RAPTOR PRESENCE IN AND AROUND THE NATIONAL WIND TECHNOLOGY CENTER:

AN ASSESSMENT OF RISKS AND MANAGEMENT ALTERNATIVES

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EXECUTIVE SUMMARY

Under a contract with the National Renewable Energy Laboratory (NREL) in the Department of Energy, the National Wind Technology Center (NWTC) was monitored for raptor activity over 17 months (23 February 1994 through 30 June 1995). The three primary objectives of the study were to determine the extent of raptor movements in and around the area, to assess the possible risks to raptors of new wind turbine research and development at the NWTC, and to suggest site-specific management alternatives for operating a raptor-safe environment.

As standard field monitoring procedure, one experienced observer monitored raptor activities in and around the NWTC for 3 three-hour blocks each week, one in the morning (near sunrise), one in mid-day, and one in the afternoon (up to dusk). Usually, these observations fell on different days of the week. Procedures were modified in April of 1995 to better quantify the extent of spring raptor migration. Following methods used by the Dinosaur Ridge Raptor Migration Station (DRRMS), two experienced observers monitored the skies from the NWTC from mid-morning through mid-afternoon on 22 dates in April. Data provided by the DRRMS for the same dates allowed us to assess the fraction of their sightings that were being detected at the NWTC. Eagle counts obtained through observations at the NWTC were supplemented with late afternoon observations from a vantage point near the entrance to the NWTC (CO 128) on 12 dates between 19 December, 1994, and 26 February, 1995. To estimate the number of eagles potentially using the area in and around the NWTC in winter, eagle counts were made in a roost area 6 km northwest of the NWTC in Eldorado Canyon on 5 dates between 27 December 1994 and 23 February, inclusive.

Sixteen diurnal raptors (order: Falconiformes) were censused during 786 hours of field observations conducted on the NWTC over the 17 months of the study (Table 2). Four species regularly used the NWTC for perching during one or more seasons of the year. Red-tailed hawks were year-round residents of the area, along with prairie falcons.

American kestrel used the area in spring and summer, while rough-legged hawks used the area in fall and winter months. Although all four of these species were regularly seen on the NWTC and occasionally engaged in foraging, a potentially risky behavior in and around wind turbines (Orloff and Flannery, 1992), the number of individual birds engaged in these activities was probably small (6 or less, depending on species), especially compared with the size of their regional populations. Thus, site management designed to address turbine risks to these resident species does not appear warranted at this time.

An additional 11 species were mostly censused during spring migration and probably pass through the area in fall as well. Using the DRRMS as a reference point, we detected only about 12% of the birds that passed by that viewing site in April. The "detection rate" varied with species, being highest for turkey vultures and kestrels (23% and 12%, respectively). It appears that the majority of the migrants seen passing by the DRRMS probably stay close to the foothills and thus miss the NWTC by 3 to 4 km. Only kestrels were seen passing over the NWTC in numbers and at heights that would raise potential concerns about significant numbers of collisions with wind turbines. Other studies have identified kestrels as common victims of turbine collisions (Orloff and Flannery, 1992) but these may have been birds that were trying to hunt or nest in and around wind turbine farms. What risk these structures might pose to kestrels on migration is not known. Regardless, the majority of migrating kestrels pass through the vicinity of the NWTC on a few days in April. Using information supplied by the DRRMS, site managers at the NWTC might be able to modify operations and reduce potential risks on days of heavy kestrel movement.

The last four species of raptors were resident in the vicinity of the NWTC for one or more seasons of the year but did not appear to focus their activities on the site in any significant way. Of the species in this group, the bald eagle and peregrine falcon are federal or state listed as threatened or endangered, the golden eagle is protected under the Bald Eagle Protection Act, and the turkey vulture is protected under the federal Migratory Bird Treaty Act. The turkey vulture is a common spring migrant near the NWTC and is observed sporadically during the summer months. However, their risks of collision with wind turbines at the NWTC appear minimal and would not have consequences at the population level in any event. Two pair of peregrine falcons nest within 6 km or so of the NWTC (Jerry Craig, Colorado Division of Wildlife). However, we had only one sighting of this species at the NWTC (immature perched in Boulder County Open Space immediately north of the site) and do not believe that wind turbines at the NWTC pose risks to this species.

During the 786 hours of field observations conducted on the NWTC, 124 eagles were counted, including 39 balds, 67 goldens, and 18 "unidentifieds." Most were seen from mid- to late-afternoon in the winter months (October through February). Numbers may have been greater in the winter of 1994 than 1995, perhaps related to higher populations of prairie dogs in towns lying 5 to 10 km east of the NWTC. Although golden eagles occasionally flew directly over the NWTC and some of these at heights that could bring them in contact with wind turbines (at or below 30 m), the risks posed by turbines on the site is probably low for this species because the NWTC lacks a significant prey base to attract them.

Based on counts made in Eldorado Canyon, a minimum of 10 bald eagles wintered in the vicinity of the NWTC in 1994-5. Over the course of many days, a number of these birds probably flew near the NWTC during late afternoon flights to the roost area in the canyon. Some of these flights passed directly over the NWTC at elevations that could have brought them in contact with wind turbines (under 30 m elevation). However, the extent of the risk remains unclear without knowing more about how meteorological conditions affect the flight patterns of the eagles, the operation of the wind turbines, and the interaction between the two (eagle responses to moving turbines). Additional research might help resolve these questions. The answers are needed to fully resolve how the presence of wind turbines at the NWTC might impact bald eagles in the area.

1.0 Introduction

The National Renewable Energy Laboratory (NREL) is phasing in a series of new wind turbines as part of an expanded program of wind turbine research and development at the National Wind Test Center near Golden, Colorado. Four new wind turbines were installed in 1994 and additional turbines are planned for the 114 ha site (Thresher et al., 1994). Wind turbines pose potential risks to raptors (Orloff and Flannery 1992; Predatory Bird Research Group 1995). Moreover, the wind resources that make the NWTC attractive for wind energy research are likely to attract a diverse community of raptors as well (National Avian-Wind Power Planning Meeting, July, 1994). NREL staff had already noted occasional flights of bald and golden eagles over the Wind Site (D. Amidaneau, pers. comm.). In addition, spring counts of migrant raptors at the Dinosaur Ridge Raptor Monitoring Station (DRRMS) located 10 km due south of the NWTC were recording two to three thousand birds, indicating a sizable movement of these species along the Colorado Front Range in spring. Included among the migrants were two species that are listed as endangered under the Federal Endangered Species Act (ESA), bald eagles and peregrine falcons. Both these species were also known to nest within 6 km of the NWTC (bald eagle pair at Stanley Lake and two active peregrine aeries in the vicinity of Eldorado Canyon and the Flat Irons. Two other raptor species that occur as both migrants and residents in the area, the Swainson's and ferruginous hawk, have been mentioned as candidate species for listing under the ESA (Tate 1986, Knopf 1988).

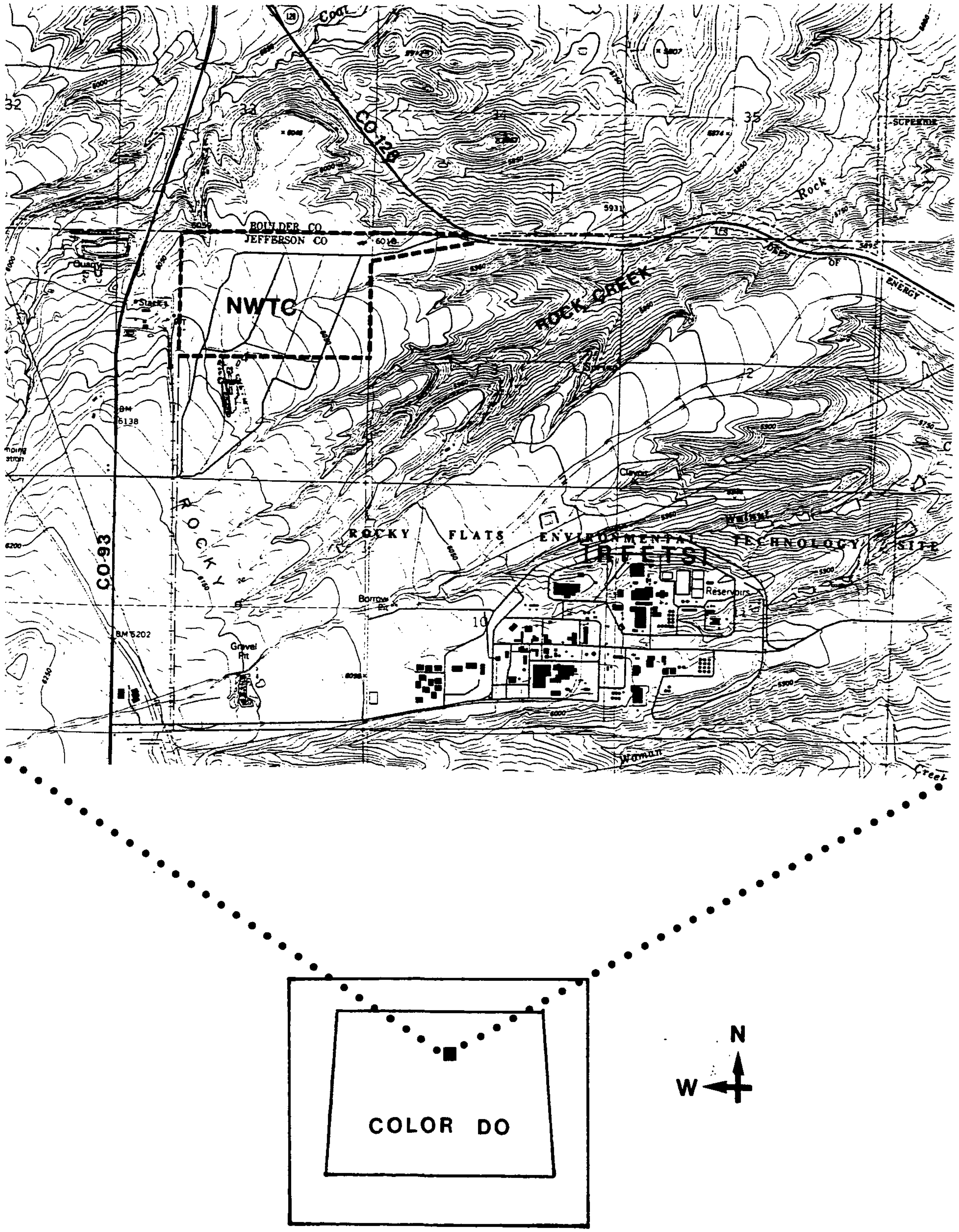
Under subcontract no. AAL-4-14169-01, "Raptor Use of the National Wind Technology Center," the present study was initiated in February of 1994 to assess the extent and nature of raptor use of the NWTC prior to construction of new turbines and to monitor raptor use of the area during the first year of turbine installation (June, 1994, through June, 1995). These results are intended to help assess the potential risks to raptors of wind turbine research and development at the NWTC and to guide site managers in operating a raptor safe environment. The results of the study should also provide important baseline information on raptor use of the area against which to judge long-range impacts of wind turbine research at the NWTC.

Field monitoring of raptors at the NWTC began in mid-February of 1994 and continued through June, 1995. Results for late winter (February through March of 1994), spring (April through May of 1994), summer (June through August of 1994), and fall and early winter (September through December of 1994) were summarized in a series of interim reports (Monahan 1994a, 1994b, 1995a, and 1995b, respectively). The purpose of those interim reports was to summarize and interpret the results of field observations conducted over relatively short periods of one to four months. The present document summarizes the methods and principle findings of the full study, including field data from January through June of 1995 that had not been summarized in previous reports. These results are than used to assess the risks posed to raptors by wind turbine development at the NWTC and to suggest management strategies at the NWTC for minimizing raptor collisions with wind turbines. In short, the present report is meant to supersede the interim reports and does not depend on them for understanding.

2.0 STUDY AREA

The National Wind Technology Center (Figure 1) lies on the northwest corner of the Rocky Flats Environmental Technology Site (RFETS) near the junction of CO 128 and 93. The 114 ha site rests on a gentle, northeast trending bench of the Rocky Flats Alluvium, a coarse gravel in sand matrix (U.S. Department of Energy, 1992). Maximum elevational change on the site is about 36 m (120 ft), the low point lying at 1821 m (5980 ft) near the site entrance from CO 128 and the high point near the southwest corner at 1858 m (6100 ft). The area mostly drains eastward into Rock Creek, although the extreme west margin of the site drains northwest into the Coal Creek Watershed. The site supported a more or less uniform cover of grasses and forbs typical of the xeric mixed grassland community type described for the Rocky Flats Environmental Technology Site (U.S. Department of Energy, 1992). Several dozen ponderosa pine (*Pinus ponderosa*) with heights reaching 15 m were stretched along a 300-m long outcrop of sedimentary rock in the northwest corner of the site. A few ponderosa pine with heights under 3 m were scattered over the site. A gravel operation and cement plant

Figure 1. Location of the National Wind Technology Center relative to the Rocky Flats Environmental Technology Center (RFETS), State highways, and local topographic relief. From 7.5 minute topographic series of the United States Geological Survey.



formed the south and west perimeter of the Center, while the Rocky Flats Environmental Technology Site (RFETS) and Boulder County Open Space were contiguous with the site on the east and north, respectively.

Although the Center sits on a relatively flat bench (Figure 1), the alluvium within 0.5 km of the site on three sides (east, north and west) was incised by drainages to depths of 50 m or so. On a broader geographic scale, the Center lies 6 km from the Front Range, north-south trending peaks of the Rocky Mountains with heights ranging to 2990 m (9800 ft). The foothills between these mountains and Wind Site are dissected by drainages that feed Coal and South Boulder Creeks to the north.

As seen in an aerial photo taken in September of 1993 (Figure 2), the Center was dominated by a variety of human-made structures from the onset of the present study, including roads, buildings, sheds, fences, and poles and towers of various kinds and heights, but no wind turbines. Most of these features were the product of earlier wind research programs that began at the site in 1976 (Thresher and Hock, 1994). Over the course of the 17-month study of raptor activities in the area, many structures on the site were removed and new ones were added. These activities had the effect of changing the number and types of vertical structures available to raptors for perching and the construction activities in 1994 resulted in disturbances to the vegetation that may have altered raptor foraging opportunities as well. Because of their potential importance to raptor use of the NWTC, the nature and schedule of these changes are summarized here.

An overview of the changes is gained by comparing high resolution aerial photos taken annually in the fall of 1993 (Figure 2), 1994 (Figure 3), and 1995 (Figure 4). These time periods represent pre-construction, construction, and post-construction views of the site, respectively. Certain features remained the same throughout the study. The entrance road onto the site from CO 128 consisted of a 0.8 km long, paved two-lane road. In addition, a network of one-lane, gravel service roads provided access to wind turbine pads and other test facilities (see for example, Figure 2). The primary element of this road

Figure 2. Aerial photo of the NWTC taken on 4 September 1993 and reflecting the condition of the site at the onset of the present study on 23 February 1994. Approximate scale = 58 m to 1 cm.

Figure 3. Aerial view of the NWTC taken near the end of the new construction in October, 1994. Approximate scale = 58 m to 1 cm.

Figure 4. Aerial view of the NWTC taken on 25 September 1995 showing the condition of the site during the last 6 months of the study. Approximate scale = 58 m to 1 cm.

network consisted of a 3-km long perimeter road that encircled about 53% (60 ha) of the 114 ha site. Shaped roughly as a square-sided parallelogram (0.82 km east to west and 0.75 km north to south), this area was bisected into thirds by north-south trending roads that provided service to old and new wind turbine sites. As seen in Figure 3, numerous construction roads were added in the summer of 1994, some of which were retained as access routes to new turbine pads and met towers (Figure 4).

Two permanent buildings occupied the site during the present study, Building 251 for administration and research on the northeast corner of the perimeter road and a test facility 500 m to the west of Bldg 251 on the north perimeter road. Also associated with the test facility were two "house" trailers and a number of storage sheds. An array of storage sheds were added to the area north of the lab building in the summer of 1994 (see Figure 3 and 4), and the two house trailers were removed sometime after the construction period in fall, 1994 (compare Figures 3 and 4). Together, these two areas of buildings, parking lots and sheds occupied about 4.2 ha or about 3.5% of the NWTC.

The remaining facilities on the site at the onset of the present study in February, 1994, consisted mainly of abandoned sheds associated with old wind pads. Most were located along the east perimeter road and east-most interior road (see Figure 2). Though not easily seen in Figure 2, many of the old wind pads had partially standing, wooden corrals around them measuring 50 m on a side. These sheds and corrals were removed in the spring and summer of 1994 to make way for construction of new wind turbine pads and met towers and the equipment buildings associated with these new structures (see Figure 4).

Perhaps most important from the standpoint of raptor use of the area, the Center held some 39 towers and poles of various types and heights at the onset of the study in late February, 1994. As construction activities progressed at the site, many of these "vertical structures" were removed and others were added. Because these vertical structures served as perching locations for raptors, their number and distribution are potentially relevant to understanding changes in raptor use of the site over the course of the study.

Figure 5 shows the spatial distribution and heights of the various categories of vertical structures occupying the wind site at the onset of the study, and their dates of removal, if applicable. Figure 6 shows the spatial distribution and heights of the various towers and poles at the end of the study (30 June, 1995) and dates of installation of structures that appeared during the course of the study.

Comparing Figures 5 and 6, three trends are relevant. First, the number of man-made vertical structures providing elevated perches for raptors on the site decreased by 38%, from 39 to 24, over the 17 months of the study. Second, the structures in place at the end of June, 1995, were less evenly distributed over the site than those in place at the onset of the study (compare Figures 5 and 6). Third, although the number of towers and poles decreased over the course of the study, heights of the remaining structures tended to be greater. This is seen by comparing the number and percent of towers at 10-m increments at the start and end of the current study. As seen in Table 1, towers and poles under 20 m accounted for 72% of the total in February, 1994, but just 46% by 30 June 1995 when the study ended. In addition, a second 50-m met tower (southeast corner) and two 80-m met towers (Sites M-2 and M-3) were erected over the course of the study.

Four new "towers" added to the site over the course of the study were wind turbines. The first two were added in May, 1994. A "lattice" type wind turbine (Figure 7) replaced the 11-m tower located 200 m south of Bldg 251. This wind turbine was removed in September, 1994, and one of similar type, presumably the same one, appeared soon thereafter at wind pad Site 1.1 (Figure 6). The second tower to appear in May of 1994 was a tubular style (Figure 7) and located at wind pad Site 3.1. The other two wind turbines, both tubular style, were located at wind pad Sites 1.1 and 1.2, appearing in September of 1994 and January of 1995, respectively.

Figure 5. Location and heights of the various meteorological towers (steel, lattice) and poles (wood or cement) at the onset of the study and their approximate dates of removal, as applicable.

