors and other large birds in examining the effects of wind resource areas (WRAs; Osborn et al. 1998). Janss (2000) noted that raptors might be especially susceptible to collisions with aerial structures because of their high wing loading and average aspect ratios, which tend to decrease flight maneuverability. Because raptor communities vary greatly across landscapes and among habitats (Bock and Lepthien 1976), WRA risks to avian communities must be evaluated on an individual basis.

The National Wind Technology Center (NWTC) is located at the eastern edge of the Rocky Mountain front, south of Boulder, Colorado. It is situated on a mesa dominated by ungrazed grassland with scattered patches of ponderosa pine (*Pinus ponderosa*). A prior study of the site found significant use of the area by raptors but concluded that little impact was occurring (Monahan 1996). However, this study predicted that raptor use of the site could change with future expansion of the site or with shifts in prey abundance in the area.

Objectives

The objectives of this study were to:

- Document current avian use of the NWTC site in relation to other nearby areas
- Document bird fatalities resulting from collisions with wind turbine and other aerial structures
- Identify factors that may influence avian use of the site.

Methods

This project was conducted as a Phase I study, according to guidelines adapted from Morrison (1994) and Anderson et al. (1999). However, we expanded the scope of the study to include bats (addressed in Part II of this document) and nonpredatory birds (Erickson et al. 1999) as well as raptors. Generally, methodology was divided into two activities: determining avian use of the WRA and determining fatalities.

Non-Raptor Abundance and Behavior

To provide uniform coverage of the NWTC, we set out six 100-m-radius plots (Figure I-1). One was centered on a rocky outcrop with ponderosa pine in the northwestern corner of the site while four others were in grasslands that included wind turbines and related facilities. A final plot was located on a grassland site south of the current facility that is scheduled for future use. Twelve additional plots were established near the NWTC, five on Rocky Flats and seven on Boulder Open Space (Figure I-2), for the purpose of comparing birds on and off the site, in areas with and without wind turbines. These plots were located to match the vegetation of the NWTC plots as closely as possible, so that two were in ponderosa pine and ten were on grassland mesas. We conducted 45 10-min, 100-m-radius, fixed-distance point counts (Ralph, Sauer, and Droege 1995) on each of the 18 plots, at varying times of day between May 15, 2001, and May 15, 2002.

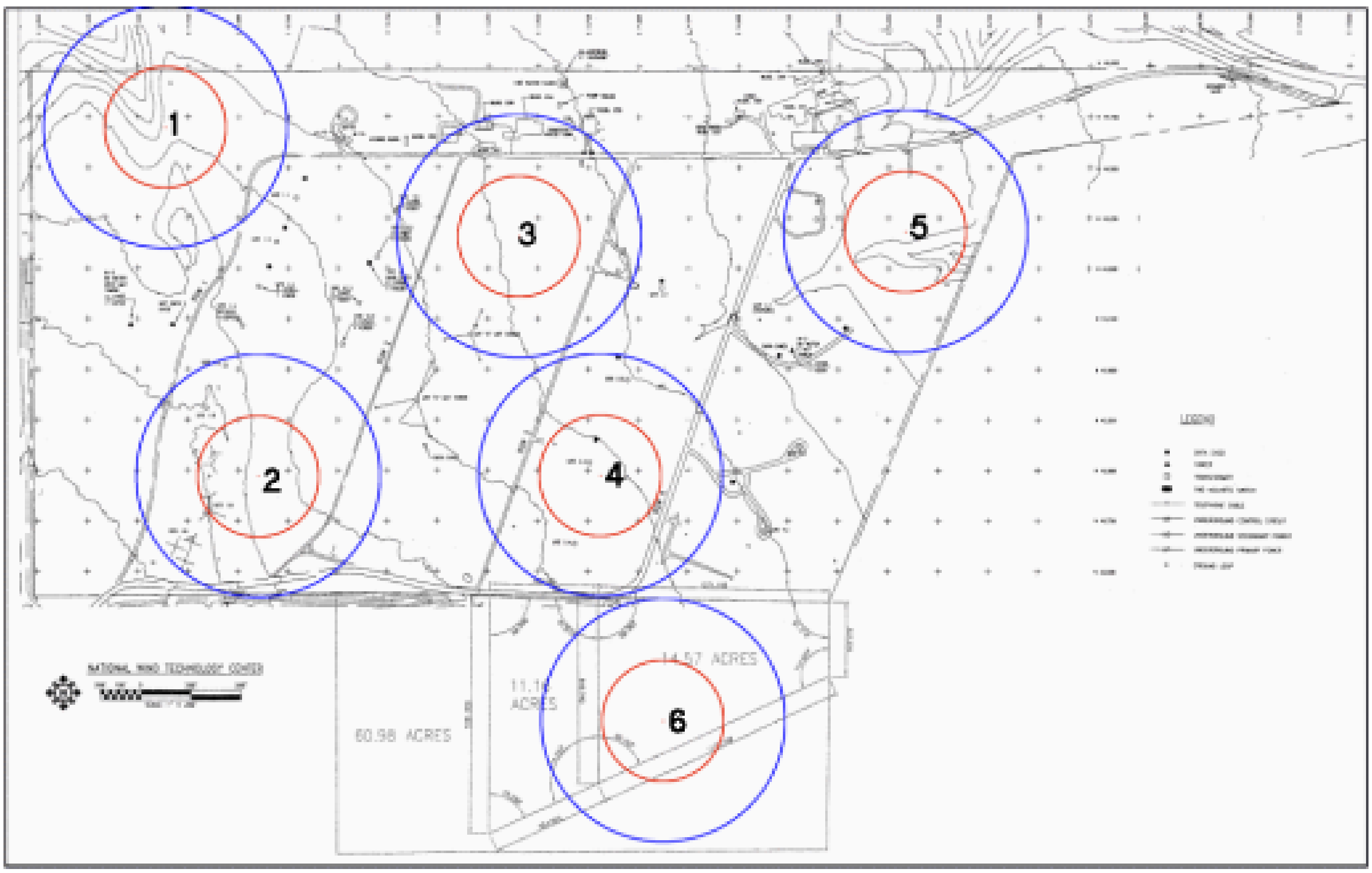

Figure I-1. Location of point counts on the NWTC

Notes: Red circles indicate areas used for non-raptor point counts. Blue circles indicate areas used for raptor point counts. Plots were numbered 1 through 6 from northwest to southeast.