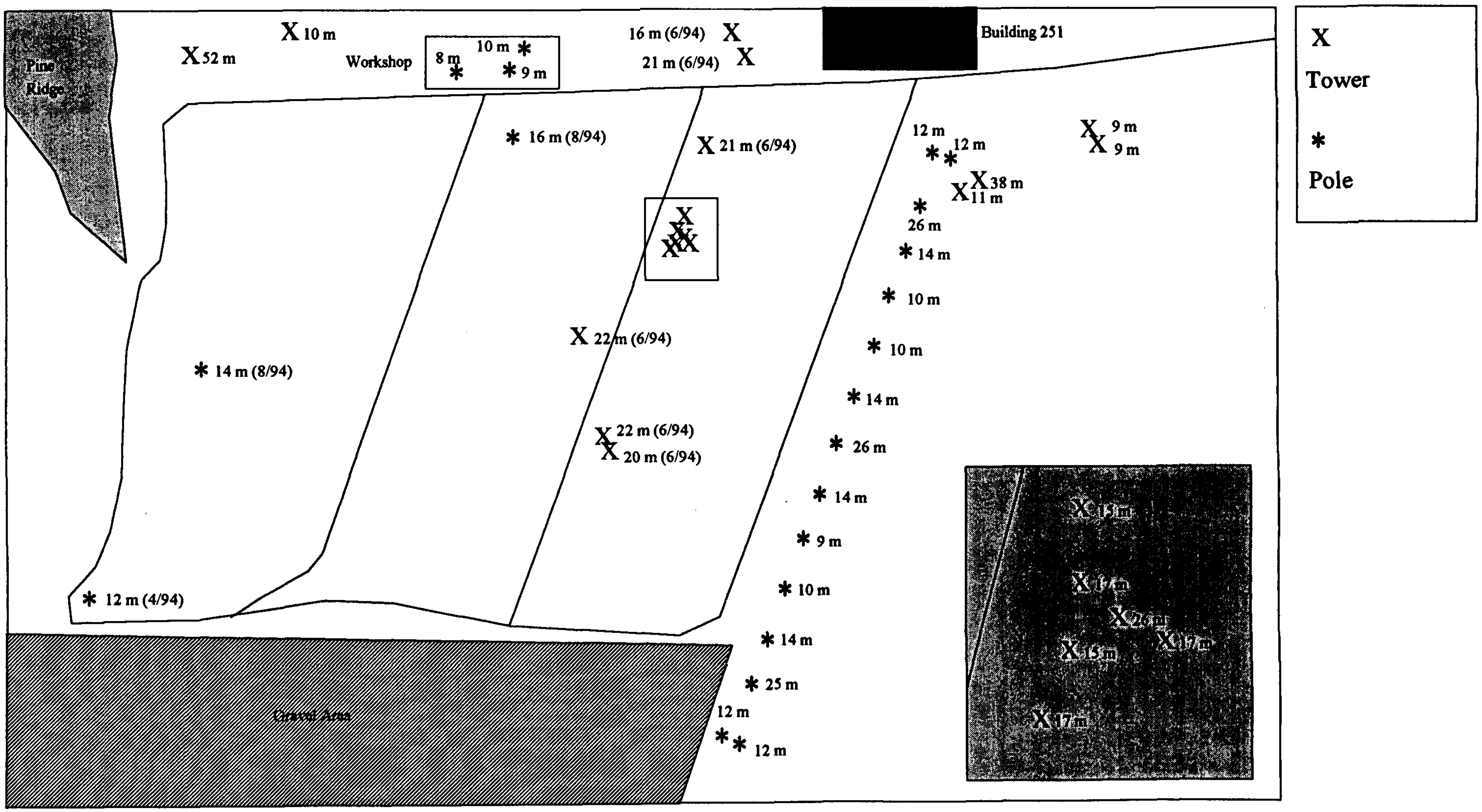


Figure 6. Location and heights of the various meteorological towers, poles, and wind turbines at the end of the study and the approximate dates of installation, as applicable.

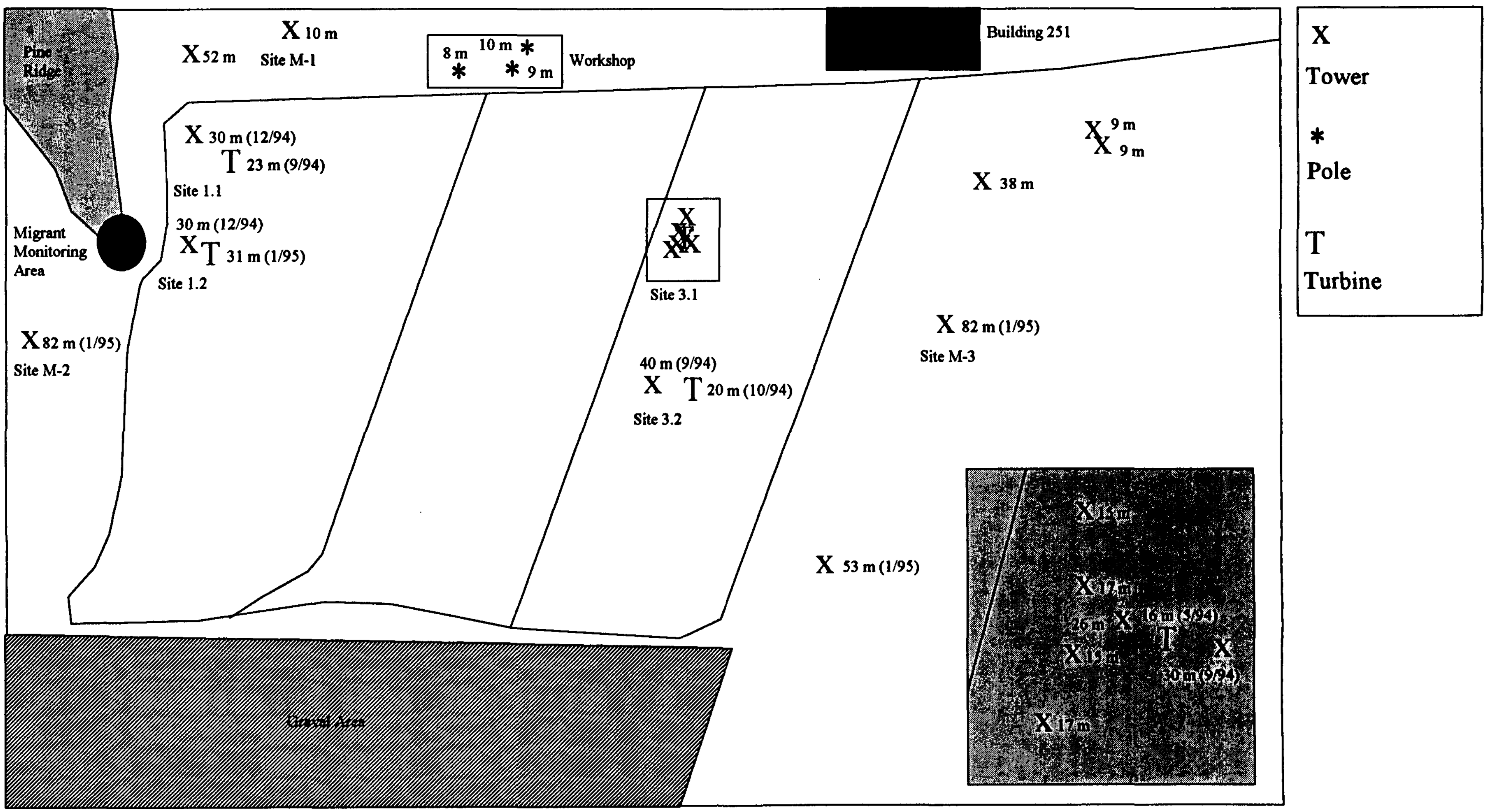
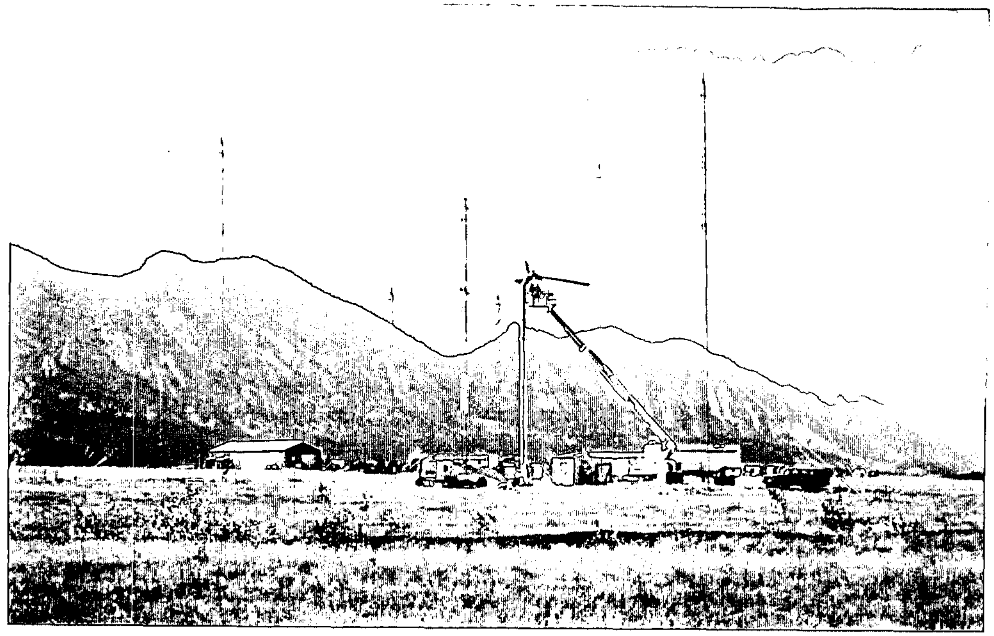
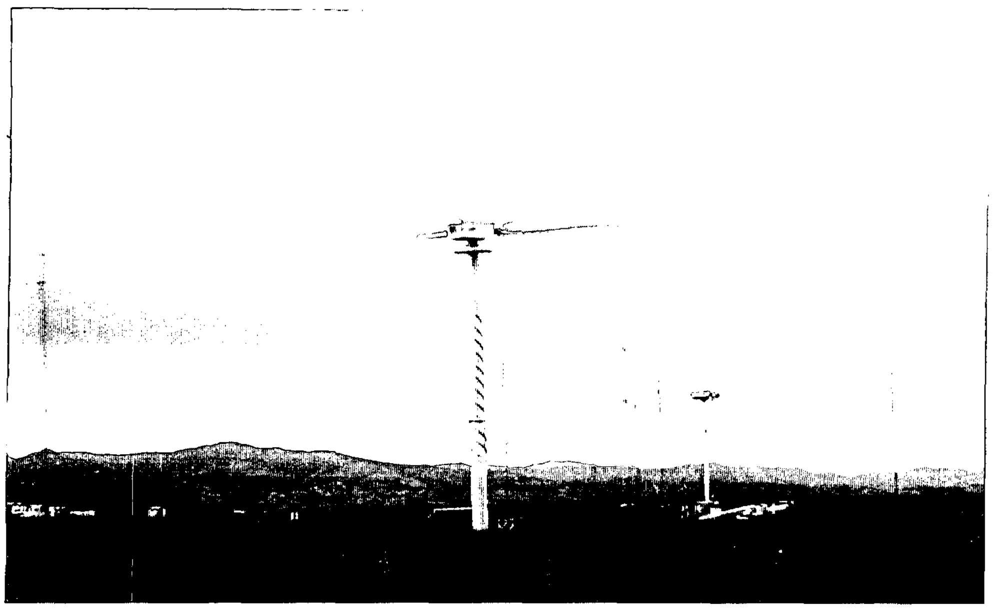


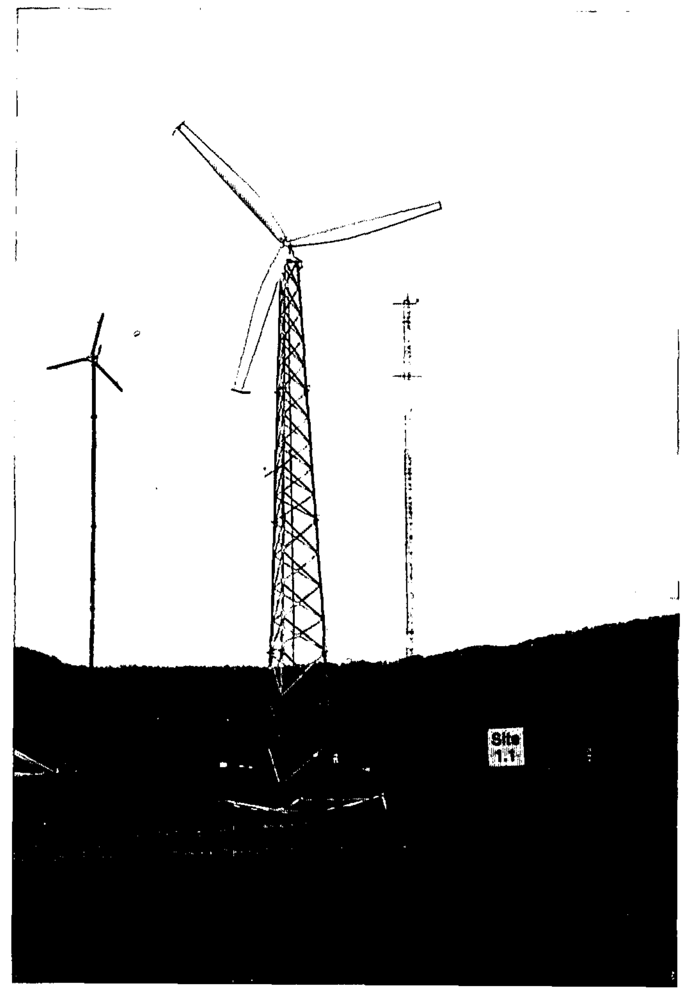
Table 1. Number and percentage of towers and poles at 10-m height increments at the beginning and end of the study period.

Height Class	Feb., 1994		June, 1995	
	N	(%)	N	(%)
0 -10 m	10	(26)	6	(25)
10-20 m	18	(46)	5	(21)
20-30 m	9	(23)	3	(12)
30-40 m	1	(3)	5	(21)
40-50 m	0	(0)	1	(4)
50-60 m	1	(3)	2	(8)
60-70 m	0	(0)	0	(0)
70-80 m	0	(0)	0	(0)
80-90 m	0	(0)	2	(8)

Figure 7. Photos of the four wind turbines installed during the current study. The 3-blade, tubular style turbine in the upper left was located in the cluster of met towers at Site 3.1. The 2-blade, tubular style turbine in the lower left was located at Site 3.2. The right-hand photo shows the 3-blade lattice and tubular towers at Sites 1.1 and 1.2, respectively.







3.0 METHODS

3.1 WEEKLY CENSUSING OF RAPTORS AT THE NWTC

The standard sampling protocol for monitoring raptor movements in and around the NWTC during the present study consisted of three 3-hour observation periods each week, one conducted in the morning (first 3 hours of daylight), one in the mid-day, and one in the evening (last 3 hours of daylight). Most of these weekly surveys were conducted by one experienced observer, Steve Faulk serving in this role during the first 3 months of the study and Dianne Koshak during the remaining 14 months. Supplementing and assisting in these field observations were two additional observers, M. W. Monahan and W. B. Monahan.

The field surveys involved maintaining continuous visual inspection of the site, usually from a vehicle parked at various points on the perimeter or interior roads. In addition, the site and air space above were carefully surveyed with binoculars at 15-minute intervals. All raptors or vultures sighted from the NWTC during field observations were recorded as to species and behavior for the period of time they were visible. Special attention was given to raptors seen flying over or landing on the Wind Site. For raptors that landed on site, their position and movements were monitored to estimate time spent on individual perches and the number, location and outcome of any attempted prey strikes.

3.2 CENSUSING OF RAPTORS IN APRIL, 1995.

To address possible concerns that the standard sampling protocol might not be adequate to quantify movement of raptors through the area during spring migration, field observations were intensified during the height of the spring migration in April, 1995. During this month only, field observations were conducted daily by two experienced observers from mid-morning through mid-afternoon. This sampling protocol paralleled one being used by the Dinosaur Ridge Raptor Migration Station (DRRMS) at a site 10 km south of the NWTC. Previous data from the DRRMS (Frank Hein, pers. comm.) had indicated that the majority of spring raptor migrants passed by their station on the hogback at I70 during the month of April. By duplicating their procedures in April, we could determine what fraction of the raptors and vultures passing by their location were visible from the NWTC. The period of increased coverage ran from 3 - 27 April, although adverse weather caused suspension of censusing at both sites on 3 dates in that period (9, 10 and 21 April).

Monitoring of the NWTC during April of 1995 was conducted from a fixed location at the south end of the pine ridge along the west perimeter road (see Figure 6). This spot was chosen because it offered a full view of the skyline to the west, south and east and thus maximized detection of raptors approaching from south. At the same time, the NWTC was in full view from this location which allowed us to simultaneously monitor raptor activities in and around the site itself. Since field observations in April of 1995 were conducted from mid-morning to mid-afternoon, they largely conformed to the "mid-day" census period followed in other months of the study. As a consequence of the extended site coverage during mid-day, early-morning and late-afternoon censusing of the site was suspended during April of 1995.

During this period of extended field observations, separate records were maintained of raptors judged as "residents" or "migrants." Raptors were judged to be migrants if they showed direct and sustained movement through the area in a northerly direction. They were classified as "residents" if their movements were localized to the field of view or if their movements were directed and sustained but in a direction other than north. On a few occasions, raptors exhibited sustained flight in a direction other than north but were still scored as migrants because their flight path appeared to be routing them around localized storm "cells."

Raptors judged to be "residents" that landed on the NWTC were monitored according to procedures established for other months of the study (see above). However, because field observers were also involved in monitoring the sky for migrating birds, continuous monitoring of "resident" raptors was not achieved at all times. In practice, the lapse in coverage was generally no more than a few minutes and never greater than 15 minutes, the time interval between systematic searches of the Wind Site.

Procedures for recording the height and lateral distance of migrants from the observer were modeled after those used by the Colorado Hawkwatch Program. However, they were modified to focus on the number and fraction of migrants that flew directly over the wind site and at heights that could have brought them in contact with wind turbines or other associated towers. In practice, the heights of migrating raptors were determined relative to the heights of wind turbines and meteorological towers. Four height categories were used,as follows:

- H1 Below the height of the tallest wind turbine (30 m)
- H2 Between the tallest wind turbine and the tallest met tower (30 to 80 m)
- H3 Between one and two met towers high (80 to 160 m)
- H4 Greater than two met towers high (>160 m)

The flight path followed by individual migrants was classified according to their lateral distance from the Wind Site. The categories consisted of flights directly over the Center (FO) and those passing east (E) or west (W) of the site. The latter were further subdivided into three categories depending on whether or not their path took them within 300 m of the Center(W1, distance to the cement plant on the west perimeter), 300 m to 3 km (W2, approximate distance to the 6200 ft contour on the west side of CO 93, or 3 km to 6 km (W3, approximate distance to the ridge line on the east flank of the Front Range).

3.3 SUPPLEMENTAL EAGLE SURVEYS

Based on preliminary field observations in February, 1994, it appeared that wintering bald and golden eagles were flying from east to west through the vicinity of the NWTC during late afternoons. The speculation was that these birds were moving from foraging areas (prairie dog towns) 5 to 10 km east of the NWTC to roosting areas in the vicinity of Eldorado Canyon located 6 km west northwest of the NWTC. To gain a better understanding of the numbers and flight behavior of these birds, regular censusing of the

NWTC was supplement with late afternoon surveys on 12 dates from 19 December, 1994, through 26 February, 1995, inclusive. These surveys were all conducted from a vehicle parked at an elevated location on the north side of CO 128, 120 m west of the entrance to the NWTC. This site was chosen because it offered favorable viewing to the south, east and north of the NWTC. Observations from the NWTC had suggested that some eagles might be passing sufficiently low and north of the Wind Site that they might be under counted. These supplemental counts from CO 128 were designed in part to determine if more eagles were passing through the area in late afternoon than we were detecting from vantage points at the NWTC. All supplemental observations from CO 128 started between 1300 and 1400 hours and continued until darkness prevented detection of eagles in flight (generally 1700 hrs, advancing to 1800 hrs as days lengthened).

Eagles seen flying past the NWTC on winter afternoons were invariably heading towards the vicinity of Eldorado Canyon, a straight-line distance from the NWTC of 6 km. To determine if eagles were moving into the canyon area in late afternoon and, if so, their numbers by age class and species, late-day observations were conducted from the mouth or interior of the canyon on five dates in late December, 1994, through mid-February, 1995. These observations began between 1500 and 1600 hrs and lasted until dark (about 1700-1730 hrs). They were conducted from one of two locations. The first three on 27 December 1994 and 16 and 26 January 1995 were made from an elevation of about 1850 m (6075 ft) on the south side of the canyon entrance. The last two counts were made from the Eldorado Trail on the north side of the canyon and about 1.5 km west of the Eldorado Springs townsite. Two field observers were involved in conducting 4 of these counts (M. W. Monahan and W. B. Monahan), a single observer (M. W. Monahan) handling one of them.

4.0 RESULTS

4.1 WINTER, SUMMER OR MIGRANT STATUS OF RAPTORS

Raptors (Order: Falconiformes) known to occur along the Colorado Front Range are listed in Table 2 by season (winter and summer) or migratory status (information drawn from Colorado Birds by Andrews and Righter, 1992). Also shown is the status of these same species as determined from data collected in the present study at the NWTC. Of the 18 species expected to occur in the area of the NWTC at one or more seasons of the year, 16 were actually observed over or near the NWTC during 786 hours of field observations from 23 February 1994 through 30 June 1995. These 16 species fell into three groups on the basis of their frequency of occurrence in or around the NWTC and whether or not they used the NWTC for perching or foraging. Four species, redtails, kestrels, prairie falcons, and rough-legged hawks, regularly used the NWTC during the winter or summer or both. The two eagle species, balds and goldens, were seen more or less regularly at certain seasons of the year but were seen perching on the NWTC on only single occasions in the 17 months of the study. The remaining 11 species identified in Table 2 as having been sighted over or near the NWTC in the present study were seen infrequently and rarely or never landed on the NWTC. The following treatment of raptor use of the NWTC addresses the species by these three groupings. Nocturnal raptors in the form of owls (order: Strigiformes) were represented chiefly by occasional great horned owls (*Bubo virginianus)* that appeared in late evening on the site. While not the focus of the present study, some mention will be made of this sightings in the Discussion.

4.2 SPECIES USING THE NWTC ON A REGULAR BASIS

Four species of raptors were seen perching on the NWTC on a regular basis during one or more months and thus could be regarded as residents of the area for at least a portion of the year. These four species were the red-tailed hawk, prairie falcon, American kestrel and rough-legged hawk. In the results that follow, these species are examined for amount of time spent perching on the NWTC, minimum size of the resident populations, effects of site modifications on site use, tower preferences, and evidence of foraging and breeding behavior.

Table 2. Winter (W) and summer (S) occurrence and management status of raptors and vultures in the foothills of Colorado as reported by Andrews and Righter (1992) and based on results of the present study.

Species	Foothills Status W	Foothills Status S	NREL Status W	NREL Status S	Management Status
Bald Eagle *(Haliaeetus leucocephalus)*	c	r	c	a	FE,CE,EA
Golden Eagle *(Aquila chrysaetos)*	uc	r	c	uc	EA
Osprey *(Pandion haliaetus)*	r	r	r migrant		-
Turkey Vulture *(Cathartes aura)*	vr	c	a	c	-
Northern Harrier *(Circus cyaneus)*	uc/c	uc	r migrant		NASBL
Sharp-shinned Hawk *(Accipter striatus)*	r/uc	r/us	r migrant		-
Cooper's Hawk *(Accipter cooperii)*	r/uc	r/uc	r migrant		NASBL
Northern Goshawk *(Accipter gentilis)*	r/uc	r/uc	r migrant		-
Red-shouldered Hawk *((buteo lineatus)*	vr migrant		a	a	-
Broad-winged Hawk *(Buteo platypterus)*	r migrant		r migrant		-
Swainson's Hawk *(Buteo swainsoni)*	a	c	a	a	NASSCL,F2
Red-tailed Hawk *(Buteo jamaicensis)*	uc/c	uc/c	c	c	-
Ferruginous Hawk *(Buteo regalis)*	c	r/uc	a	a	NASSCL,F2
Rough-legged Hawk *(Buteo lagopus)*	c	a	c	a	-
American kestrel *(Falco sparverius)*	uc/c	uc/c	vr	c	-
Merlin *(Falco columbarius)*	r/uc	r	vr migrant		-
Prairie Falcon *(Falco mexicanus)*	uc	r	c	c	-
Peregrine Falcon *(Falco peregrinus)*	vr	r	a	vr	FE,CE

Occurrence Status:
a = absent
c = common
uc = uncommon
r = rare
vr = very rare

Management Status:
FE: Federally Endangered
CE: Colorado Endangered
EA: Protected under Bald Eagle protection Act
F2: Federal candidate species (Knopf 1988) - Category 2 (may warrant listing but biological information inadequate at present time
NASBL: National Audubon Society Blue List (Tate 1986)
NASSCL: National Audubon Society Species Concern List (Tate 1986)

4.2A PERCH-TIME BY MONTH AND SPECIES

The amount of perch-time spent on the NWTC by each of the four resident species of raptors was examined on both a diurnal and seasonal basis. Diurnal patterns could be addressed by comparing observations taken in the morning, mid-day and evening. Seasonal patterns were addressed by averaging perch-time for different months of the study period. The latter analysis was complicated by the fact that individual observation periods varied in length (range, 1.5 to 8 hours but generally averaging 3 hrs). In the analyses that follow, perch-minutes by species by observation period were scaled to 180 minutes, the typical length of most field observation periods. One minor drawback of splitting up the data in this way is that the number of observation periods contributing to the estimate of mean number of perch-minutes by species was relatively small. Actual sample sizes are shown by month and time interval in Figure 8 and ranged from 3 to 6 with two exceptions. Only one mid-day observation period was conducted in February, 1994, reflecting the fact that field observations did not begin until the 23rd of that month. In addition, all observation periods in April, 1995, were conducted during mid-day (n = 22).

Average number of perch-minutes per 180 minutes of field observation is plotted by month for the morning, mid-day and evening observation periods for rough-legged hawks in Figure 9, American kestrels in Figure 10, prairie falcons in Figure 11 and red-tailed hawks in Figure 12. The bars bisecting the mean values correspond to one standard deviation above and below the mean value. One generalization common to each of these graphs is that the standard deviations are invariably large, often equaling or exceeding the mean value. Exceptions were those months and time periods of the day where no perch-minutes were documented (means and standard deviations both equal zero). Large standard deviations were partly a function of small sample sizes but these also reflect large day to day variation in use of the Wind Site by each species. One or two individuals of a species might spend considerable time perching on the site on one day and than not appear at all during other observation dates in the same month and time period. Of course, large standard deviations imply large uncertainty about the true value of the population mean (if

Figure 8. The number of morning, mid-day, and afternoon observation periods conducted each month during the study. Most observation periods lasted 3 hours, those in April of 1994 lasting about 7 hours each.

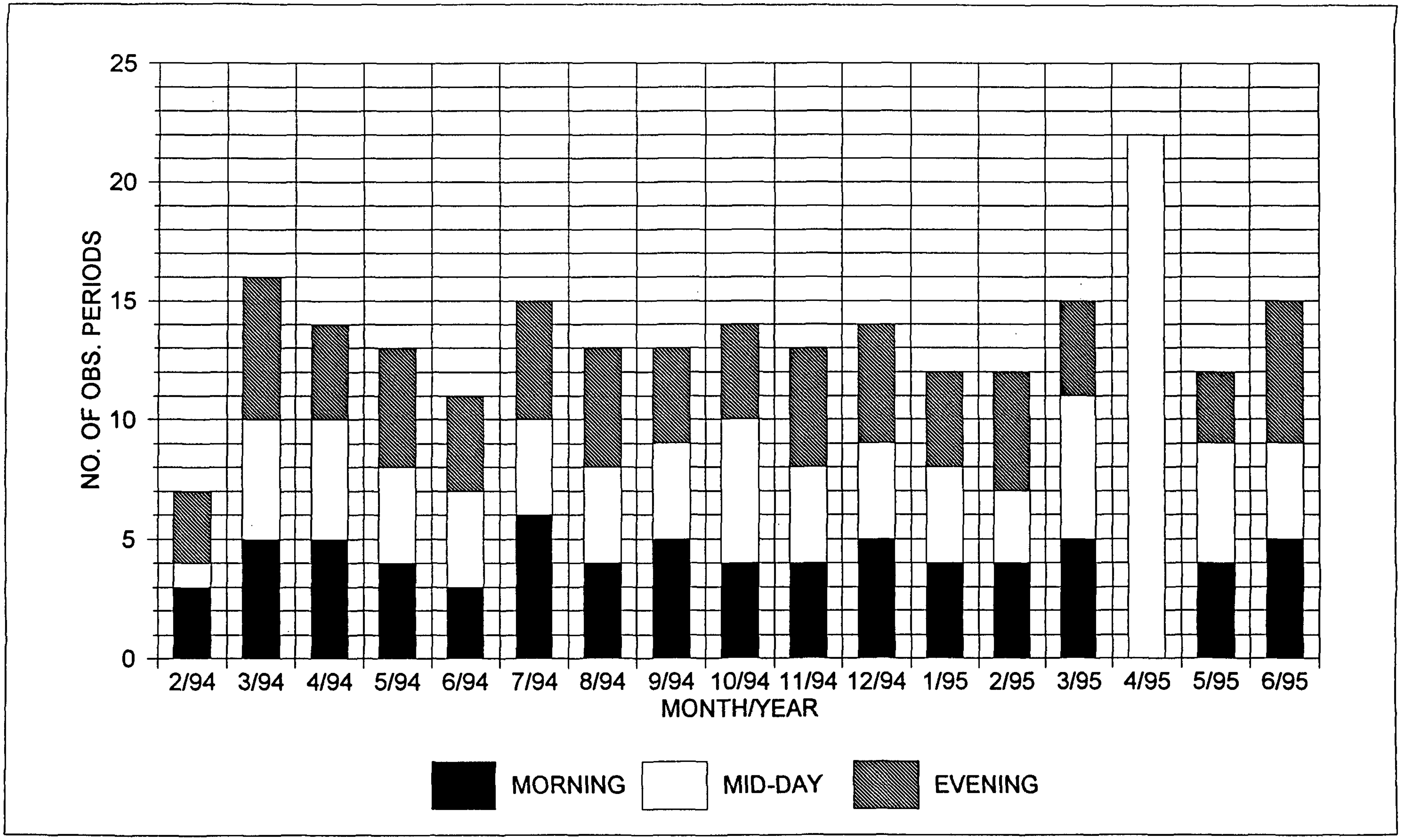


Figure 9. **Mean and standard deviation of perch-minutes for <u>rough-legged hawks</u> on the NWTC by month and period of the day. Results for the morning, mid-day and afternoon observation periods appear in the upper, middle, and lower graphs, respectively. Perch-minutes scaled to 3 hrs of field observations.**

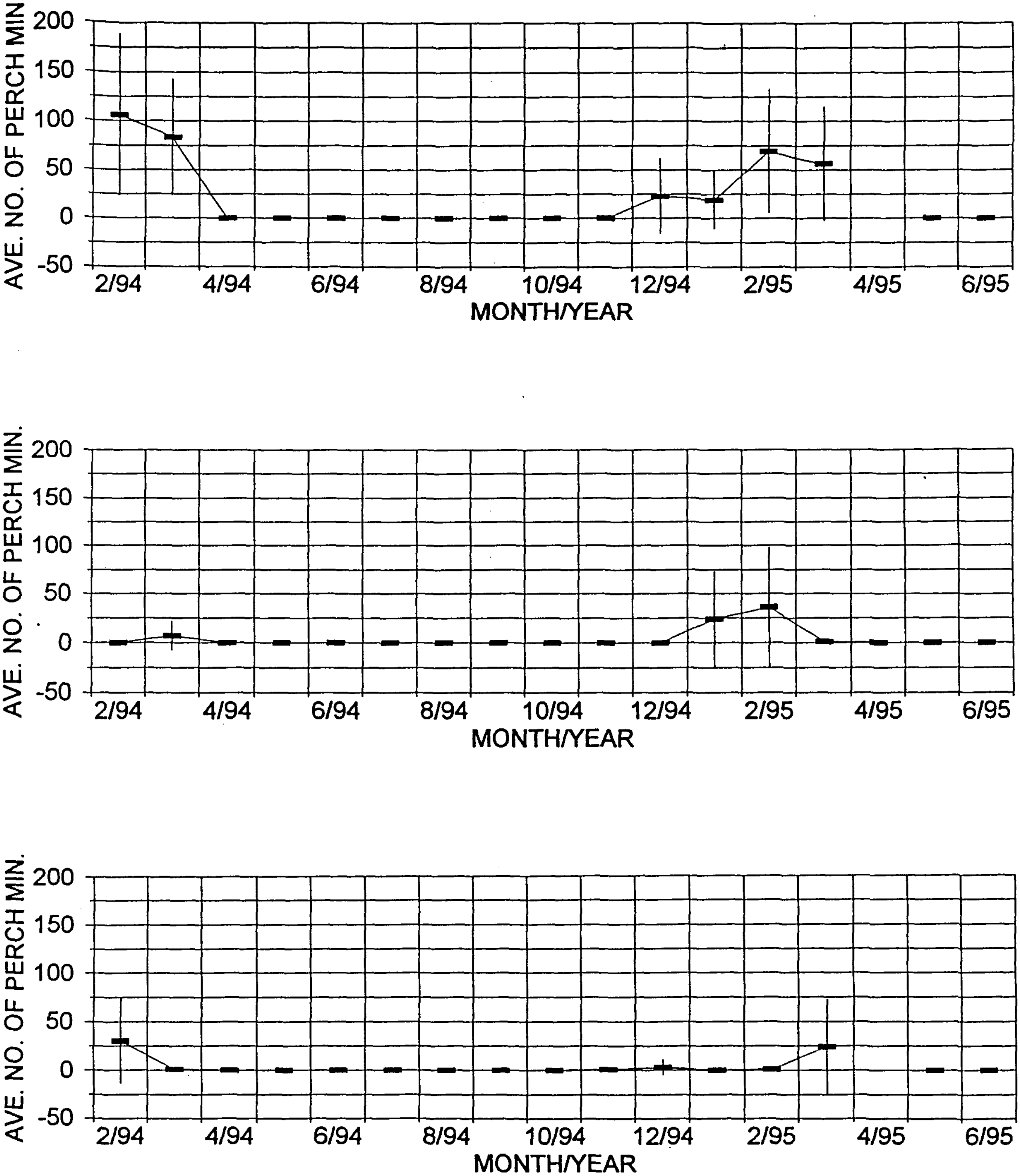
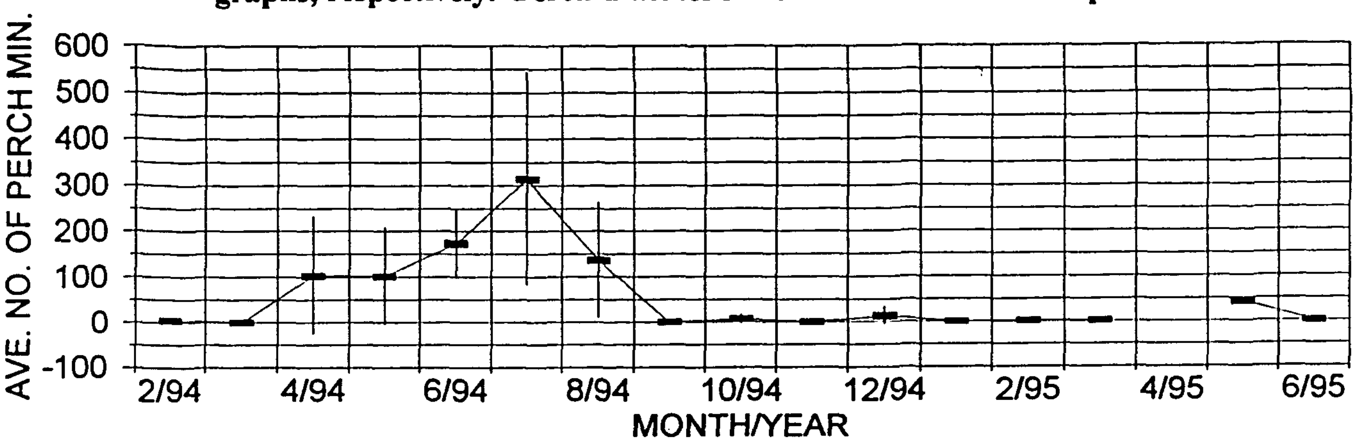
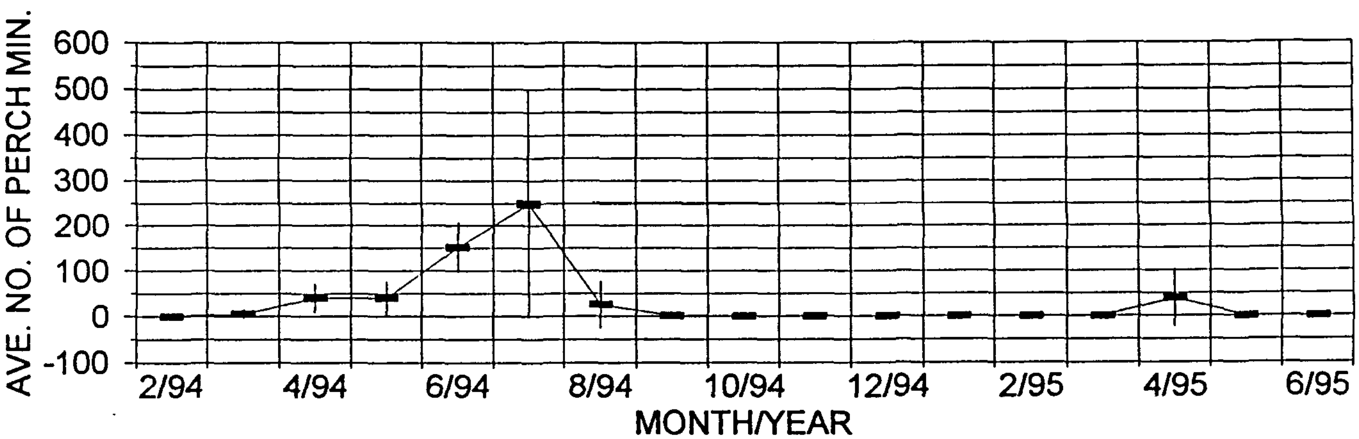


Figure 10. Mean and standard deviation of perch-minutes for American kestrels on the NWTC by month and period of the day. Results for the morning, mid-day, and afternoon observation periods appear in the upper, middle, and lower graphs, respectively. Perch-minutes scaled to 3-hr observation periods.