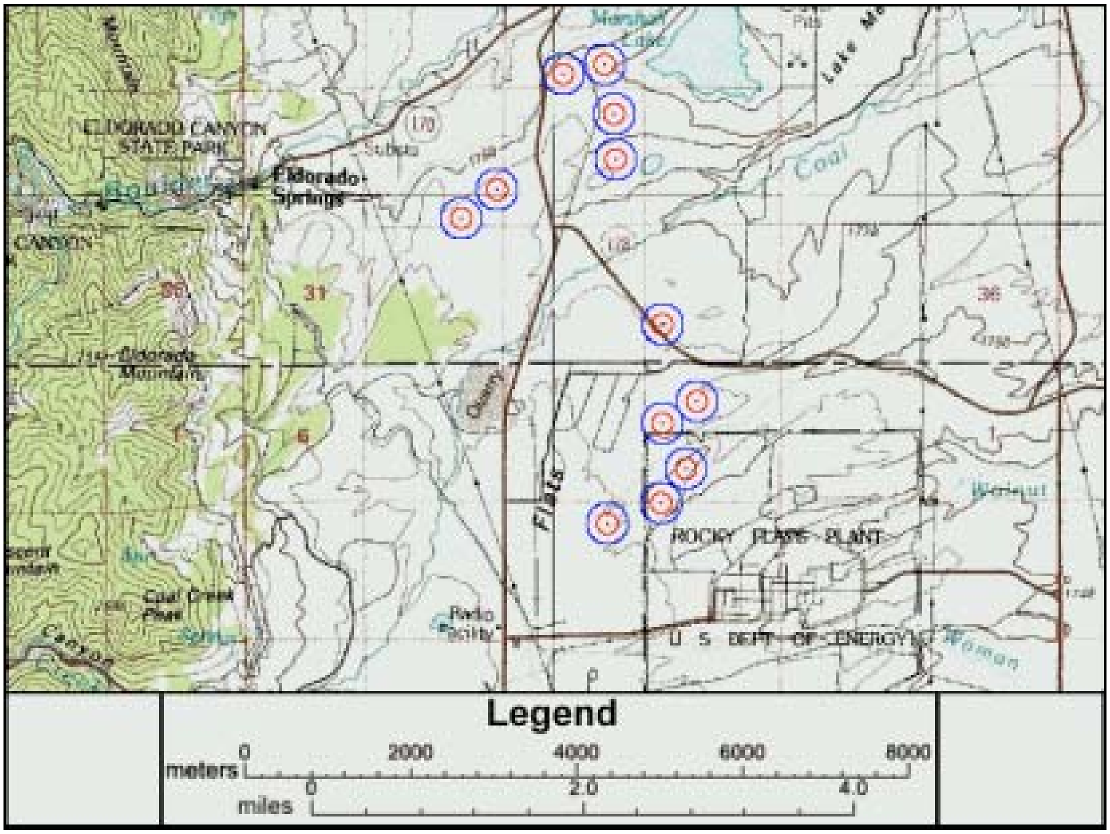

Figure I-2. Location of point counts surrounding the NWTC.

During grassland point counts we placed each bird sighting into one of four categories of flight height (<6, 6–20, 21–50, or >50 m aboveground) and, at the NWTC, distance to the nearest aerial structure (<50, 50–100, 100–200, or >200 m). We also placed each sighting at the NWTC into one of six categories based on apparent responses (or a lack of them) to structures: (1) no alteration of behavior; (2) perching, which included the act of landing on turbines, meteorological towers, or guide wires; (3) abrupt altitude change; (4) circling the structure; (5) reversal of flight direction after approaching a structure; and (6) collision with a structure (Savereno et al. 1996).

Raptor Abundance

We counted raptors on the 18 plots simultaneously with non-raptor species and recorded the same behavioral data for each. However, because of the relative visibility and scarcity of raptors, we expanded each plot radius to 200 m (Figures I-1 and I-2) and extended each count time to 30 min.

Determination of Bat and Avian Mortality

We established ten 50-m-radius carcass search plots at the NWTC in positions where the presence of wind turbines or other aerial structures such as meteorological towers made impacts on birds and bats likely (Figure I-3). Ten similar plots were set out off the NWTC, five each on Rocky Flats and Boulder Open Space. We searched each plot at the beginning of the study and removed all carcasses. A single observer then walked each plot once every 2 weeks for the 12-month duration of the project, noting the date, location, and identity of any carcass found (Savereno et al. 1996).

Figure I-3. Location of carcass search plots on the NWTC.

To accurately quantify bat and avian mortality, we needed to estimate rates of carcass scavenging (removal) as well as observer efficiencies in carcass detection (Osborn et al. 2000). To determine scavenger rates, ten bird and mouse (to simulate bats) carcasses were placed throughout the NWTC site four times per year and revisited once every 4 to 5 days for a period of 21 days. These experiments began on July 5, 2001; November 15, 2001; January 9, 2002; and April 11, 2002, respectively. During each visit, we recorded data on the presence or absence of the carcass and on signs of scavenging activity in the area. To estimate searcher efficiencies, a third party placed an undisclosed number of bird carcasses or simulated bird carcasses in the NWTC search area four times during the course of the study, at places and times unknown to the searchers. In all, 41 objects were set out during the course of the study.

Statistical Analyses

For all tests, we considered $p < 0.05$ to be statistically significant and $p < 0.10$ to be marginally significant. Nonparametric statistics were applied in most cases because of unequal variances or lack of replication (Zar 1999).

Raptor and Non-Raptor Utilization

For grassland birds, we computed the mean number per point count for each species on each plot averaged across all 45 counts, and then compared these on the NWTC site versus off site using the Kruskal-Wallis H statistic. Raptor and non-raptor species richness was estimated as the average number of species observed per count. We then compared these between the sites using repeated-measures analysis of variance, with sampling date as the within-subjects (repeated measures) factor, and site type (NWTC versus off-site plots) as the between-subjects (treatment) factor. In the event of significant interaction between sampling date and treatment factor, we divided richness data into winter (November through February) and summer seasons, calculated the average richness for each plot per season, and used Kruskal-Wallis tests to determine how seasonal variation influenced richness on versus off the site.

Because there was room for only one ponderosa pine plot on the NWTC site, we were severely limited in our ability to make meaningful statistical comparisons of pine forest birds on versus off the site. We compared the total numbers of birds counted on the NWTC plot during the year against combined numbers counted on the two pine plots on Boulder Open Space, using Chi-square goodness-of-fit tests against null expectations of twice as many birds being counted on the open space. We took a similar approach to comparing birds counted on the single undeveloped grassland plot on the NWTC site compared to the four developed plots. In cases in which expected values for bird sighting frequencies were less than 5, we were unable to conduct Chi-square tests (Zar 1999).

Behavioral Responses

Chi-square tests of independence were used to compare frequencies of flight height categories of raptors and non-raptors on versus off the NWTC site, and to compare behavioral responses of non-raptors versus raptors to aerial structures at the NWTC.

Mortality

The average number of control birds recovered by searchers generated an estimate of searcher efficiency (proportion of birds found). The number of carcasses remaining after 21 days yielded an estimate of birds lost to scavenging. As indicated in Table I-1, these estimates were then applied to the actual numbers of dead birds found, to estimate bird mortality.

Table I-1. Procedures for calculating the Total Bird Mortality Estimate

Formula Component	Function
Proportion of Birds Not Lost to Scavenging (PBNLS)	Measured
Proportion of Birds Found (PBF)	Measured
Probability of Not Being Scavenged and of Being Found (POBF)	(PBNLS) * (PBF)
Total Dead Birds Found (TDBF)	Measured
Total Bird Mortality Estimate	(TDBF) / (POBF)

Results

We counted 2,453 individual birds, of which 212 were raptors.

Birds in Grasslands

The average number of raptor species per count did not differ between the NWTC and adjacent areas over the whole year, but it was higher overall in winter (Table I-2). During winter, raptor species richness per count was nearly two times higher at the NWTC than in adjacent areas (Table I-3). However, no individual species of raptor or other large bird differed in abundance on versus off the NWTC site (Table I-4). The average point count yielded about 0.27 more non-raptor species in grasslands off the NWTC than on it, a statistically significant difference (Table I-2). However, only one species (the horned lark) differed among treatments (Table I-5), being more than 16 times more common off the site.

Non-raptors were observed at similar heights on versus off the NWTC site (Table I-6). Raptors were seen within 5 m of the ground about 32% of the time at the NWTC, but they were this close to the ground 49% of the time in adjacent areas. This result indicates that birds of prey flew and perched somewhat higher on the NWTC than in areas without wind-generating structures, although this difference was only marginally significant (Table I-7). On the NWTC site, raptors were more likely to be within 50 m of an aerial structure than were non-raptors (47% versus 15% of sightings; Table I-8). Raptors also were much more likely than non-raptors to respond to an aerial structure by perching on it at NWTC (27% versus 3%; Table I-9).

Birds on NWTC Grasslands With and Without Facilities

The total count of non-raptors on the undeveloped grassland plot south of the NWTC facility did not differ from that of the average on the four developed plots (Table I-10). However, raptors used the undeveloped plot less than half as often as the areas with wind-energy-generating facilities.

Birds in Pine Forest

Three bird species were counted significantly more often than expected on the NWTC pine plot compared to the two pine plots on Boulder Open Space: American kestrel, mountain bluebird, and chipping sparrow (Tables I-11 and I-12). One species, the tree swallow, showed the opposite trend.

Scavenger Tests

During the four trials, six, four, five, and six of the original ten carcasses, respectively, remained after 21 days, for an average of 52.5% not lost to scavenging.

Table I-2. Means and (standard errors) of raptor and non-raptor richness per count on NWTC and off-site grassland plots

Comparison					Treatment Factor F	Treatment Factor *p*	Temporal Factor F	Temporal Factor *p*	Intercept Factor F	Intercept Factor *p*
	NWTC		Off Site							
Raptor richness	0.267	(0.033)	0.196	(0.022)	1.44	0.251	1.677	0.005	1.810	0.002
Non-raptor richness	1.018	(0.072)	1.291	(0.065)	8.649	0.012	1.377	<0.001	0.138	0.057

Notes: Significant ($p < 0.05$) differences in treatment factor analyses indicate differences in richness between sites. Significant differences in temporal factor analyses indicate significant seasonal variation within richness, and significant intercept values indicate interactions between site and season (n_{NREL}= 225, $n_{Off\ Site}$ = 450, treatment d.f. = 1, temporal and intercept d.f. = 44).

Table I-3. Post hoc seasonal comparisons of mean raptor richness per plot of grasslands on and off of the NWTC (n_{NWTC}.=5, $n_{Off\ Site}$=10)

Season	NWTC		Off Site		Kruskal-Wallis H	Kruskal-Wallis *p*
Summer	0.265	(0.068)	0.219	(0.023)	0.707	0.480
Winter	0.324	(0.044)	0.153	(0.147)	2.547	0.011

Table I-4. Mean abundance per count and (standard error) of raptors and other large birds per 30-min 200-m-radius fixed-distance point count on the NWTC grassland plots versus nearby grassland plots on Boulder Open Space and the Rocky Flats Environmental Technology Site

Species		NWTC		Off Site		Kruskal-Wallis H	Kruskal-Wallis *p*
Canada goose	*Branta canadensis*	0.000	(0.000)	0.004	(0.004)	0.566	0.572
Mallard	*Anas platyrhynchos*	0.013	(0.013)	0.000	(0.000)	1.273	0.203
Double-crested cormorant	*Phalacrocorax auritus*	0.004	(0.004)	0.007	(0.005)	< 0.001	1.000
Great blue heron	*Ardea herodias*	0.013	(0.008)	0.004	(0.003)	0.870	0.385
Turkey vulture	*Cathartes aura*	0.013	(0.008)	0.016	(0.009)	0.204	0.839
Northern harrier	*Circus cyaneus*	0.027	(0.011)	0.027	(0.008)	0.319	0.750
Golden eagle	*Aquila chrysaetos*	0.004	(0.004)	0.011	(0.006)	0.739	0.460
Bald eagle	*Haliaeetus leucocephalus*	0.000	(0.000)	0.007	(0.004)	1.234	0.217
Red-tailed hawk	*Buteo jamaicensis*	0.062	(0.017)	0.069	(0.016)	< 0.001	1.000
Rough-legged hawk	*Buteo lagopus*	0.004	(0.004)	0.013	(0.005)	0.739	0.460
Ferruginous hawk	*Buteo regalis*	0.004	(0.004)	0.016	(0.007)	0.806	0.420
American kestrel	*Falco sparverius*	0.160	(0.030)	0.078	(0.015)	1.368	0.171
Prairie falcon	*Falco mexicanus*	0.004	(0.004)	0.002	(0.002)	0.415	0.678
Peregrine falcon	*Falco peregrinus*	0.004	(0.004)	0.000	(0.000)	1.273	0.203

Note: Kruskal-Wallis p values < 0.05 indicate significant differences between NWTC and off-site abundances (n_{NWTC} = 5, $n_{Off\ Site}$ = 10).