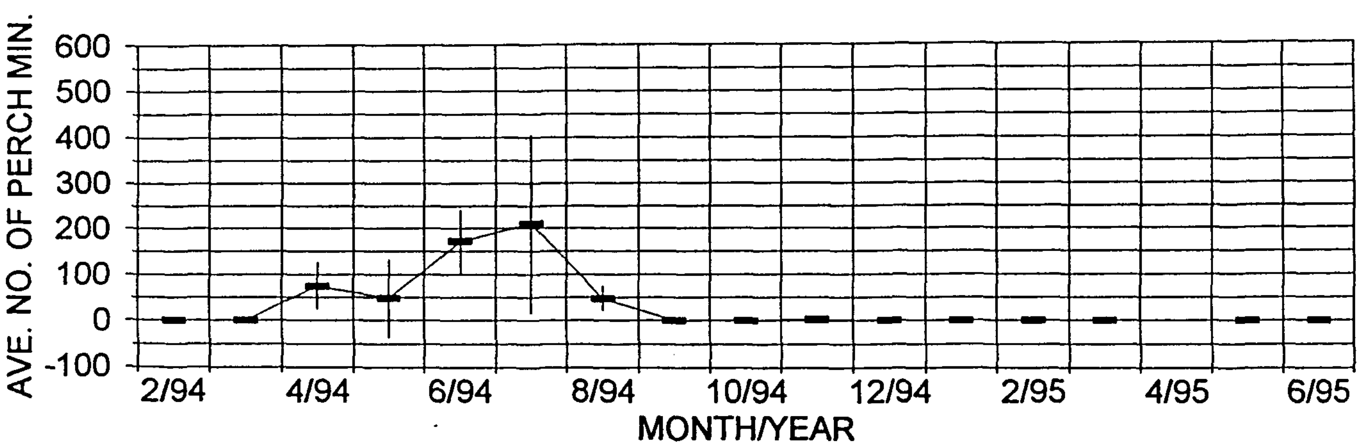
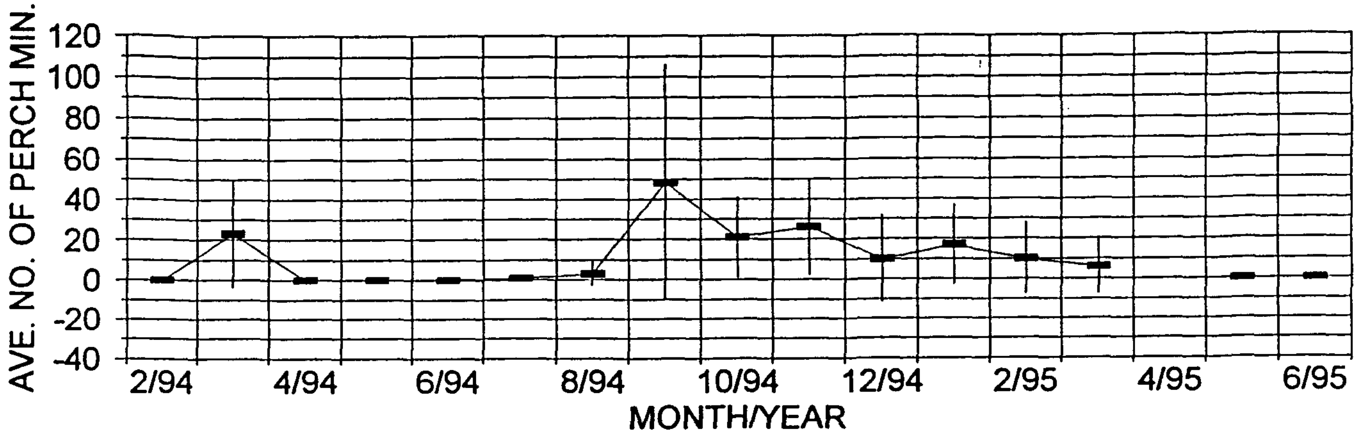
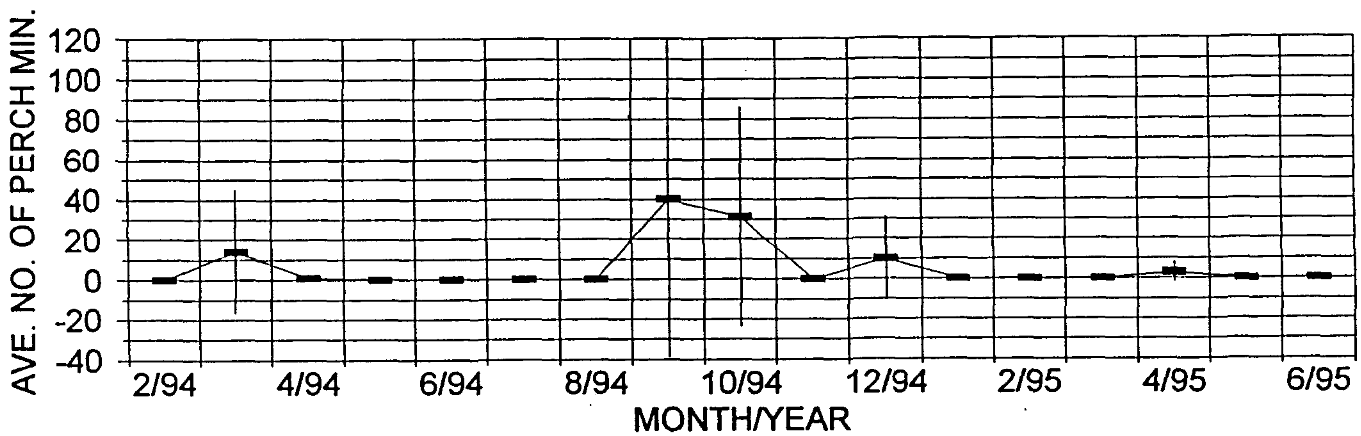


Figure 11. **Mean and standard deviation of perch-minutes for <u>prairie falcons</u> on the NWTC by month and period of the day. Results for the morning, mid-day and afternoon observation periods appear in the upper, middle, and lower graphs, respectively. Perch-minutes scaled to 3-hr observation periods.**





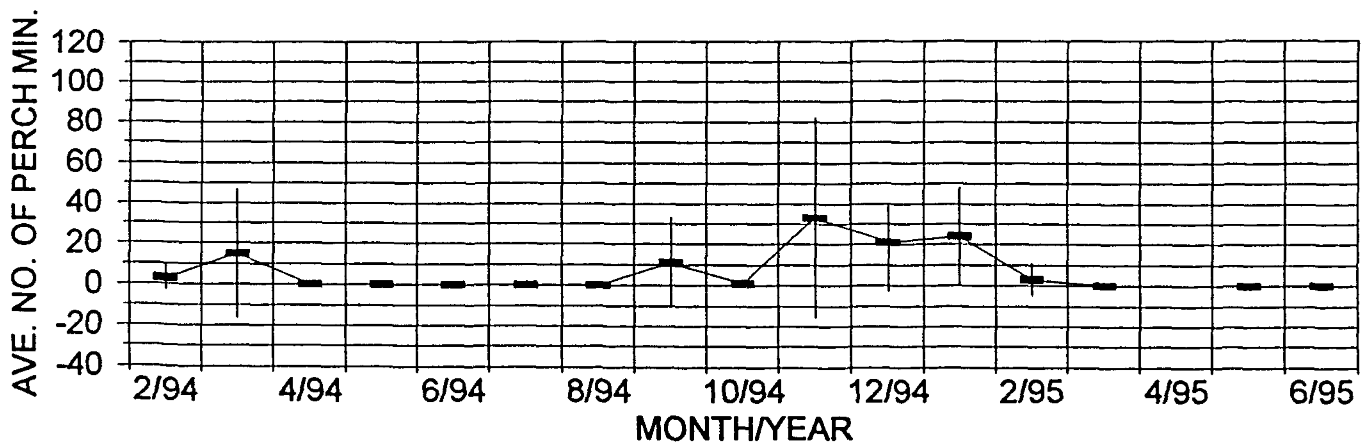
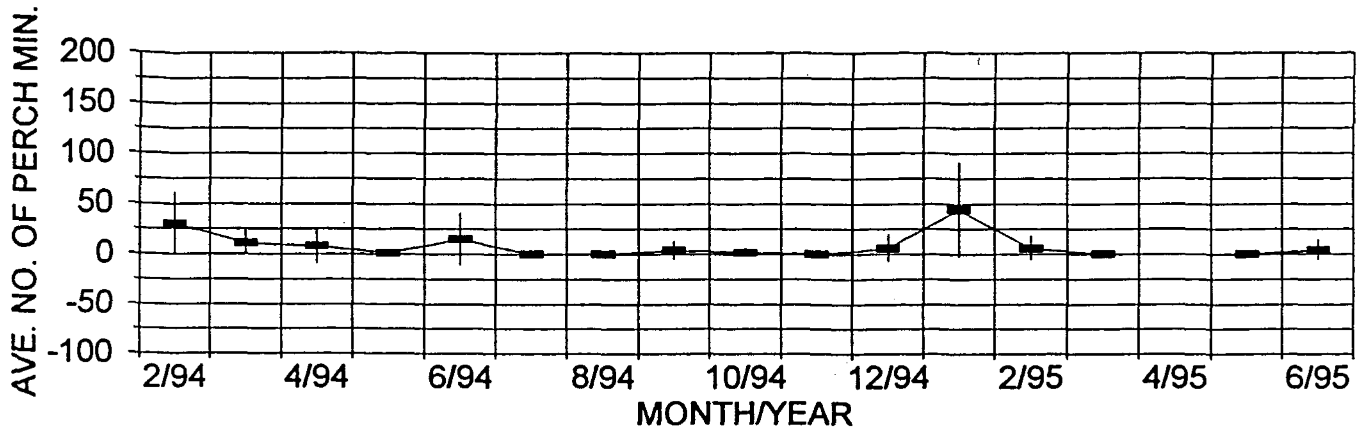
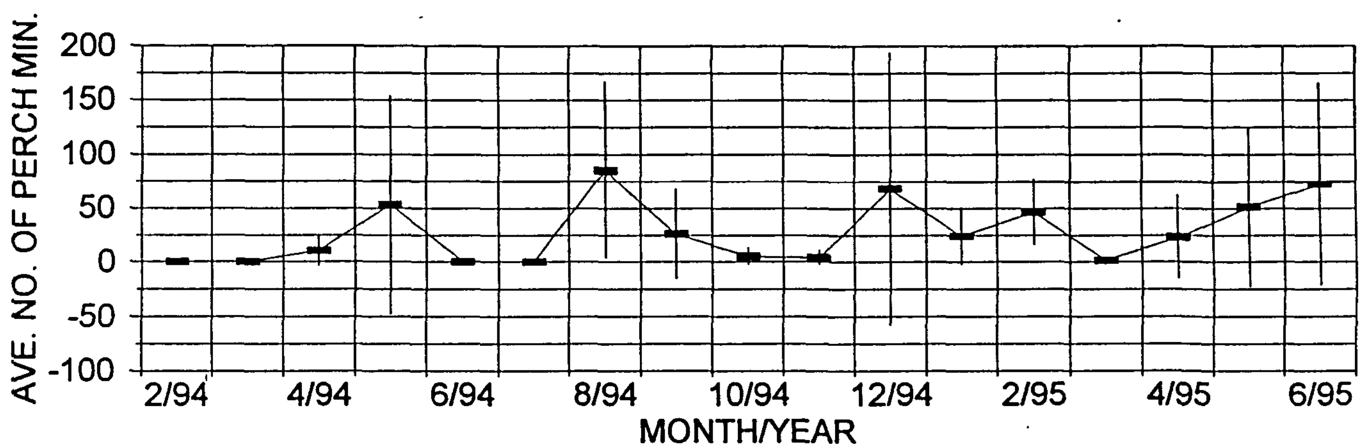
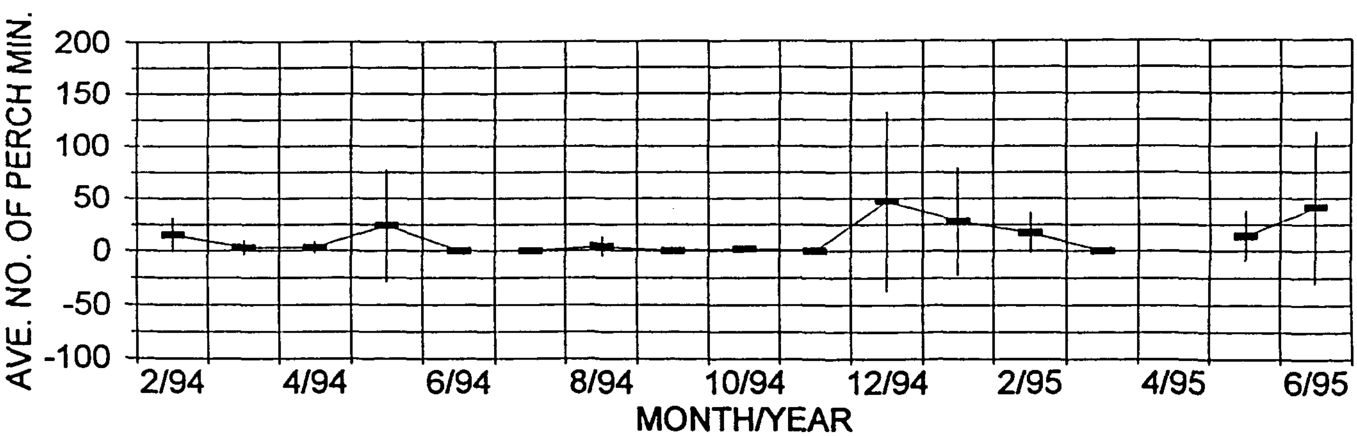


Figure 12. **Mean and standard deviation of perch-minutes for red-tailed hawks on the NWTC by month and period of the day. Results for the morning, mid-day, and afternoon observation periods appear in the upper, middle, and lower graphs, respectively. Perch-minutes scaled to 3-hr observation periods.**







perch-minutes had been measured on each and every date in the month). Nevertheless, these plots are useful in identifying those months and time periods when these four species were most likely to be encountered on the NWTC.

Kestrels and rough-legged hawks were seasonal residents of the area, while also showing diurnal variation in use of towers and poles on the NWTC for perching. Thus, rough-legged hawks were strictly winter residents at the NWTC, appearing in December and vacating the area by the first of April (Figure 9). This pattern of use is consistent with the fact that this species breeds in the tundra and is strictly a winter resident in the lower 48 states (Bent 1961; Clark and Wheeler 1987). It is also clear from the data that perch-minutes by rough-leggeds on the NWTC were concentrated in the morning hours.

By contrast, Kestrel use of the NWTC for perching was mainly concentrated in the spring and summer months (Figure 10). This pattern is most evident in 1994 when a pair of kestrels nested on the NWTC (see 4.2F). Kestrels are year round residents in Colorado but no birds were seen to winter in the vicinity of the NWTC during the present study. Although perch-time by kestrels was minimal in the spring and summer of 1995, two pair of kestrels appeared briefly on the NWTC in April. One pair probably nested near the cement plant on the west margin of the Wind Site, while the other pair disappeared. The pole used for nesting by the resident pair of kestrels in 1994 (14-m pole along the west perimeter road in Figure 5) had been removed in August of 1994 as part of site preparation for construction of new wind turbine pads. For the five months that the nesting pair of kestrels used the NWTC in 1994, the distribution of perch time was about evenly distributed between the 3 time periods of the day (Figure 10).

Redtails and prairie falcons, the other two common resident species of raptors, were seen year round in the vicinity of the NWTC but showed some variation in perch use on the NWTC as a function of season and time-of-day. Thus, prairie falcons (Figure 11) were reasonably common on towers and poles at the NWTC from September through January (one winter of data) and were totally absent from the site in May and June (two years of data). Their presence was noted in February, March, and April of some time periods in one or both years, although total accumulated perch-time was brief in these months (averaging less than 15 minutes in a 3-hour observation period). Prairie falcons used the NWTC for perching during all daylight hours but tended to concentrate their use in the morning observation periods (upper-most plot in Figure 11)

Of the four species to regularly perch on the NWTC, redtail use of the site appeared most variable across time periods, months and years (Figure 12). Diurnally, redtails tended to accumulate the greatest amount of perch-time during mid-day observation periods. The exceptions occurred in February and March of 1994 when perching on the site was minimal and limited exclusively to mornings and evenings. Seasonally, redtails were recorded perching on the NWTC in all months of the year except June and July of 1994 and March of 1995.

Although the data set has limited value in addressing year to year variation, a comparison of average monthly perch time from February through June of 1994 and 1995 (Figure 12) suggests some tendency for annual variation in redtail use of the site as well. For example, redtails were not seen perching on the site in February or June of 1994 but accumulated 45 perch-minutes or more in these months in 1995.

Comparing average monthly perch-minutes across species, the highest values were recorded for kestrels in July of 1994 when upwards of 6 birds were using the NWTC (pair of adults and 4 young) and average perch-time per 3-hour observation block exceeded 300 minutes (Figure 10). The next highest values were recorded for rough-leggeds in February, 1994, perch-time per 3 hr observation period running close to 100 minutes (Figure 9). Redtails never averaged more than 85 minutes of perch time per 3-hr observation period (Figure 12), while prairie falcons never averaged more than 50 minutes (Figure 11).

4.2B MINIMUM NUMBERS OF INDIVIDUALS BY SPECIES

While average monthly perch-time on the site provides one measure of potential exposure to wind turbine risks, it does not necessarily reflect the number of individual birds actually using the site. Because raptors in the study were not individually marked, it was not possible to know with confidence how many individuals of each species used the site on a daily, monthly and yearly basis. However, a conservative estimate of the number of raptors contributing to perch-time on the NWTC is obtained by considering how many individuals of each species were seen at any one time or the number of separate sightings where the birds were distinguishable on the basis of plumage variation. Using these criteria, the minimum number of birds of each species using the NWTC for perching in any one season was between 2 and 6. In the case of rough-legged hawks, two were observed perching on the site at the same time in March of 1994. As for kestrels, two pairs of adults were noted on the NWTC in April of 1994 although one pair vacated the area. The other pair proceeded to rear 4 young on the west perimeter of the Wind Site (see 4.2F). Thus, 6 kestrels briefly occupied the area in July, 2 adults and 4 newly fledged young. A maximum of 4 adult redtails were observed on the site in May of 1995. One adult used poles along the east perimeter road and departure flights from the area generally took it eastward. In addition, a pair of adults generally perched throughout the NWTC and also were seen perching on poles to the west of the site near the gravel and cement operations. Also, in the fall of 1994, a total of 3 redtails were frequently seen perching on the NWTC, a pair of adults and one immature bird. In the case of prairie falcons, a minimum of 2 birds, one adult and one immature, were occasionally observed together on or near the NWTC in the fall of 1994.

4.2C EFFECTS OF NEW CONSTRUCTION

Perch Events and Perch Time.--The period from July through December of 1994 saw a number of changes to the Wind Site that could have affected raptor use of the area. Various towers and poles were removed or added during this period that affected the number and spatial distribution of potential elevated perches. In addition, the site was subjected to considerable disturbance during August and September of 1994 as construction crews installed underground electrical cable and the instrumentation buildings and cement pads for new wind turbine sites. In the course of these activities, roughly 18 ha of the site were bulldozed or the vegetation was compressed by construction activities.

The timing of these site changes offered the opportunity to compare raptor use of the site in the four-month period prior to the start of major renovations with the same four-month period in 1995 after changes to the site had been completed. The fieldwork for the project began on 23 February 1994 and removal of towers began in late June. Thus, the pre-construction period was defined as 23 February through 30 June, 1994. The same dates were used to define the post-construction period. This was done to control for effects of season on raptor use of the NWTC.

The periods before and after site modifications were compared for number of recorded landings and total accumulated perch time on the NWTC by kestrels, redtails, rough-legged hawks and prairie falcons. To adjust for differences in amount of observation time, perch events and perch time were scaled to 100 hours of field observations. Since redtails and prairie falcons were both known to be resident in the vicinity of the NWTC throughout the periods under comparison, their actual use of the NWTC was scaled against the total hours of field observations conducted from 23 February through 30 June. In contrast, rough-legged hawks were only present in the area through March while kestrels were only present in the area after 1 April. Thus, perch events and perch time by these species were scaled relative to the hours of field observation time logged when these species were actually present in the area (23 February through 31 March for rough-leggeds and 1 April through 30 June for kestrels).

The results of these analyses are shown in Table 3. The absolute number of perch events and perch time recorded during field observations are shown by species and year in the first two rows of the table. Hours of field observation time appears in the third row. Number of perch events and perch time is scaled to 100 hours of field observation in the fourth and fifth rows of the table. Focusing on these scaled values, use of the NWTC by

Table 3. Absolute and relative measures of perch event frequency and perch time by species and year.

Variable	Red-tailed Hawk		Prairie Falcon		American Kestrel		Rough-legged Hawk	
	1994	1995	1994	1995	1994	1995	1994	1995
No. of perch events	48	86	18	15	270	112	67	16
Perch time (hrs)	11.2	32.8	5.0	3.2	39.2	27.0	16.2	8.7
Observation time (hrs)	195	269	195	269	121	216	74	53
Perch events per 100 hrs	25	32	9	6	223	52	90	30
Perch time per 100 hrs	5.7	12.2	2.6	1.2	32.4	12.5	21.8	16.4

redtails was higher following the changes to the site while numbers for the other 3 species were down. In the case of redtails, number of perchings per 100 hours of observations was up by 30% (from 25 to 32, see Table 3) from 1994 to 1995, while perch time increased by 114% (from 5.7 to 12.2, Table 3). These increases were associated largely with heavy use of the new meteorological tower at Site M-2 on the west side of the site that was installed in January, 1995 (see 4.2D).

Use of the NWTC by the other three species was appreciably lower following modifications to the site. In the case of prairie falcons (Table 3), perching events were down by 39% and perch time by 54%. Loss of perches was probably not responsible for this decline because the number of tall perches ostensibly preferred by this species (see 4.2D) actually increased between years. Another possibility is that habitat disturbance in and around the preferred perches may have reduced foraging opportunities.

Use of the NWTC by rough-legged hawks was down sharply in 1995 (Table 3) as measured by perch events (from 90 to 30 per 100 hrs of field observation). Perch time was down but by a lesser degree (from 22 to 16 hrs of perch time per 100 hrs of field observation). Thus, rough-legged hawks spent somewhat less time on the NREL following site modifications and tended to move around less on the site while perched there.

In the case of kestrels, perch events were down by 77% (from 223 to 52) while perch time was down by 61% (Table 3). These differences are explained by the fact that a pair of kestrels nested on the NWTC in 1994 but not in 1995, the pole containing the nest cavity having been removed after young fledged the nest in 1994.

Perch Changes.-- Among the factors likely to affect the risk of bird collisions with wind turbines will be the extent of within site movements. Except for occasional prey strikes (see 4.2E), within site movements typically involved flight from one elevated perch to another. To evaluate the extent of such movements, the pre- and post-construction periods were compared by species and year for frequency of perch changes by individual birds. As seen in Table 4, anywhere from 25 % to 42% of raptors seen landing on the NWTC changed perches at least once before departing the area, variation depending on species and year. The number of perch changes by individual birds never exceeded 3 for prairie falcons but ranged upwards of 8 for redtails, 13 for kestrels, and 10 for rough-legged hawks.

In view of the changes to the Wind Site during the summer and fall of 1994, including some loss of habitat and elevated perches, we predicted that frequency of use of multiple perches might decrease from 1994 to 1995. The data were analyzed using a chi-square contingency test (Sokal and Rohlf, 1969) where the null hypothesis was that frequency of perch changes was independent of year. As seen in the right hand columns of Table 4, the tendency to use multiple perches was different in the pre- and post-construction periods for prairie falcons and kestrels but not for redtails or rough-legged hawks. From inspection of the data for prairie falcons and kestrels, use of multiple perches was higher in 1995 than in 1994. However, it is hard to know what biological significance to attach to these results. In the case of prairie falcons, sample sizes were relatively small in both years (just 25 birds total across the two years). As for kestrels, their volume of activity on the NWTC was much greater in 1994, ostensibly because they were nesting on the site. With two adults tending the nest, movements were so numerous over short time frames that it was often not possible to follow individual birds for any length of time. Thus, the

Table 4. Frequency of perch changes by species in the pre- and post-construction periods. Data for redtails, kestrels, and rough-legged hawks tested as 2 x 4 contingency tables, data for prairie falcons tested as a 2 x 2 contingency table.

Species	Year	Number of Perches				G	(df)	P
		1	2	3	4+			
Redtails								
	1994	19	3	2	3	1.628	(3)	ns
	1995	38	12	3	4			
Prairie Falcons	1994	16	1	0	0	13.042	(1)	<.01
	1995	2	5	1	0			
Kestrels								
	1994	179	31	18	3	13.458	(3)	<.01
	1995	27	6	5	6			
Rough-leggeds	1994	19	4	1	7	8.252	(3)	ns
	1995	3	0	3	1			

apparent tendency towards fewer perch changes for this species in 1994 may be an artifact of sampling. Alternatively, it may reflect behavior associated with adults feeding nestlings.

4.2D SPATIAL DISTRIBUTION OF PERCH EVENTS AND PERCH TIME

Efforts to minimize risks of raptor collisions with wind turbines may benefit from knowing how the height and placement of vertical structures affect their use as perches. Many factors may influence the amount of use received by individual towers and poles, including features of the structures themselves (height, horizontal surfaces for perching, presence of support cables) and their location (proximity to human activities, nature of surrounding vegetation, proximity to foraging or breeding territories). The present analysis looked at height and location as determinants of perch use. Because the assortment of towers and poles remained relatively constant from February through June of 1994 and from January through June of 1995, these two periods were examined separately by species.

The spatial distribution of perch events and perch time is shown for the pre-construction and post-construction periods for rough-legged hawks in Figure 13, kestrels in Figure 14, prairie falcons in Figure 15 and redtails in figure 16. The first and most striking trend in perch use on the Wind Site was the tendency of all 4 species to concentrate perch events and perch time on the taller structures where they are available. The clearest illustration of this trend is seen by comparing pole use along the east perimeter road where there were 8 wooden "power" poles under 15 m and 3 at 25 m (see Figure 5). Use of these short and tall poles is summarized by species in Table 5 (years pooled). Prairie falcons showed the clearest preference, only using the taller poles. For both redtails and rough-legged hawks, perch events and perch time were about 4-fold greater for the taller poles, even though they were only a third as common. Of the 4 species, kestrels were most likely to use the short poles but even this species used the tall poles more heavily than would have been expected by chance alone.

The tendency for raptors to favor taller poles for perching was examined systematically by comparing the availability of poles in different height categories against the number of

Figure 13. Number of recorded landings and perch-minutes by tower or pole for <u>rough-legged hawks</u> in the pre-construction (upper panel) and post-construction (lower panel) periods.

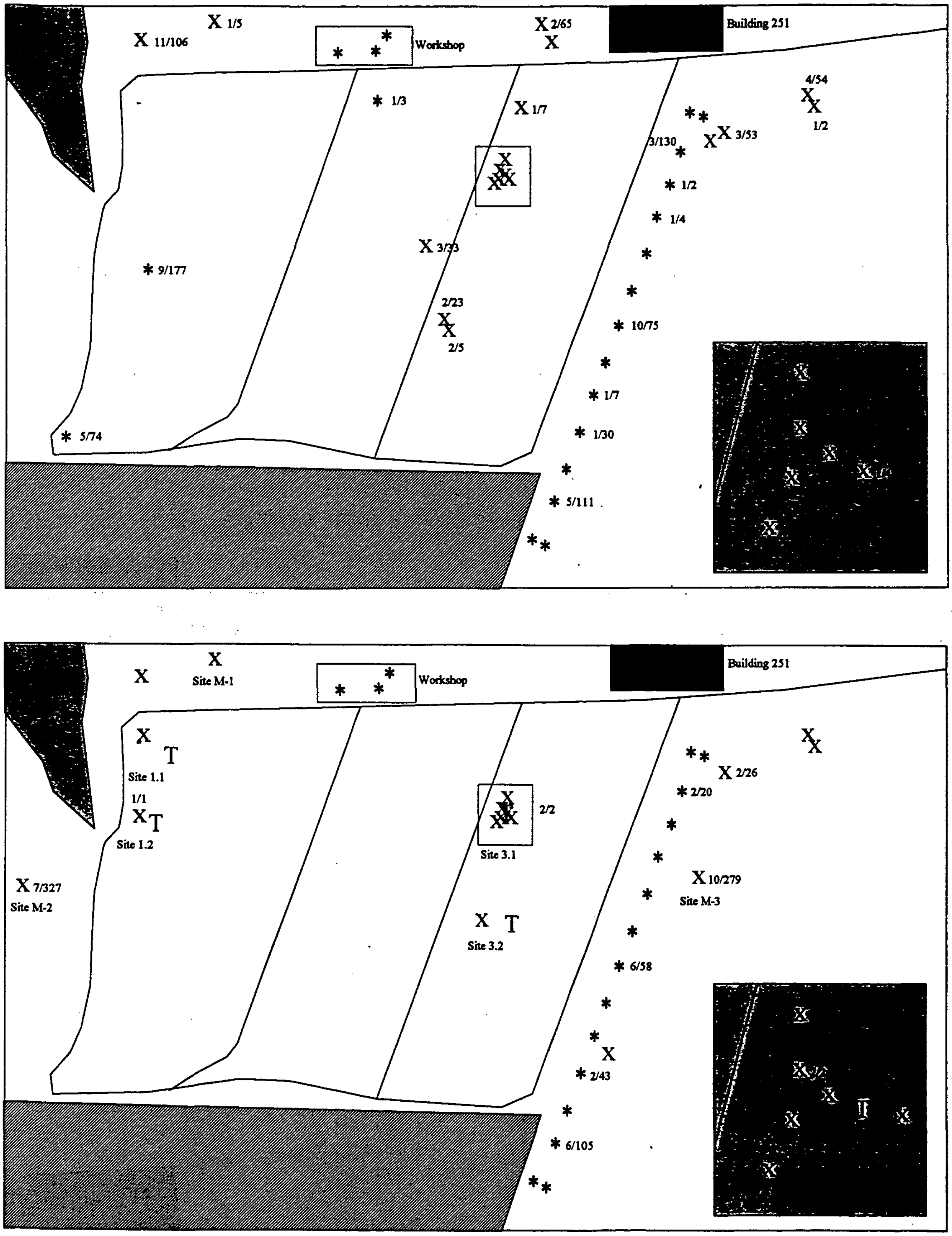


Figure 14. Number of recorded landings and perch-minutes by tower or pole for American kestrels in the pre-construction (upper panel) and post-construction (lower panel) periods.

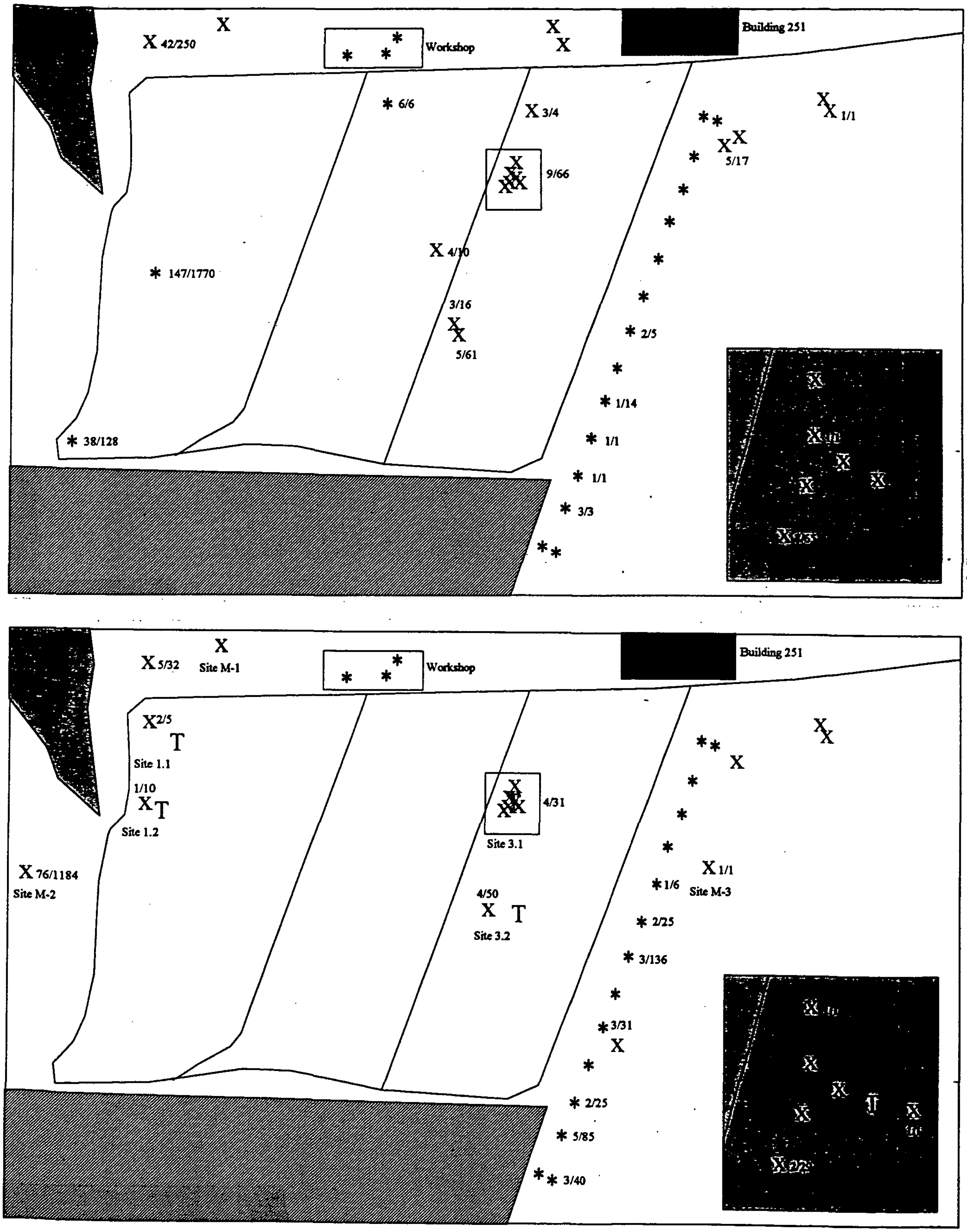


Figure 15. Number of recorded landings and perch-minutes by tower or pole for prairie falcons in the pre-construction (upper panel) and post-construction (lower panel) periods.

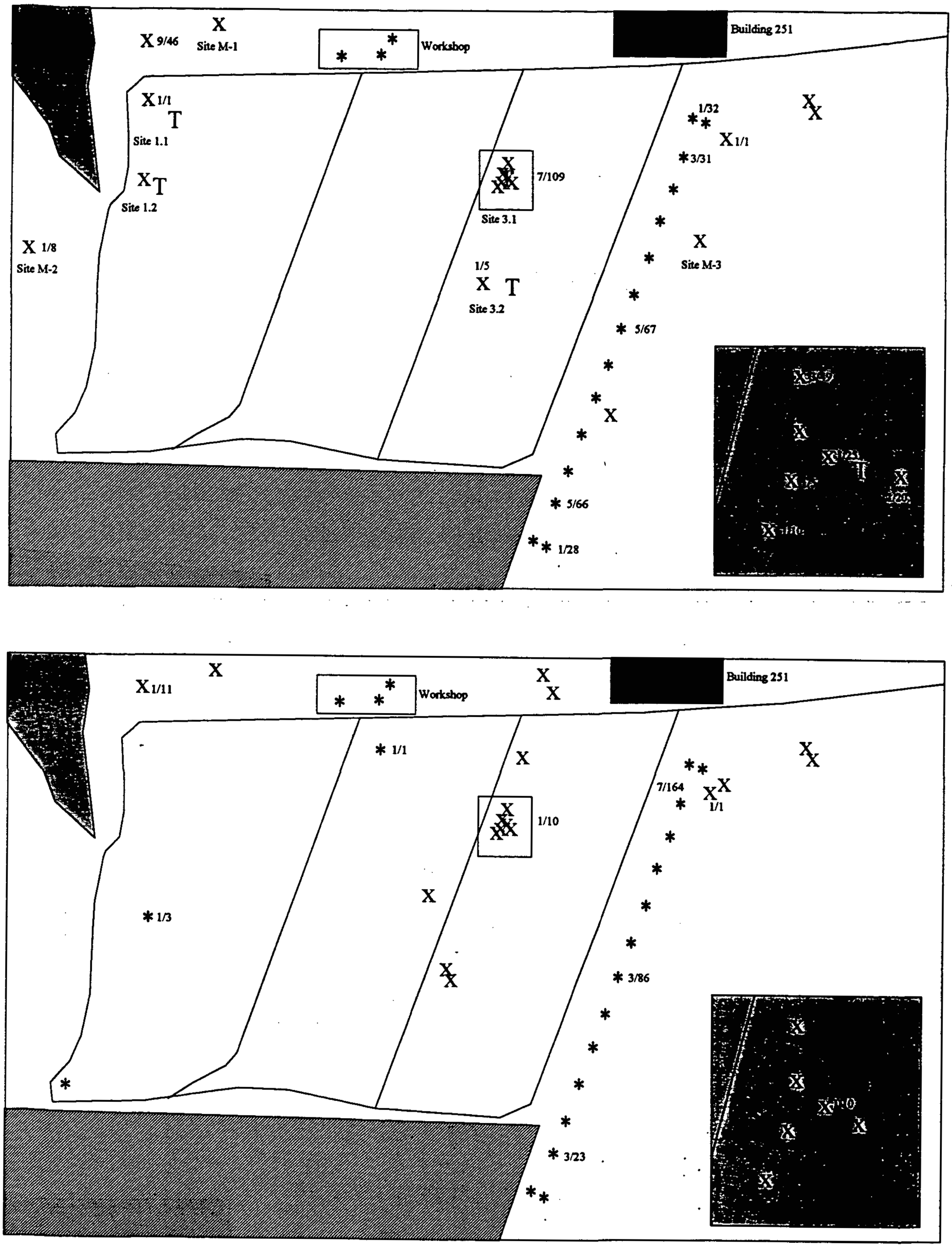


Figure 16. Number of recorded landings and perch-minutes by tower or pole for red-tailed hawks in the pre-construction (upper panel) and post-construction (lower panel) periods.