Table I-5. Mean abundance per count and (standard error) of songbirds and other small birds per 10-min 100-m-radius fixed-distance point count on the NWTC grassland plots versus nearby grassland plots on Boulder Open Space and the Rocky Flats Environmental Technology Site

Species		NWTC		Off Site		Kruskal-Wallis H	Kruskal-Wallis *p*
Ring-billed gull	*Larus delawarensis*	0.000	(0.000)	0.002	(0.002)	0.566	0.572
Mourning dove	*Zenaida macroura*	0.058	(0.024)	0.029	(0.011)	0.954	0.340
Budgerigar	*Melopsittacus undulatus*	0.000	(0.000)	0.002	(0.002)	0.566	0.572
Common nighthawk	*Chordeiles minor*	0.009	(0.009)	0.031	(0.013)	1.202	0.229
Broad-tailed hummingbird	*Selasphorus platycercus*	0.000	(0.000)	0.002	(0.002)	0.566	0.572
Northern flicker	*Colaptes auratus*	0.000	(0.000)	0.002	(0.002)	0.566	0.572
Say's phoebe	*Sayornis saya*	0.031	(0.013)	0.011	(0.006)	1.185	0.234
Western kingbird	*Tyrannus verticalis*	0.000	(0.000)	0.004	(0.003)	0.934	0.350
Black-billed magpie	*Pica hudsonia*	0.053	(0.016)	0.049	(0.014)	0.320	0.749
Common raven	*Corvus corax*	0.013	(0.008)	0.076	(0.024)	0.894	0.371
Horned lark	*Eremophila alpestris*	0.022	(0.016)	0.360	(0.054)	2.408	0.016
Cliff swallow	*Petrochelidon pyrrhonota*	0.018	(0.014)	0.142	(0.061)	1.575	0.115
Barn swallow	*Hirundo rustica*	0.009	(0.006)	0.042	(0.014)	0.988	0.323
Mountain bluebird	*Sialia currucoides*	0.000	(0.000)	0.022	(0.022)	0.566	0.572
American robin	*Turdus migratorius*	0.000	(0.000)	0.002	(0.002)	0.566	0.572
European starling	*Sturnus vulgaris*	0.067	(0.024)	0.027	(0.009)	1.622	0.105
Green-tailed towhee	*Pipilo chlorurus*	0.004	(0.004)	0.000	(0.000)	1.273	0.203
Spotted towhee	*Pipilo maculatus*	0.000	(0.000)	0.002	(0.002)	0.566	0.572
Chipping sparrow	*Spizella passerina*	0.000	(0.000)	0.002	(0.002)	0.566	0.572
Lark sparrow	*Chondestes grammacus*	0.000	(0.000)	0.040	(0.024)	1.228	0.220
Grasshopper sparrow	*Ammodramus savannarum*	0.040	(0.013)	0.060	(0.015)	0.127	0.899
Lark bunting	*Calamospiza melanocorys*	0.000	(0.000)	0.002	(0.002)	0.566	0.572
Savannah sparrow	*Passerculus sandwichensis*	0.000	(0.000)	0.002	(0.002)	0.566	0.572
Vesper sparrow	*Pooecetes gramineus*	0.751	(0.092)	1.022	(0.085)	1.289	0.197
Blue grosbeak	*Guiraca caerulea*	0.000	(0.000)	0.002	(0.002)	0.566	0.572
Western meadowlark	*Sturnella neglecta*	0.853	(0.088)	0.776	(0.062)	0.676	0.499
Red-winged blackbird	*Agelaius phoeniceus*	0.004	(0.004)	0.042	(0.020)	1.599	0.110
Common grackle	*Quiscalus quiscula*	0.022	(0.022)	0.000	(0.000)	1.273	0.203
Brewer's blackbird	*Euphagus cyanocephalus*	0.000	(0.000)	0.009	(0.005)	1.228	0.219
Brown-headed cowbird	*Molothrus ater*	0.000	(0.000)	0.016	(0.007)	1.761	0.078
Bullock's oriole	*Icterus bullockii*	0.000	(0.000)	0.002	(0.002)	0.566	0.572
American goldfinch	*Carduelis tristis*	0.022	(0.010)	0.049	(0.011)	1.004	0.286

Note: Kruskal-Wallis p values < 0.05 indicate significant differences between NWTC and off-site abundances ($n_{NWTC} = 5$, $n_{OffSite} = 10$).

Table I-6. Frequency of non-raptor flight and perch height occurrence on NWTC and off-site grassland areas

Site	Flight Height Category			
	<5 m	6–20 m	21–50 m	>50 m
NWTC	88.66%	9.62%	1.58%	0.00%
Off site	89.36%	9.82%	0.63%	0.13%

Note: Chi-square results indicate no significant differences (n = 2231, d.f. = 3, Chi-square = 5.432, p = 0.143).

Table I-7. Frequency of raptor flight and perch height occurrence on NWTC and off-site grassland areas

Site	Flight Height Category			
	<5 m	6–20 m	21–50 m	>50 m
NWTC	32.26%	46.24%	20.43%	1.08%
Off site	48.84%	31.78%	17.05%	2.33%

Note: Chi-square results indicate marginal differences (n = 222, d.f. = 3, Chi-square = 7.419, p = 0.062).

Table I-8. Frequency of raptor and non-raptor occurrence at varying lateral distances from aerial structures on the NWTC grasslands

Comparison	Lateral Distance from Aerial Structure			
	<50 m	51–100 m	101–200 m	>200 m
Non-raptor	15.46%	13.41%	17.82%	53.31%
Raptor	47.31%	11.83%	12.90%	27.96%

Note: Chi-square analyses indicate significant differences between raptor and non-raptor use (n = 727, d.f.=3, Chi-square = 53.842, p < 0.0001).