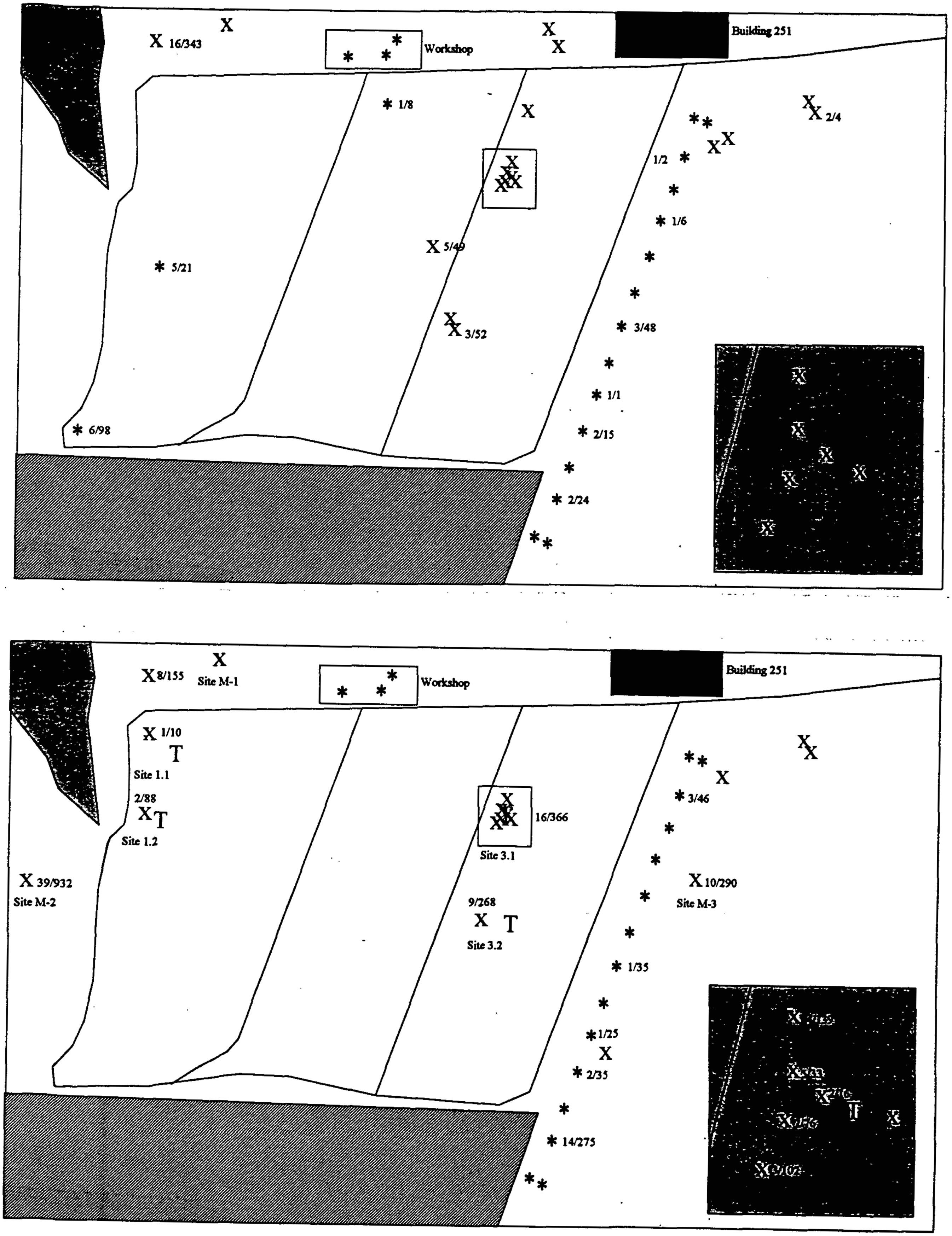


Table 5. Number of landings and total perch time by species for "short" and "tall" wooden "power" poles along the east perimeter road (see Figure 5). The 8 short poles ranged in height from 10 to 14 m, the three "tall" poles were all 25 m high.

Species	Pole Height: Short		Pole Height: Tall	
	Perch Events		Perch Events	
	No.	(Time)	No.	(Time)
Redtails	6	(82)	24	(430)
Prairie Falcon	0	(0)	26	(437)
Kestrel	11	(103)	13	(229)
Rough-legged	6	(86)	32	(499)

times poles in these height categories were used for perching. Poles and perch events were grouped by 4 height categories, 0 to 10 m, 11 to 20 m, 21 to 30 m, and above 31 m. Using a 2 x 4 contingency test, the null hypothesis was that perch events were distributed across pole height categories in proportion to their availability. Non-random use of poles in the different height categories is revealed by a significantly low probability of the G statistic being due to chance. The data from 1994 are based on field observations conducted between 23 February and 30 June 1994, those from 1995 between 1 January and 30 June 1995.

The results of these analyses are summarized in Table 6. Two trends are worth noting. First, in both years, birds of all 4 species tended to favor taller poles for perching. The trends are highly statistically significant ($P < .001$) for all cases except rough-legged hawks in 1994. In the latter case, preference for tall perches is significant but at a lower level ($P < .025$). The other generalization from these results is that poles in the shorter height categories are not avoided entirely. Thus, it appears that elevated perches of any height will get some use, although the birds showed a preference for poles in the taller categories.

In the case of redtails, prairie falcons, and rough-legged hawks, taller perching poles also meant higher perch locations because they tended to perch at or near the tops of the poles. However, kestrels presented an exception to this trend, especially when using the taller met towers. Typically they sat on the cables supporting the towers and thus did not take full advantage of the pole height for perching.

4.2E FORAGING BEHAVIOR BY SPECIES

Raptors may be attracted to taller poles for perching because they experience less ground disturbance while using the perch to loaf or perform maintenance activities. Alternatively, they may gain advantage in searching for prey. On occasion, all 4 species spent extended periods at individual perches, the behavior being most notable in redtails and rough-legged hawks. On many of these occasions, birds were seen performing preening activities or

Table 6. Use versus availability of poles in different height categories by species in the first 5 months of the study (pre-construction) and last 6 months (post-construction).

Pre-construction Period (2/23/94 - 6/30/94)

	Height Category				Statistical Test		
	0 - 10m	11 - 20m	21 - 30m	31+m	G	P	
No. poles	9	18	9	2			
RT landings		6	12	14	16	14.1	<.01
PF landings	0	2	14	2	21.0	<.001	
AK landings		3	206	20	42	39.4	<.001
RL landings		9	19	26	14	10.2	<.025

Post-construction Period (1/1/95 to 6/30/95)

	0 - 10m	11 - 20m	21 - 30m	31+m	G	P	
No. poles	9	12	7	6			
RT landings		3	14	23	66	31.9	<.001
PF landings	0	7	16	12	19.4	<.001	
AK landings		4	10	12	86	42.7	<.001
RL landings		2	2	15	19	22.6	<.001

simply appeared to be resting. However, as described in the previous section, the birds were prone to changing perches during individual stops at the Wind Site, a behavior consistent with searching for prey. Supporting this view, the poles on the Wind Site were also used as platforms for launching prey strikes.

Except for kestrels in the spring and summer of 1994, prey strikes were relatively uncommon. Thus, in 786 hours of field observations over 17 months, the number of attempted prey strikes was 9 for redtails, 7 for prairie falcons, and 10 for prairie falcons. Of the 9 strikes by redtails, 1 resulted in the capture of a vole, 3 were unsuccessful and the outcome of 5 could not be determined. Of the 7 prey strikes by rough-legged hawks on the NWTC, 2 were successful (probably voles) and 5 were unsuccessful. In the case of prairie falcon strikes, 2 of 10 were successful, one resulting in the capture of a northern flicker (*Colaptes auratus*), the other a mountain bluebird (*Sialia currucoides*). Six other strikes were unsuccessful and the outcome of 2 was not known.

Kestrels were the primary foragers on the NWTC during the present study. A total of 136 prey strikes were attempted, 35 being successful, 41 unsuccessful, and 60 of uncertain outcome. Voles appeared to be the most common prey item, although insects probably formed part of their diet (Bent, 1961). Prey strikes were frequently launched from perch sites, either the tops of poles or from support cables associated with the 52-m and 82-m met towers in the northwest corner and west side of the site, respectively. Perhaps equally frequently, kestrels would make prey strikes while conducting hovering flights over the site.

Based on the hunting success of kestrels, small mammals apparently were numerous on the Wind Site, at least during the summer of 1994. From visual inspection using binoculars, many of the prey items captured by kestrels appeared to be voles (genus *Microtus*). However, small mammal trapping in mixed-xeric habitat on the RFETS has indicated that deer mice (genus *Peromyscus*) constitute 50 to 75% of the small mammal numbers in this habitat, voles most of the balance (U.S. Department of Energy, 1992).

This habitat type lacks prairie dogs at the RFETS and none were seen on the Wind Site during the course of the study. The only other possible mammal prey item observed on the site consisted of a few cottontail rabbits (genus *Sylvilagus)* living near sheds along the north perimeter road.

Besides voles and deer mice, the other potential form of raptor prey on the Wind Site consisted of various species of songbirds that resided in the area from spring through fall. Of the four species of raptors that used the site for perching, only the prairie falcon would be expected to pursue these prey items to any significant degree (Bent, 1961).

4.2F COURTSHIP AND BREEDING

In both springs of the study, redtails and kestrels used the Wind Site for courtship and mating and kestrels nested and raised 4 young on the site in 1994. In the case of redtails, a breeding pair showed courtship flight (male presenting female with a prey item) over the site and used various towers for copulation in spring of both 1994 and 1995. These behaviors were noted on just one date in 1994 (4 May), the single recorded mating taking place on the met tower on the northwest corner of the site. With daily extended coverage during April of 1995, redtail use of the NWTC for courtship and mating was more fully documented. Courtship feeding was observed over the site on 3 and 23 April and 7 copulations were recorded between 15 April and 4 May, 3 on the met tower at Site M-2, 3 at the cluster of towers at Site 3.1, and 1 at the met tower in Site 3.2 (see Figure 6 for locations of these sites). An immature later appeared with adult redtails on the Wind Site. Based on repeated searches, we know that the nest site was not in the ponderosa pine adjoining the west side of the site. We suspect it may have been located in the drainage between the Wind Site and CO 93 (see Figure 1).

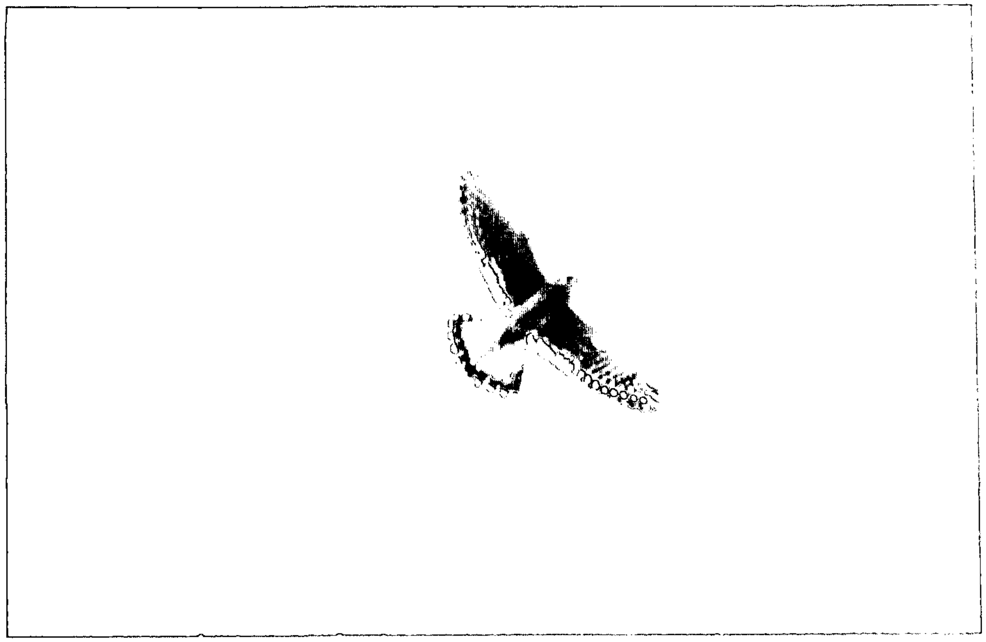
On 4 May of 1995, two pairs of redtails were observed at the same time in the general vicinity of the wind site. In addition, a distinctively marked redtail (especially white chest) was observed perching along the east perimeter of the site and on one occasion was seen being displaced by a second redtail. We suspect that the second pair had a breeding territory that extended east of the site, while the pair using the site on a regular basis had a breeding territory that extended west.

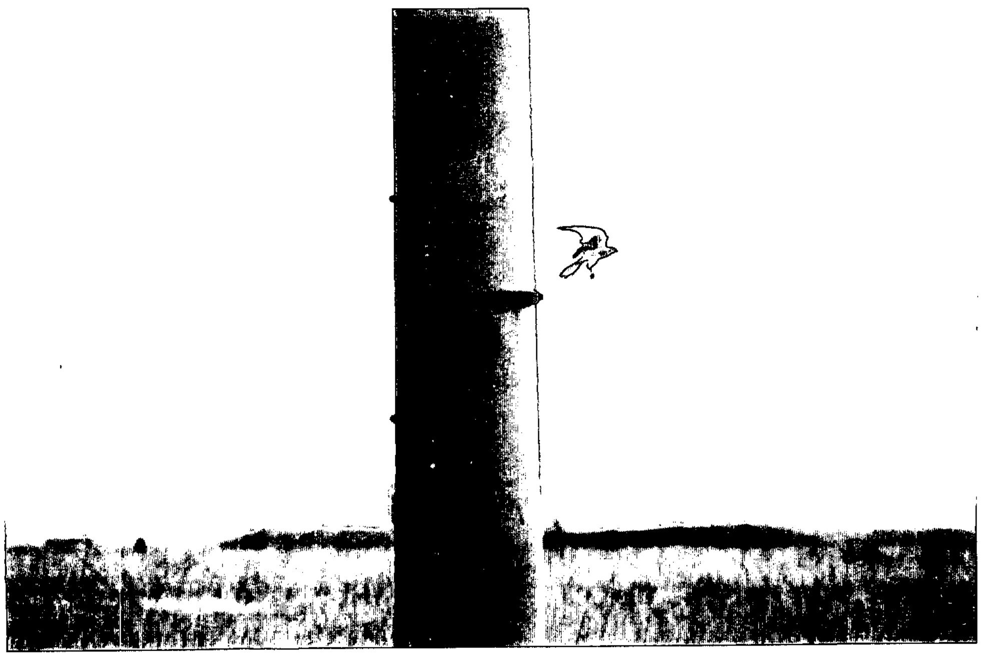
Kestrels also conducted courtship and matings on the NWTC during both springs of the study and proceeded to nest and rear 4 young on the site in 1994. The nest pole was located along the west perimeter road and consisted of a 14-m tall, cement pole with a hollow center (Figure 17). The pole had a south-facing opening 2.3 m above ground that served as the entrance to the nest cavity. The hollow center extended from the cavity entrance to the top of the pole and was capped by a metal plate. A total of 21 matings were recorded between 7 and 17 May April, 17 on the nest pole and 4 on the pole in the southwest corner of the site. The 4 young left the nest over a 5-day period, beginning on 30 June. Assuming an incubation period of 28 days and a nestling period of 30 d (Bent, 1961), egg laying probably began about the first of May, with hatching on about 1 June.

A second pair of kestrels was present on the Wind site in mid-April of 1994. One or the other of these pairs was seen "inspecting" a metal canister at the top of one of the towers immediately west of the Bldg 251. Kestrels are generally regarded as obligate cavity nesters (Bent, 1961).

In the spring of 1995, two pairs of kestrels again showed up in early April on the Wind Site. A pair was observed copulating on a support cable to the met tower at Site M-2 on 6 April. On 18 April, a pair of kestrels were seen perching on the wind turbine at Site 3.2 (only recorded sighting of any raptors perching on wind turbines during the course of the present study). Subsequently, the female was observed trying to maneuver around the base of the blades. Although the blade was not turning at that time, a female kestrel was seen at the same turbine 2 hours later. A check for feathers or carcass on the following day turned up nothing. This time the blade of the turbine was rotating as the female tried get near the base of the blades. On 26 April, a pair of kestrels was seen copulating on a telephone line near the cement plant and no kestrels were attending the Wind Site on a regular basis.

Figure 17. Kestrels on the NWTC and the cavity entrance to the nest site used by them in 1994. This pole was removed in August of 1994 to prepare the area for installation of new underground power lines, wind turbine pads and equipment buildings.





4.3 EAGLE MOVEMENTS

4.3A DIURNAL PATTERNS

During 786 hours of field observations on the premises of the NWTC, the number of separate eagle sightings totaled 124, including 39 bald eagles, 67 golden eagles, and 18 eagles that could not be identified to species. The frequency of sightings of both species tended to vary with the hour of the day and the season. Looking first at diurnal trends (Figure 18), most sightings of eagles were made between 1400 and 1800 hours. This time frame encompassed 77% of the bald eagle sightings (30 of 39) and 60% of golden eagles (40 of 67). Most of the remaining sightings of golden eagles (21 of 67) were made between 1100 -1400 hours. About half of these (11 of the 21) were recorded during extended mid-day coverage in April of 1995 and may have been migrants (see 4.4A). Thus, sightings of both species tended to be concentrated in the late afternoons, the trend being stronger for bald eagles than for golden eagles. Although the data in Figure 18 were not standardized for the amount of field observation time conducted at each hour of the day, the diurnal patterns just described probably reflect patterns of movement on the part of the birds themselves since field coverage was about evenly distributed throughout the day (see Figure 8).

4.3B SEASONAL PATTERNS

On a seasonal basis, sightings of bald eagles were confined exclusively to an 18-week period beginning the third week in October and ending the last week in February. Thus, the earliest sighting occurred on 20 October (one fall of data) and the latest sightings occurred on 26 February in 1994 and 22 February in 1995. Within this 4-month period the number of sightings appeared to rise as the winter progressed. To adjust for variation in field observation time from month to month, sightings were standardized to 100 hours of field observation. The standardized counts for balds, goldens and unidentified eagles are plotted in Figure 19. The encounter rates are based on field observation time that was distributed across the entire day. The sighting rates would be much higher if based solely on late afternoon censusing.