Table I-9. Frequency of raptor and non-raptor behavioral responses on the NWTC grasslands

Site	Behavioral Response				
	No Response	Perch	Altitude Adjustment	Circle	Reversal
Non-raptor	96.21%	3.47%	0.00%	0.32%	0.00%
Raptor	62.37%	26.88%	1.08%	8.60%	1.08%

Note: Results of Chi-square tests indicate significant differences (n = 727, d.f. = 4, Chi-square = 132.997, p < 0.001).

Table I-10. Total abundance of raptors and non-raptors counted on one undeveloped plot and the mean of four developed plots on the NWTC

Species	Developed Mean Total Abundance	Undeveloped Total Abundance	Chi-Square Value	Chi-Square p
Non-raptor	86.5	103	2.42539	n. s.
Raptor	16.5	6	6.125	< 0.025

Note: Significant (p < 0.05) Chi-square values indicate differences in total abundance compared to the null expectation of even distributions among treatments.

Table I-11. Total abundance of songbirds and other small birds counted on one ponderosa pine plot on the NWTC and the mean of two plots off the NWTC site

Species		NWTC Total Abundance	Off Site Mean Total Abundance	Chi-Square Value*	Chi-Square *p*
Mourning dove	*Zenaida macroura*	2	0		
Broad-tailed hummingbird	*Selasphorus platycercus*	1	0		
Northern flicker	*Colaptes auratus*	8	0		
Say's phoebe	*Sayornis saya*	4	0		
Black-billed magpie	*Pica hudsonia*	17	10	2.650	n.s.†
Common raven	*Corvus corvax*	1	1		
Tree swallow	*Tachycineta bicolor*	0	12.5	12.490	<0.001
Cliff swallow	*Petrochelidon pyrrhonota*	5	0		
Barn swallow	*Hirundo rustica*	0	1.5		
Black-capped chickadee	*Poecile atricapilla*	1	0		
Blue-gray gnatcatcher	*Polioptila caerulea*	2	0		
Mountain bluebird	*Sialia currucoides*	20	0	39.970	<0.001
American robin	*Turdus migratorius*	3	0.5		
European starling	*Sturnus vulgaris*	4	0		
Green-tailed towhee	*Pipilo chlorurus*	4	0		
Chipping sparrow	*Spizella passerina*	49	22.5	14.948	<0.001
Lark sparrow	*Chondestes grammacus*	2	0		
Vesper sparrow	*Pooecetes gramineus*	15	13.5	0.107	n.s.
Western meadow lark	*Sturnella neglecta*	25	15.5	3.219	n.s.
Common grackle	*Quiscalus quiscula*	1	0.5		
Brown-headed cowbird	*Molothrus ater*	1	0		
House finch	*Carpodacus mexicanus*	2	0		
American goldfinch	*Carduelis tristis*	13	0		
Lesser goldfinch	*Carduelis psaltria*	0	2.5		

*Conducted only where Chi-square expected values were greater than or equal to 5 (Zar 1999).
†not significant

Note: Significant ($p < 0.05$) Chi-square values indicate differences in total abundance compared to the null expectation of even distributions between sites.

Table I-12. Total abundance of raptors and other large birds counted on one ponderosa pine plot on the NWTC and the mean of two plots off the NWTC site

Species		NWTC Total Abundance	Off Site Mean Total Abundance	Chi-Square Value	Chi-Square *p*
Double-crested cormorant	*Phalacrocorax auritus*	1	0		
Northern harrier	*Circus cyaneus*	2	0.5		
Golden eagle	*Aquila chrysaetos*	1	0		
Red-tailed hawk	*Buteo jamaicensis*	5	1		
American kestrel	*Falco sparverius*	14	5	6.75	<0.025

Note: Significant ($p < 0.05$) Chi-square values indicate differences in total abundance compared to the null expectation of even distributions between sites.

Searcher Efficiencies

Of the 41 carcasses or carcass models placed in the search areas, the searchers found 17. Eleven objects disappeared (could not be found by the individual who placed them), and we presumed that these were blown away by wind, carried away by an animal, or scavenged completely. Because we were unable to determine whether the 11 missing objects were present at the time of carcass searches, we disregarded them in determination of carcass searcher efficiency. Therefore, we calculated carcass searcher efficiency as 17 of 30, or 56.7%.

Carcass Searches

Two carcasses were discovered during initial searches of the NWTC: a yellow-rumped warbler (*Dendroica coronata*) and an American kestrel (*Falco sparverius*). Only four carcasses were found during successive searches at the NWTC during the subsequent year. A black-billed magpie (*Pica hudsonia*) was found at the base of a large turbine on July 14, 2001; a western meadowlark (*Sturnella neglecta*) on August 8, 2001; a Wilson's warbler (*Wilsonia pusilla*) under guide wires at a met tower on August 24, 2001; and a chickadee (*Poecile* sp.) beneath guide wires on March 5, 2002. We were unable to determine the species of the chickadee because its head was not present.

No carcasses were found on search plots located off the NWTC site.

Total Mortality Estimate

Following the procedures outlined in Table I-1, we estimate 13 fatalities of birds in the area searched at the NWTC during the 12-month period. This calculation is the probability of a carcass not being scavenged (0.525) times the probability of a carcass being found (0.57), divided into the number of carcasses found (4), to equal 13.445.

We estimate that our search area incorporated 55.6% of all aerial structures on the NWTC site. Assuming that mortality rates were similar across the site, this would increase the number of fatalities per year to approximately 24 birds. If our limited sample of actual carcasses is representative, few if any of these 24 would be raptors.

Discussion and Recommendations

With regard to the core questions NREL posed about bird use and fatalities at the NWTC site, our study suggests the following:

- With the exception of one American kestrel found during initial searches of the area, we found no evidence of raptor fatalities at the site. Extrapolating from four passerine carcasses found during our searches, we estimate about 24 small birds might be killed per year at the NWTC as it is presently configured. The majority is likely to be killed by wires supporting the meteorological towers rather than by the turbines. None of the birds killed was rare or unusual. Future expansion of the site would be expected to increase fatalities in proportion to the numbers of turbines and associated facilities, as well as to the amount of land involved.

- Birds other than raptors (specifically, songbirds) seem largely unaffected by the NWTC as presently configured. Only one songbird species differed in abundance on versus off the site (the horned lark), and it appears to have been attracted to Boulder Open Space rather than the NWTC because of its preference for short-stature grasslands created by livestock grazing (Beason 1995).

Birds of prey may be attracted to the NWTC because of increased perch availability, but this effect is minor and mostly confined to winter. Despite this possible attraction, we found little evidence of raptor mortality.

- Future expansion of the NWTC site, to include the area immediately south of the present wind turbines and associated facilities, is unlikely to have any significant impacts on bird populations. The site is embedded in a large undeveloped area (Boulder Open Space and the Rocky Flats Buffer Zone) that is unlikely to change significantly in the foreseeable future. Movements of birds such as eagles and falcons across this landscape are unimpeded by the NWTC because it encompasses a relatively small amount of the regional landscape.

Boulder Valley grasslands support a rich variety and abundance of both songbirds and birds of prey, largely because of current levels of protection of open space (Jones and Bock 2002). However, most species tend to avoid urban edges (Berry and Bock 1998; Haire et al. 2000), and regional persistence of many species may depend on future levels of development. As presently configured, the NWTC site is part of that relatively large natural area, in addition to lands that are part of the Rocky Flats site, and the open space lands managed by both the city and county of Boulder. Based on the documented sensitivities of both raptors and songbirds to development elsewhere in the region, potential negative impacts of the NWTC are more likely to come from extensive development of buildings and roads rather than the wind turbines.

Birds of prey are particularly common in the Boulder Valley region in winter (Berry and Bock 1998), and the results of this study suggest that they are attracted to the NWTC site at this season, although the effect is small. During our study, the NWTC was used primarily by American kestrels and red-tailed hawks.

Results of this study make clear the moderate numerical and behavioral responses of birds to the NWTC in grassland areas. However, we have relatively little confidence that our data from the forested rocky outcrop at the NWTC, compared to nearby pine sites on Boulder Open Space, suggest anything about the impacts of wind facilities on birds in this habitat type. The unavoidable lack of pine plot replication makes it highly likely that differences we found were due to chance differences in the places we sampled. In fact, the outcrop area on the NWTC site is unusual in the area, especially for its amount of shrub cover.

For future studies, estimates of mortality could be improved with better protocols for measuring searcher efficiency, especially on smaller wind facilities where mortalities are infrequent. We suggest that rather than using dead carcasses (which may be unavailable on smaller sites) for searcher efficiency tests, accurate models of varying sizes may be more appropriate, especially if they can be physically attached to the ground to prevent loss to scavengers. Additionally, future studies may investigate the differences between using larger and smaller models, to better simulate raptor and smaller bird mortality. Finally, estimates of raptor and non-raptor mortality should be calculated separately, to control for differences in carcass visibility.

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Part II: Bat Use and Fatalities at the National Wind Technology Center, June 2001–June 2002

Introduction

The purpose of this study was to ascertain actual and potential impacts of wind energy technologies on bat populations on the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) National Wind Technology Center (NWTC) site. The principal field site is the facility per se, which is located immediately north of the Rocky Flats Environmental Technology Site (RFETS), and just east of the intersection of Colorado highways 93 and 128, in northern Jefferson County, Colorado. We evaluated the impacts by conducting an initial examination of species richness and abundance of bats on the NWTC site and the overall study area. This report describes a Phase I study (Morrison 1994; Anderson et al. 1999) of the NWTC.

We predicted low abundance and diversity of bats associated with grasslands of the NWTC, based on previous studies (Adams 1990; Armstrong, Adams, and Freeman 1994). Species expected in the vicinity of the NWTC are listed in Table II-1 (Armstrong, Adams, and Freeman 1994).

The study objectives were to address core questions NREL posed about possible impacts of the NWTC on bat populations:

- What levels of bat mortality are associated with the present NWTC facility, and how might this change with future expansions at the site and with regional land use changes?
- How does the present NWTC facility affect abundance and movement patterns of bats, both on the site and regionally?
- How might these abundance and movement patterns change in the future as the NWTC site is expanded and as regional land use patterns develop? Of particular interest here is the likely conversion of the present Rocky Flats Buffer Zone into a National Wildlife Refuge.

Methods

Four methods were proposed to address the core questions and achieve the overall objectives: ultrasonic detection, visual and acoustic counts, capture surveys, and carcass searches.

We conducted visual and acoustic counts on the same 18 observation points used for counting birds (see Part I): six plots on the NWTC, seven on Boulder Open Space, and five at the RFETS. For the acoustic counts, we used a Batbox heterodyne detector. Our original study design called for equal detection efforts on all 18 plots. However, because of the limited survey season, we concentrated most of the sampling effort on the NWTC site—counting bats on 27 nights at the NWTC, six nights on Boulder Open Space, and six nights on the RFETS, between June 6, 2001 and June 12, 2002 (Table II-2). Counting occurred from 30 min before sunset to 1hr after sunset because this is the period of highest bat activity (Jones et al. 1996).

Table II-1. Some natural history traits of bats documented from Boulder and/or Jefferson counties, Colorado (data from Armstrong, Adams, and Freeman 1994; Fitzgerald, Meaney, and Armstrong 1994)

Species	Common Name	Habitat		Diet	Hibernal Habits
		Roosting	Foraging		
Myotis ciliolabrum	Western small-footed myotis	Rock outcrops, caves, mines	Roughlands, among boulders, shrubs	Flies, small beetles, winged ants	Hibernates locally in mines, caves, tunnels
Myotis evotis	Long-eared myotis	Tree hollows, abandoned buildings, mines	Over water, forest gaps, near trees	Beetles, moths, flies	Presumed migrant
Myotis lucifugus	Little brown bat	Attics, mines, buildings	Over water, clearings, lawns	Moths, aquatic insects	Hibernates locally, sometimes in buildings
Myotis thysanodes	Fringed myotis	Crevices, trees, caves	Over shrubs, woodlands	Moths, beetles, phalangerids, winged ants, caddisflies, wasps	Presumed to hibernate locally
Myotis volans	Long-legged myotis	Under bark, rock fissures, buildings	Over ponds, streams, forest gaps and edges	Moths	Presumed to hibernate locally
Lasiurus borealis	Eastern red bat	Deciduous trees	Over and among trees	Moths, flies, beetles	Long-distance migrant; hibernal range unknown
Lasiurus cinereus	Hoary bat	Trees, broad-leafed and deciduous	Forest openings, edge	Moths, smaller bats	Long-distance migrant; hibernal range unknown
Lasionycteris noctivagans	Silver-haired bat	Trees, beneath bark, open caves	Over ponds, clearings in forest	Moths, flies, beetles	Long-distance migrant; hibernal range unknown
Eptesicus fuscus	Big brown bat	Buildings, caves, crevices	Open areas	Larger insects, especially beetles	Hibernates locally
Plecotus townsendii	Townsend's big-eared bat	Caves, mines, structures	Near shrubs, over water, forest gaps	Moths, flies, beetles, aquatic insects	Hibernates locally
Tadarida brasiliensis	Mexican free-tailed bat	Caves, mines	Over shrublands, fields	Moths	Long-distance migrant; Mexico?