Figure 18. Number of sightings of bald eagles, golden eagles, and unidentified eagles recorded by hour of the day over the course of the 17-month study (n = 124).

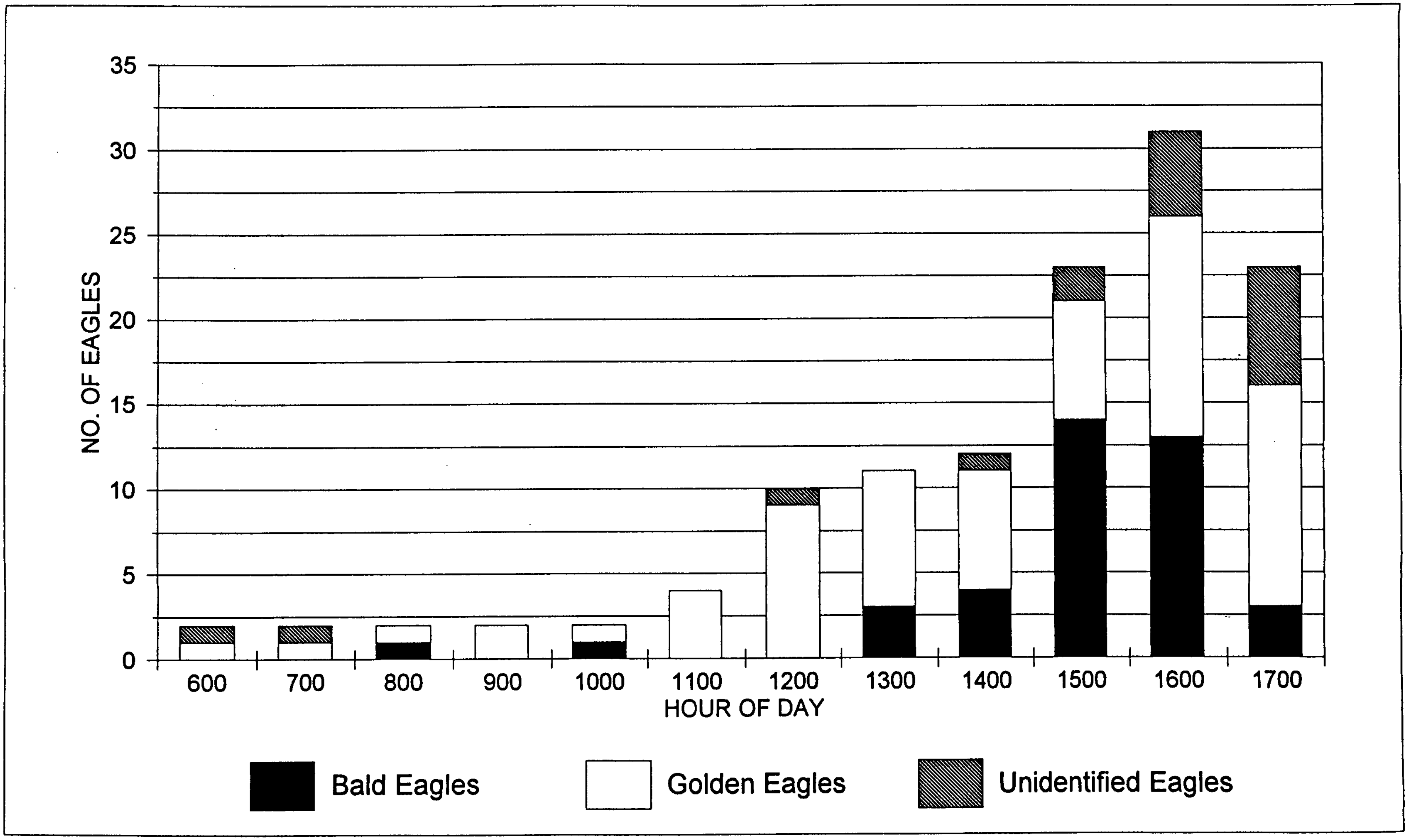
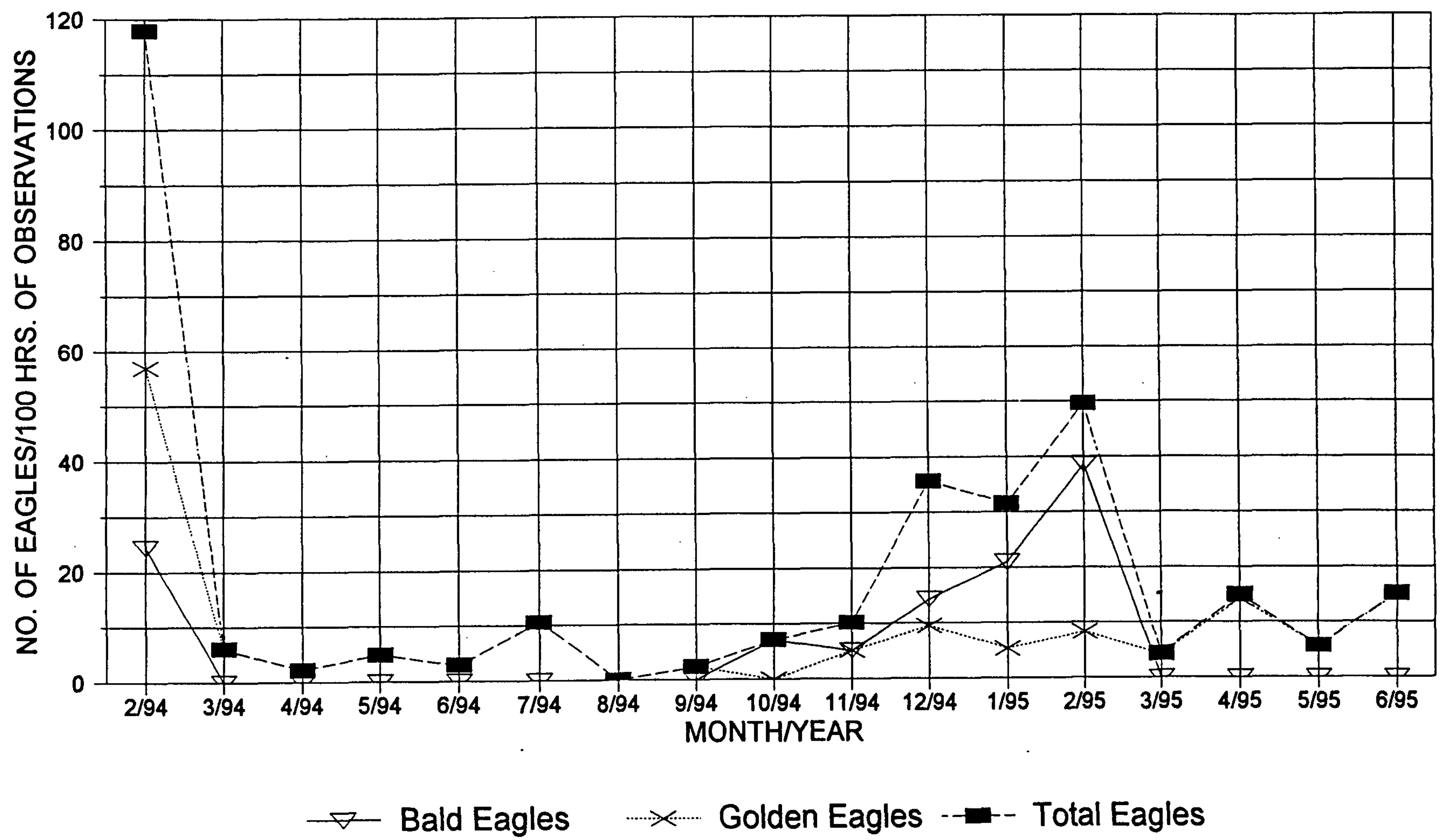


Figure 19. Number of bald eagles, golden eagles, and all eagles combined (balds, goldens, and unidentified) according to month, results scaled to 100 hours of field observations.



Based on just one complete winter of data (1994-5), sightings of bald eagles appeared to rise as the winter progressed, running at just 5 birds per 100 hours of field observation during November but reaching 39 birds per 100 hrs by February (Figure 19). The plot also suggests that sightings were more frequent in February of 1995 than in February of the previous year. However, the numbers are not strictly comparable since the calculated rate of eagle sightings in February of 1994 was based on just 24 hours of field observations conducted in the last week of the month (study began on 23 February 1994). Eagle sightings in February of 1995 were based on 46 hours of field observations conducted over the entire month. Since bald eagles seem to disappear about the end of February, a sighting rate based only on the last week of the month would be expected to produce a low value.

In contrast to bald eagles, golden eagles were observed during almost every month of the study (Figure 19). Except for February of 1994, sightings of golden eagles generally numbered fewer than 15 per 100 hours of field observations. In terms of seasonal trends in golden eagle sightings, only one was sighted in close to 180 hours of field observations conducted on the NWTC from August through September. Sighting rate was relatively high in April of 1994 (10 birds per 100 hours) and 1995 (14 birds per 100 hrs), perhaps reflecting the travel of migrants through the area (see 4.4A). Sighting rate was also relatively high in June of 1995, perhaps reflecting local movements of a family group in the general vicinity of the NWTC. In any case, sighting rates of goldens generally did not reach the peak values recorded for bald eagles in February of 1994 and 1995. The exception was the high rate of golden eagle sightings in February of 1994 at 57 birds per 100 hours of field observations. In retrospect, it might be tempting to raise doubts about the accuracy of these sightings, given that they were obtained in the first week of the study when field procedures were still being developed. However, the size and flight patterns of these birds left little doubt that they were eagles (M. W. Monahan, pers. obs.). The only major uncertainty would be whether not they were correctly classified as to species of eagle.

For various reasons, some eagles sightings could not be scored to species. Contributing factors included distance from the viewer, sky conditions, amount of daylight, flight elevation, and flight speed. Unidentified eagles totaled 18 for the study, including 9 in February, 1994, when the field work was just getting started. To see how these birds affect encounter rates of eagles, the three categories (balds, goldens and unidentifieds) are pooled and plotted in Figure 19. Since bald eagles were only present in the vicinity of the NWTC from October through February, sighting rates of eagles in all other months were probably dependent solely on golden eagles. The other feature worth noting in this plot is the extremely high encounter rate of eagles in February, 1994 (117 birds per 100 field hours). Interestingly, the sighting rate was also high in February of 1995, though still only about 40% of the rate seen in 1994. Therefore, it appears that eagle numbers were lower in the winter of 1995 than in 1994. This same period also saw a decline in prairie dog numbers in the north Denver area as a result of bubonic plague (Monte Deatrich, Tri-County Health Department). Thus, the apparent drop in eagle numbers between late winter of 1994 and late winter of 1995 may have been caused by declining prey populations. This point is discussed in the concluding remarks to the present report.

4.3C MINIMUM NUMBERS OF EAGLES

The above description of seasonal and diurnal variation in rates of eagle sightings provide one measure of the extent to which wind turbines might present risks to eagle populations in the area. However, the risks are difficult to assess without knowing how many individual birds contributed to these sightings. Since we were not working with individually marked birds, it is difficult to know how many different eagles contributed to the 124 sightings recorded over the 17 months of the present study. With the exception of some of the golden eagle sightings recorded in the spring and fall migration periods (see 4.4A), it is likely that the remaining sightings involved birds that were resident in the vicinity of the NWTC. If so, we were probably seeing the same birds on a repeated basis.

NREL Surveys.--A conservative estimate of the total number of bald and golden eagles under observation at any one time is to consider how many separate birds were recorded moving past the Wind Site during late afternoon movements, ostensibly to night roosts in the foothills (see below). The single largest movement of eagles recorded in the present study occurred on 26 February 1994 when a total of 19 eagles were sighted in a two-hour period, including 5 balds (4 adults and 1 subadult), 8 goldens (3 adults and 5 subadults) and 5 eagles not identified to species. By comparison, the maximum number of eagles recorded during any one observation period on the NWTC in the winter of 1994-5 was 4 balds (2 adults and 2 subadults) and just 1 golden eagle.

Supplemental Surveys along CO 128.--To address possible concerns that observations conducted from the vantage point of the NWTC were underestimating the number of eagles passing through the vicinity during late afternoon movements to roosting areas in the foothills, supplemental eagle surveys were conducted from an elevated point along CO 128 near the entrance to the NWTC. This location provided a 360 degree view of the area surrounding the NWTC. Counts from this location were roughly comparable to those obtained on the NWTC. Thus, a maximum of 4 bald eagles (3 adults and 1 subadult) was seen from this viewing location during any given afternoon. The maximum number of golden eagles detected by these supplemental observations was 4, consisting of 2 adults, 1 subadult and 1 bird of unknown age.

Supplemental Surveys at Eldorado Canyon.--As described later, the flight paths of eagles seen passing by the NWTC in late afternoon were taking them in the direction of Eldorado Canyon and probable roost areas. Counts were made of eagles entering the canyon on four separate dates in January and February of 1995 in an effort to verify that the canyon was being used for roosting and to determine the number of birds using the roost area. These numbers are useful in providing a minimum estimate of the number of different eagles that might have contributed to sightings recorded at the NWTC. Total eagle counts on those four dates were reasonably consistent at 10,9, 9 and 9. The maximum number of bald eagles recorded in a single afternoon was 7. Since that count consisted only of mature birds and we counted a minimum of 3 subadult birds on another occasion, we estimate that a minimum of 10 bald eagles roosted in or near the Canyon in January and February of 1995, though perhaps not all at one time.

As for the number of golden eagles using the canyon for roosting, we counted a maximum of 3 birds in adult plumage on one occasion and a subadult on other dates, suggesting that a minimum of 4 golden eagles were roosting in the area.

Although results for the winter of 1993-4 are limited to two late-day observations in the last week of February, 1994, the data suggest that the number of eagles flying within detection range of the NWTC was higher in the winter of 1993-4 than in the winter of 1994-5. Thus, during two 3-hour, late-day counts from the NWTC on 23 and 26 February 1994, the number of eagles sighted was 8 and 18, respectively. The number of bald eagles in these counts was 1 and 6, respectively. However, the numbers of bald eagles recorded on those two dates were probably conservative for two reasons. First, some eagles were counted but not classified as to species. Second, it remains possible that some eagles recorded as goldens were in fact subadult bald eagles. As discussed in the next section, many of these birds were flying at considerable distance from the NWTC under low light, making species identification difficult at times. In addition, these two census periods came in the first week of the study when standards for verifying species identity were still being formulated. Regardless of the exact species and age composition of eagles in these two samples, their identity as eagles is not in question. Thus, we are left to conclude that the number eagles passing through the vicinity of the NWTC was about twofold greater in February of 1994 than in February of 1995.

4.3D EAGLE LANDINGS ON THE NWTC

Among the possible factors contributing to potential risks of eagle collisions with wind turbines on the NWTC will be the extent to which eagles attempt to land or forage within the boundaries of the site. On this basis, the risks appear slim. Bald and golden eagles were seen landing on the NWTC on one occasion each. The lone instance of a golden eagle seen landing on the site involved a subadult bird that was first detected while perched on one of the low wood poles along the east perimeter drive. The bird was feeding on a snake at 0900 hrs on 17 June 1994. While under observation over a 15-minute period, the bird flew to an adjoining wooden pole with its prey. On one other occasion, a golden eagle of undetermined age came within 30 m of the ground on the NWTC in what appeared to be a dive or "stoop" towards a potential prey. The bird regained altitude without reaching the ground and quickly disappeared towards the northwest. The date (13 April 1995), time of the day (1200 hrs), and flight direction (northwest) were consisted with a migrant status for this bird.

The lone instance of a bald eagle landing on the NWTC occurred at 1300 hrs on 11 January 1995. A bird in mature plumage landed for a second or two on the top of the met tower in the northwest corner of the site. As detailed below, bald eagles were seen flying over the site on occasion but we had no evidence that they were attempting to hunt prey or to land on the site.

4.3E FLIGHT BEHAVIOR OF EAGLES

Instead of perching or foraging in or near the NWTC, most eagles censused during our field observations were showing directed and sustained flight through the area. Accordingly, their risk of collision with a wind turbine on the NWTC should be dictated in large part by their flight paths and flight elevations. These two aspects of flight behavior are examined separately by species for seasonal and diurnal patterns. The analysis of data for each species ends by considering the flight elevations of eagles that passed over or near the perimeter of the NWTC.

4.3E1 BALD EAGLES

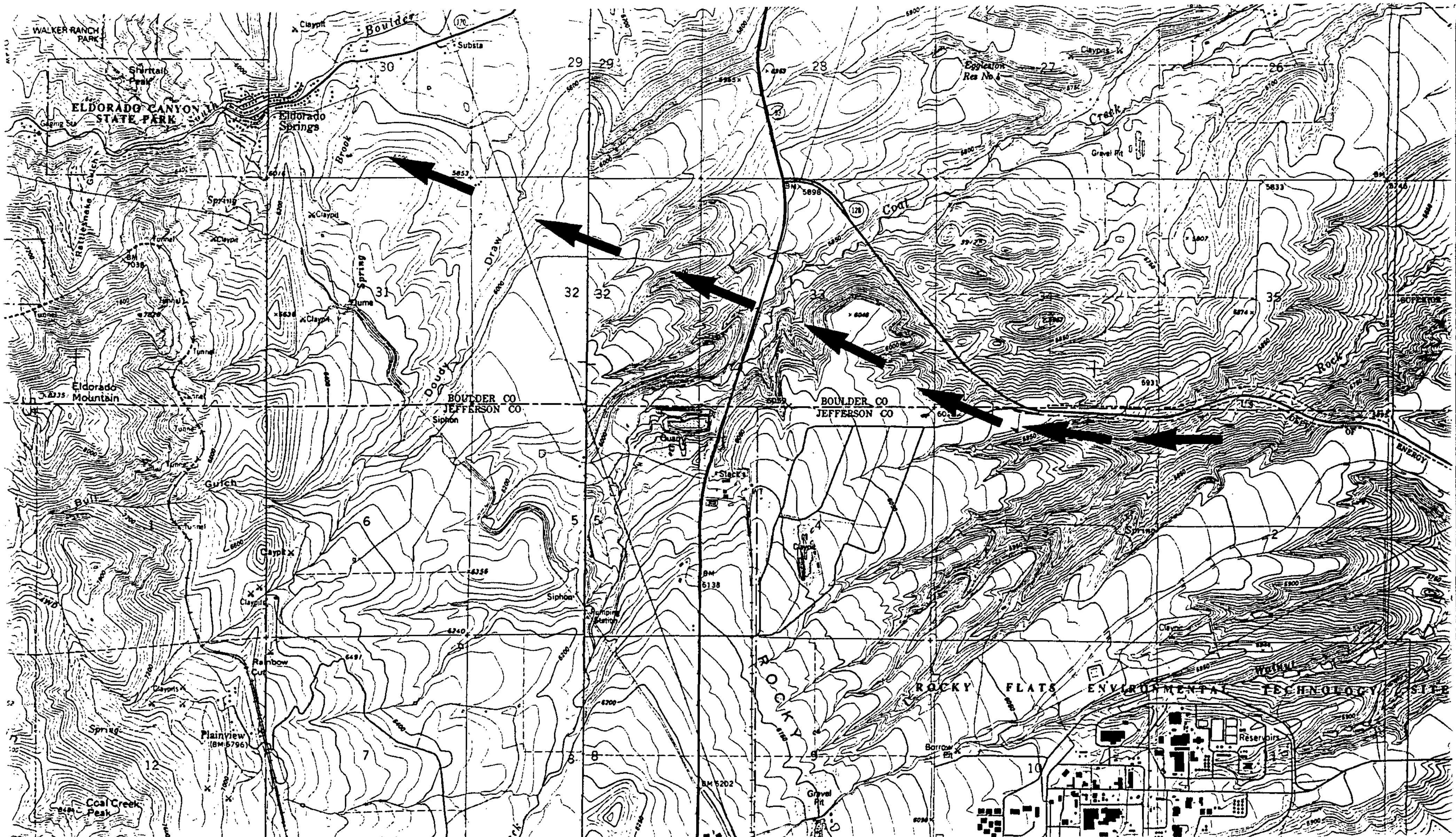
Flight Directions.--Of 39 bald eagle sightings, flight directions were recorded for 37. Of these, the flights paths of 33 were heading west to northwest, the general direction of Eldorado Canyon . The four exceptions were sightings made in the morning or early afternoon. Of these, two bald eagles seen flying east and southeast were recorded at

0825 hrs and 1045 hrs, respectively. Presumably, these birds were working their way eastward from the roost area in the foothills. Of the other two bald eagles that were flying in directions other than west, one was the adult that briefly landed on a met tower before heading north. The other was seen circling 200 m west of the NWTC at 1305 hrs and could not be followed because of trees obstructing the line of sight.