Table II-2. Results of nights spent collecting visual and acoustic data and number of bats observed

Date	Plots						Boulder Open Space	Rocky Flats	Feeding Buzzes
	1	2	3	4	5	6			
06/06/01	0								
06/14/01			0						
06/27/01							5		No
06/28/01		2							No
07/02/01					2				No
07/03/01							5		No
07/09/01								7	No
07/12/01				18					Yes
07/17/01							17		No
07/18/01						—			No
07/24/01							0		
07/25/01						43			Yes
07/30/01				7					Yes
08/14/01			—						
08/21/02								0	
08/23/01								1	
08/28/01							0		
08/29/01								4	Yes
09/04/01						3			No
09/10/01		7							Yes
09/24/01				0					
09/25/01							1		No
09/26/01								0	
04/15/02	0								
05/06/02	0								

Notes: Survey nights begun and then cancelled because of weather are indicated by "—". NWTC plots are broken into individual plots; Boulder Open Space plots and Rocky Flats plots are grouped.

Ultrasonic detection surveys were also conducted primarily on the NWTC plots (Table II-3). In all, 22 surveys were conducted during this study (Table II-3). Eleven ultrasonic detection surveys were carried out simultaneously with a visual and acoustic count. In addition, there were 11 ultrasonic detection surveys in which the recording system was set to run automatically while the field technician performed a visual and acoustic survey on a separate plot. We expected to distinguish bat species using ultrasonic recordings with the SonoBat software on a Panasonic Toughbook laptop computer in conjunction with a Pettersson 240X detector (Parsons, Boonman, and Obrist 2000; Szewczak 2000). This detector is a heterodyne, time-expansion detector that allows harmonics to be captured, stored, and analyzed. Although this system is well suited for analyzing bat echolocations, it has a decreased sensitivity to weak signals that are detected by heterodyne detectors without time expansion, such as the Batbox. Further, while this system is detecting a call and subjecting it to time expansion (approximately 17 s), no other bat passes are recorded. Therefore, ultrasonic surveys were often conducted in conjunction with a visual and acoustic survey to accomplish a more accurate count of bat passes. Surveys in which the Pettersson detector was left alone to record echolocations occurred primarily on the NWTC site because regular security patrols ensured that this expensive equipment would not be stolen.

Table II-3. Results of nights spent collecting ultrasonic data and number and possible species identification of bats detected

Date	Plots						Boulder Open Space	Rocky Flats	Species Detected	Feeding Buzzes
	1	2	3	4	5	6				
07/05/01			0							
07/30/01	43									Yes
08/08/01							4			No
08/13/01			—							
08/15/01					2				*Lasionycteris noctivagans* and/or *Tadarida brasiliensis*	No
08/20/01	35								*Myotis ciliolabrum* and/or *Myotis volans, Myotis lucifugus* and *Lasiurus cinereus*	Yes
08/21/01				0						
08/22/01			1						*Lasionycteris noctivagans* or *Tadarida brasiliensis*	No
08/23/01		0								
08/24/01			6							Yes
08/28/01							0			
08/29/01								0		
09/04/01					6				*Myotis ciliolabrum* and/or *Myotis volans*	No
09/05/01				4					*Myotis ciliolabrum* and/or *Myotis volans*	No
09/10/01	1								*Myotis ciliolabrum* or *Myotis lucifugus*	No
09/24/01			0							No
09/25/01							0			No
09/26/01								0		No
10/02/01								0		No
10/03/01	8									Yes
10/08/01	5									No
05/06/02	0									No
06/12/02	23									Yes

Notes: Survey nights begun and then cancelled because of weather are indicated by "—". Data on the NWTC site are tabulated by individual plot; Boulder Open Space plots and Rocky Flats plots are grouped.

Originally, we had hoped to establish a local call library to allow us to distinguish calls and assign them to species. Training is required for a field technician to set up a local call library, but because training could not be arranged, a library could not be established. However, because California and Colorado share all the bat species suspected to occur in the NWTC, vocalizations were compared to a library of California bats. Recordings of calls were archived on the NREL Panasonic Toughbook laptop (assigned to this and future ultrasonic recording projects for NREL), and if a Colorado call library is established in the future, these data could be reanalyzed and vocalizations assigned to a single species. Using the California data allowed us to determine and assign the calls, usually to one of two species (Table II-3).

Capture (netting) surveys were conducted at possible roosting, drinking, and/or foraging sites both at the NWTC and within 4 km surrounding the NWTC site. Because of the weather, some equipment problems, and the heightened security occasioned by the events of September 11, capture surveys became a lower priority and were conducted less frequently than originally envisioned in our study plan. There were four capture surveys on Boulder Open Space lands (because of the presence of ponds), one on the RFETS, and one at the NWTC. Because bats drink immediately on awakening from their daily torpor (Fitzgerald, Meaney, and Armstrong 1994), capture surveys were conducted using mist nets over bodies of water. Jones and colleagues (1996) described mist nets and methods of deployment in detail. Captured bats are identified by species and morphological data were recorded on capture data sheets. Typically one net (Avinet bat-specific mist net 9.0 m × 2.1 m, 30-mm mesh) was set over a pond, except on the NWTC, where several nets were placed in the trees on the northwestern section of the site.

We conducted carcass searches, scavenging tests, and searcher efficiency tests simultaneously for birds and bats, and these methods are described in Part I.

Results

During visual and acoustic surveys, ultrasonic techniques were used to detect bats emitting feeding buzzes. In addition, bats were visually observed pursuing and capturing prey. These observations occurred primarily on plots 1, 3, and 4 at the NWTC (see Part I, Figure I-1). These observation points are in areas where no turbines, weather towers, or guy-lines are currently located. Small agile bats (suspected to be a *Myotis* species) were often detected and observed to be foraging among the trees near Site 1, and these were the species identified by numerous ultrasonic recordings at this site. This site has the largest concentration of trees on the NWTC site, and it is directly adjacent to a rocky outcropping on Boulder Open Space, which may provide roosting habitat for bats such as *Myotis ciliolabrum* and *Myotis lucifugus.* Twenty-seven survey nights at the NWTC detected 216 bats, six survey nights on Boulder Open Space detected 32 bats, and six survey nights at RFETS recorded 12 bats (Table II-2). Boulder Open Space plots were divided into two west and five east of State Highway 93 (see Part I, Figure I-2). Bats were detected in small numbers in the eastern portion (five surveys, 9 bats) and in higher numbers to the west (four surveys, 23 bats). Significantly more bats were detected on the NWTC site than off the site (with Boulder Open Space and RFETS considered together; $\chi 2 = 51.77$, $p < 0.0001$).

Only 6 out of the 19 species in Colorado were identified as possibly occurring at the NWTC (Table II-3), based on ultrasonic detection methods: *Myotis ciliolabrum*, *Myotis lucifugus*, *Myotis volans*, *Lasionycteris noctivagans*, *Lasiurus cinereus*, and *Tadarida brasiliensis*. Because of uncertainties in resolving the ultrasonic signals, however, it was impossible to distinguish *Lasionycteris* from *Tadarida*, or the members of the *Myotis* sp. from one another.

The capture survey on RFETS caught no bats and recorded no bat passes. The single survey on the NWTC site caught no bats and recorded only a few passes. Two of the four Boulder Open Space surveys indicated that bats were not using those particular ponds, while a third caught no bats but recorded a few passes. The fourth survey detected many bats using the Lindsey Pond (39.9169°N latitude, 105.2620° W longitude) and we captured an adult male *Myotis thysanodes* and an adult male *Eptesicus fuscus*. Neither of these species was detected by the ultrasonic surveys.

We found no bat carcasses on any of the search plots.

Discussion

In terms of the core questions NREL posed about bat use and fatalities at the NWTC site, our study suggests the following:

- We detected no evidence of bat mortality associated with the present NWTC facility. However, the large number of detections at the western end of the site, apparently associated with the rocky outcrop nearby, suggests a high level of bat activity in this area. Future additions to the facility might take this into account.

- Although the NWTC does not support a large diversity of bat species, it appears that the area on the northwest side of the site, where trees grow close to a rocky outcropping (on Boulder Open Space), provides an important foraging and perhaps roosting habitat. This may account for the significantly higher number of bats foraging on the NWTC than on surrounding areas (Boulder Open Space and RFETS). However, it appears that the current NWTC facility does not directly affect the abundance and movement patterns of bats on the site or in the region.

- Our study results suggest that possibly six species of bats used the NWTC site for foraging, and some of these may have also roosted on nearby Boulder Open Space. Movement patterns of bats could not be determined with the techniques used in this study. Such information can be determined only by capturing bats on the NWTC site, radio-tagging them, and tracking them. Any expansion of the NWTC should consider impacts on the bats that use the site. If, in the future, activities expand at the NWTC, it will be important to monitor bat activity and movement patterns to avoid any negative effects. This study demonstrates that surveys in June, July, and August are adequate for observing the peak use of the NWTC by bats. Therefore, any future investigations of bats should be performed during the summer. Any changes of the facilities during the summer may have a higher impact on bat activity than during other seasons. As the Rocky Flats Buffer Zone is converted to a National Wildlife Refuge, the NWTC will probably not affect the abundance of bats on the RFETS because few bats were detected there. Further, because the conversion of the RFETS will not change land-use patterns, we would not predict effects on bat abundance or movement patterns. A site on the southern end of the NWTC, which may have ownership transferred from the NWTC to the adjacent quarry, also has very little bat activity and should not affect the abundance of bats in this area if land-use patterns are altered in that area. The only possible action that might negatively affect bat abundance or movement patterns would be a conversion of the wooded area in the northwestern portion of the NWTC because bats appear to forage heavily among the trees.

Results of this study were limited by technical difficulties in getting started with the ultrasonic detections, by an unusual number of nights in the summer of 2001 that were interrupted by monsoonal rains that precluded bat activity, and by limited access to the NWTC and Rocky Flats following the events of September 11. Also, from late October until April bats are not known to forage consistently so surveys were not conducted.

Bats were rarely detected on the five survey points on Rocky Flats (Table II-2). Bats were detected in small numbers in the eastern portion of Boulder Open Space and in higher numbers to the west. This result likely is attributable to the fact that the western sites were closer to the foothills, where there is more suitable roosting habitat.

The NWTC had significantly more foraging activity than was observed on the replicate plots on Boulder Open Space or the RFETS. This likely was due to the availability of a potential roost site associated with the rocky outcrop just northwest of the NWTC. Adams (1990) concluded that patterns of distributions of bats in Colorado are limited by availability of roosting habitat.

Although mist-netting on the NWTC did not produce any captures, it is likely that a concerted effort near the trees at the northwestern end of the site would produce positive results. This prediction is based on observation of bats foraging among these trees at heights low enough to be covered by the mist net. However, it was September when we attempted to net here, and bat numbers had dropped dramatically from their earlier, highest abundance. Netting would probably be more successful in July or August.

We predicted that NWTC would not have high diversity or abundance of bats based on previous assessments of bats in grasslands (Adams 1990; Armstrong, Adams, and Freeman 1994), and the data confirmed that suspicion.

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This study was conducted to ascertain actual and potential impacts of wind turbines on populations of birds and bats at the National Wind Technology Center (NWTC) in northern Jefferson County, Colorado. The NWTC, which is part of the U.S. Department of Energy's National Renewable Energy Laboratory (NREL), is located on a mesa dominated by ungrazed grassland with isolated patches of ponderosa pine. Similar lands to the north and west are part of the city of Boulder's "open space" system. Areas to the east and south are part of the Rocky Flats Environmental Technology Site.

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