Flight Routes.--The flight routes followed by bald eagles either took them over some portion of the NWTC (19 of 39 or 49%) or across the open space to the north of the NWTC (17 of 39 or 44%). Of the remaining 3 birds, 1 past the NWTC to the south while the other two were seen circling on the west side of the Wind Site. The tendency of bald eagles to pass the NWTC on the north side was also reflected at least partially in the flight behavior of birds that were scored as "flyovers." Six of the 19 birds in this category were on westerly flight paths that took them over the north edge of the Wind Site.

A somewhat different picture of bald eagle flight paths emerged from observations conducted from the elevated vantage point along CO 128 near the NREL entrance. Of 14 bald eagles counted from that location on 7 observation dates between 23 December 1994 and 16 February 1995, all but 3 birds appeared to be following the north rim of the bench where the NWTC is located. The typical flight pattern is shown in Figure 20. When first sighted, these birds were generally 1 to 2 km east of the NWTC and flying a westerly course that paralleled CO 128 but several hundred meters to the south of the road. As they approached the "bench" at the upper end of the Rock Creek drainage, they crossed the NREL access road near the highway and appeared to follow the north rim of the bench to the northwest. On occasion, some of these birds were followed with binoculars for 3-4 minutes until they disappeared from view near the general vicinity of the Eldorado Canyon entrance. Of the 3 bald eagles that followed a different route, two followed westerly flight paths that paralleled CO 128 but 1 km or so north of the road. The third followed a westerly flight path that took it roughly a half km south of the NWTC.

Figure 20. The most common flight path used by bald eagles during late-day movements to roost areas in the vicinity of Eldorado Canyon.



Flight Elevations.--Flight elevations were examined for two subgroups of bald eagle sightings, those whose flight paths took them over some portion of the NWTC and those that went wide of the site. Data are pooled across months and time periods of the day. Of the 15 balds seen flying over the NWTC for which flight elevations were available, values ranged from 10 to 120 m, averaging 56 m. Of the 14 balds flying wide of the site for which data were available, flight elevations ranged from 3 to 60 m, averaging 28 m. Comparing flight elevations for the two flight corridors (15 "flyovers" and 14 non-flyovers) by a Wilcoxan two-sample (nonparametric) test (Sokal and Rohlf, 1969), the difference is highly significant ($C = 173$, $P < .005$).

Relative to the maximum heights of existing wind turbines and meteorological towers on the site (30 and 80 m, respectively), 6 of 15 bald eagles that flew directly over the site were at or below the height of the tallest wind turbine and 13 of 15 were at or below the height of the tallest met tower.

Of course, estimates of flight elevations were subject to potential error. The presence on the Wind Site of towers and poles of known heights provided convenient "measuring sticks" for judging flight elevations of eagles as they flew over or very near the site. It was possible that the heights of eagles flying wide of the site were being systematically underestimated. However, we suspect that bald eagles flying north of the site were indeed lower in elevation as they passed by the Wind Site for two reasons. First, we had flight elevations on 7 bald eagles sighted from CO 128 during the supplemental eagle surveys and they averaged 27 m above ground (range, 15 to 90). Also, our observations from CO 128 suggested that the bald eagles were paralleling the rim of the Rocky Flats bench (see Figure 20) and may have been riding updrafts close to the bench rim to facilitate flight.

4.3E2 GOLDEN EAGLES

The flight behavior of golden eagles in and around the NWTC over the course of the study presents a more complex situation than described above for bald eagles. The reasons are that the birds were seen sporadically throughout the study and were less regular in terms of their flight behavior. The following summary of results looks at flight direction, flight paths relative to the NWTC, and flight elevations.

Flight Directions.--Flight directions were recorded for 39 of 66 golden eagle sightings made from the premises of the NWTC. Of these, 18 or 46% were judged to be heading in a westerly direction, 8 to the north or northwest, and 13 in a southerly direction (southeast to southwest). Thus, compared to bald eagle movements, goldens showed greater variation in flight direction. Also different was the lower percentage of birds scored for flight direction (39 of 66 or 59% of goldens vs 37 of 39 or 95% of balds). The reason for this difference was that the flight behavior of goldens often involved soaring (circular flight on updrafts) and lacked clear direction at the time they were first recorded. With few exceptions, bald eagles typically showed directed and sustained flight, ostensibly associated with travel to roost areas. While some of the golden eagles sighted in the present study appeared to be heading towards roost areas in the foothills as well, the flight behavior of goldens often suggested that they were riding the thermals while searching for prey. This conclusion fits with the observations that sightings were possible at any hour of the day (see Figure 18). While no golden eagles were seen taking prey on the NWTC, goldens were occasionally seen soaring over the site, usually at considerable elevation (see below). The lack of any significant prey base (medium sized mammals) probably limited feeding opportunities on the site. As mentioned earlier, a golden eagle was observed feeding on a snake (probably a bullsnake, genus *Pituophis*) while perching on the NWTC. However, bullsnakes were apparently scarce in the area, since we never observed them on the roads or in the vegetation during walks through the area.

Flight Routes.--As with flight direction, the flight routes of goldens relative to the NWTC were highly variable. Of 66 golden eagles sighted from the NWTC, 25 (38%) were seen flying over some portion of the site while under observation. Of the remaining 41 birds, 18 (24%) were located north or northeast of the site, 9 to the east or southeast over the

RFETC, and 11 at varying distances west or southwest of the site. Of the birds in the latter category, 6 were located near the foothills and were probable migrants (see 4.4A).

Flight Elevations.--As with the analysis for bald eagles, flight elevations were examined for eagles seen flying wide of the NWTC and those flying over a portion of the site. Flight elevations for 13 "flyovers" ranged from 10 to 90 m, averaging 40 m. Flight elevations for 23 golden eagles that flew wide of the site ranged from 10 to 160, averaging 68 m. Comparing the two distributions by a Wilcoxan two-sample test, the difference is marginally significant ($C = 201$, $P < .05$). Relative to the height of the tallest existing wind turbines and meteorological towers on the site (30 and 80 m, respectively), 6 of 13 golden eagle "flyovers" were at or below 30 m, 12 of 13 at or below 80 m.

4.3E3 UNIDENTIFIED EAGLES

A total of 18 eagles were sighted that could not be identified to species. Half these sightings occurred during the afternoon observations in the first week of the study, 5 in December of 1994, and 4 in the first 4 months of 1995. All but one occurred in the months of December, January, and February, which means that they could have been either bald or golden eagles. Flight elevations were recorded for just 3 of the 18 sightings, all 3 of which were within 30 m of the ground. All but one of the birds was on a westerly flight path and 7 of the 18 birds were 1 km or more north of the Wind Site. Perhaps most importantly, only 3 birds came within 400 m of the Wind Site.

4.3F EAGLE COUNTS AS A FUNCTION OF WEATHER

The possible effects of weather on the movement of eagles past the wind site was examined by testing for correlations between eagle numbers (balds, goldens and the two combined) during late day observations ($n = 21$) and weather data obtained from a met tower on the west side of the RFETS and summarized by their staff in monthly reports (Monthly Environmental Monitoring Reports). The met tower for these data was located in the west buffer zone and thus should be representative of conditions at the Wind Site. As seen in Table 7, only two

Table 7. Spearman's coefficient of rank correlation between weather variables and number of eagles sighted near the NWTC during afternoon observations (n = 21). Bald and golden eagles analyzed separately and pooled.

Weather Variable	Total Balds	Total Goldens	Total Eagles
High temp	-.234	.102	-.212
Low temp	-.124	.304	-.016
Mean temp	-.108	.268	-.043
Relative humidity	-.069	-.174	-.217
Average wind speed	.212	.380	.288
Peak wind gust	.166	.442*	.248
Barometric pressure	-.119	-.041	-.154
Solar radiation	-.158	-.145	-.265

*P < .05.

trends were statistically significant. The total number of eagles seen on a given afternoon was inversely related to the amount of solar radiation on that day, itself a measure of cloud cover. Thus, total eagle numbers were high on cloudy days. This could mean that they were more easily detected on cloudy days, perhaps flying lower and more distinguishable against cloudy than clear sky. In addition, number of golden eagles was positively correlated with maximum daily wind gusts (correlation with wind speed only slight weaker but not statistically significant). One weakness of this analysis is that eagle numbers were not highly variable across the 16 dates, ranging from 0 to 4 individuals of each species.

4.4 SPRING MIGRATION

4.4A NREL COMPARED WITH DAKOTA HOGBACK

The identity and number of raptors and vultures recorded as likely migrants during April at the NWTC are summarized by date in Table 8. A total of 290 birds of 14 species were recorded during 140 hours of field observation. Two species accounted for most of the sightings, turkey vultures (162 or 56%) and American kestrel (85 or 29%). Looking at the distribution of migrants by genera, falcons of the genus *Falco* (American kestrel, prairie falcon, merlin and unknown falcons) accounted 32% (92 of 284), hawks of the genus *Accipter* (Cooper's, sharp-shinned, northern goshawks, and unknown accipters) for 5% (n = 14), and hawks in the genus *Buteo* (broad-winged, red-tails, and Swainson's) for 5% (n = 15).

Comparing results for the NWTC with those obtained by the DRRMS at the I70 hogback (Table 9), the species lists are similar but the total volume and relative proportions of the different species tend to vary between the two sites. The DRRMS recorded 2319 migrants of 17 species over the same 22 observation dates. Thus, the number of migrants seen passing through the vicinity of the NWTC was only about 12% of the total number detected at the I70 hogback just 10 km to the south. In addition, three species were seen at the hogback that were not detected as migrants at the NWTC, the bald eagle, ferruginous hawk, peregrine falcon (four large falcons were censused at the NWTC that were either prairie or peregrine falcons).

Table 8. Distribution of spring migrants by date (April) and species at the NWTC in 1995. See Figure 9 for species' abbreviations.

	Field Observation Dates in April																					
Species	3	4	5	6	7	8	11	12	13	14	15	16	17	18	19	20	22	23	24	25	26	27	SUM
AK	0	0	0	0	1	0	2	0	1	0	0	75	1	1	0	0	0	0	0	1	2	1	85
BE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
CH	0	0	0	1	0	0	0	0	0	0	0	1	0	1	1	0	2	1	0	0	0	1	8
FH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GE	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
ML	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
NG	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	3
NH	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
OS	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	1	0	0	4
PR	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
RL	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
RT	1	1	2	0	0	0	0	0	2	0	0	1	0	1	0	0	0	0	1	0	0	0	9
SS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
SW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	3
TV	0	3	0	4	8	0	6	0	60	0	18	25	6	4	4	2	0	10	1	4	0	7	162
UA	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
UB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UF	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	1	0	0	0	0	4
UR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
SUM	2	4	2	5	9	0	8	0	66	0	22	106	7	7	5	2	4	14	6	8	2	11	290

Table 9. Distribution of migrants by date (April) and species at the I70 Hogback in 1995, data gathered by the Dinosaur Ridge Raptor Monitoring Station.

	Field Observation Dates in April																					
Species	**3**	**4**	**5**	**6**	**7**	**8**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**22**	**23**	**24**	**25**	**26**	**27**	**SUM**
AK	12	1	1	30	13	2	1	10	24	2	44	421	7	12	1	11	1	1	9	3	1	75	682
BE	0	1	1	3	1	2	0	0	5	0	2	0	0	0	0	0	0	0	1	0	0	0	16
BW 0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	3	0	0	3	3	0	6	17	
CH	7	1	4	35	3	6	1	10	48	1	34	14	16	17	0	8	18	8	7	10	1	58	307
FH	2	1	0	2	0	1	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	9
GE	1	0	0	5	0	2	0	0	2	0	4	0	0	4	0	2	2	2	1	0	0	1	26
ML	0	0	0	1	0	0	0	1	6	0	2	7	0	0	1	1	0	2	0	1	0	2	24
NG	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	3
NH	0	1	1	1	0	0	0	1	3	0	1	8	1	0	0	2	0	0	1	0	0	0	20
OS	0	0	1	2	0	0	2	2	7	0	12	6	2	3	0	2	2	2	5	1	0	7	56
PG	0	0	0	0	0	0	0	0	3	0	0	0	0	1	2	1	1	2	3	0	0	1	14
PR	0	2	1	0	0	1	0	1	0	0	1	0	1	0	0	0	0	0	0	1	0	2	10
RL	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	3
RT	23	9	6	35	23	9	3	9	26	3	36	34	0	6	4	1	7	6	8	6	0	16	270
SS	4	0	2	17	1	1	1	1	17	2	7	23	5	13	2	10	7	4	8	2	0	27	154
SW	0	0	0	0	0	0	0	0	0	0	2	1	0	2	0	0	0	0	1	2	0	1	9
TV	4	11	6	14	18	4	0	111	292	5	48	15	3	14	3	13	8	6	17	19	0	59	670
UA	2	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	1	1	0	0	5	12
UB	0	2	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	6
UF	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
UE	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	6
UU	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2
SUM	**56**	**31**	**25**	**145**	**60**	**28**	**8**	**146**	**439**	**13**	**196**	**532**	**36**	**72**	**14**	**57**	**47**	**36**	**65**	**48**	**2**	**263**	**2319**

AK = American kestrel, BE = bald eagle, BW = broad-winged hawk, CH = Cooper's hawk, FH = ferruginous hawk, GE = golden eagle, ML = merlin, NG = Northern goshawk, NH = Northern harrier, OS = osprey, PG = peregrine falcon, PR = prairie falcon, RL = rough-legged hawk, RT = red-tailed hawk, SS = sharp-shinned hawk, SW = Swainson's hawk, TV = turkey vulture, UA = unidentified accipter, UB = unidentified buteo hawk, UF = unidentified falcon, UE = unidentified eagle, UU = unidentified raptor.

As seen at the NWTC, American kestrels and turkey vultures represented the two most common migrants censused at the I70 hogback. But, whereas these two species accounted for 85% of migrants censused at the NWTC, they accounted for just 58% of the total migrant pool at the hogback. The reason for this drop was the far greater representation of redtails, cooper's and sharp-shinned hawks in the migrant pool. Thus, not only were far fewer migrants censused at NWTC than at the I70 hogback but the relative proportions of the species was strikingly different in the two samples as well.

To explore the differences in makeup of the two samples, the number of migrants of each species at the NWTC is expressed as a percentage of those seen at the I70 hogback in column 2 of Table 10. Using this percentage as a measure of "detection rate" at the NWTC, the results are highly variable across species. Some of this variability relates to the fact that several species were relatively rare at the hogback and thus small differences in number detected at the NWTC could raise or lower the detection rate by large amounts. However, even if the analysis is focused on species found to be relatively common in the census at the hogback, detection rates at the NWTC show wide fluctuations across species. To illustrate, the migrant count of five species exceeded 100 birds at the hogback (TV, AK, CH, RT, and SS). However, the detection rates ranged from a low of just 0.6% for sharp-shinned hawks to a high of 24% for turkey vultures. Species differences in body size may explain some of the variation. For example, the large-bodied turkey vulture was differentially represented in the migrant sample for the NWTC (55% of all migrants and 24% of the number counted at the hogback), perhaps because they can be detected over long distances. However, body size alone does not explain all the variation in "detection rate." For example, the detection rate was four-fold higher for the small bodied kestrel (12.5%) than for the large-bodied redtail (3.3%). Thus, other factors besides body size were probably affecting detection rates of the different raptor migrants at the NWTC.

Differences in geography of the two sampling locations probably contributed to some of the variation in census results. Chief among these, the Wind Site is located about twice

Table 10. Relationship of migrant numbers at the NWTC to the number and flight paths of migrants at the I70 hogback. Migrant numbers based on sampling from 3 - 27 April, inclusive. See Figure 9 for species' abbreviations.

Species	I70 Hogback	NWTC	(%)	I70 Hogback* % >0.6 km
AK	682	85	(12.5)	26.1
BE	16	0	(0)	81.2
BW	17	2	(11.8)	41.2
CH	307	8	(2.6)	65.5
FH	9	0	(0)	77.8
GE	26	1	(3.8)	92.3
ML	24	1	(4.2)	62.5
NG	3	3	(100)	0.0
NH	20	1	(5.0)	90.5
OS	56	4	(7.1)	62.5
PG	14	0	(0)	28.6
PR	10	2	(20.0)	60.0
RL	3	1	(33.0)	66.6
RT	270	9	(3.3)	70.0
SS	154	1	(0.6)	55.8
SW	9	3	(33.3)	55.6
TV	670	156	(23.3)	78.1
SUM	**2290**	**277**	**(12.1)**	

*Percentage of migrants exceeding 0.6 km lateral distance from viewing station.
**Most migrants passed to the west of the hogback (F. Hein, pers. comm.).

the distance from the foothills as the hogback viewing site (6 versus 2.5 km, respectively, the distance of the viewing site from the first ridge of peaks in the foothills). In addition, the hogback viewing site at I70 is higher (1980 m) than the Wind Site (1840 m) and positioned along a sharply defined ridge (Wind Site lies on a relatively flat bench). If raptors were prone to follow areas of updrafts and thus paralleled the hogback or the foothills to the west, they would be too far west of the Wind Site to be detected (except for large and high-flying species such as eagles or vulture). This hypothesis can be partially evaluated by looking at the flight paths of raptors seen passing by the I70 hogback . If these birds were mainly tracking the edge of the foothills, their flight paths would have taken them 3-6 km west of the wind site and well beyond the normal limits of detection from the NWTC.

The DRRMS used a scale of 1 to 3 to record lateral distances of birds form the hogback (Frank Hein, pers. comm.). Landscape features were used to delineate the three categories. Out to a distance of about 0.6 km, birds were given a lateral distance score of 1. Those between 0.6 km and the first ridge of peaks (e.g., Mt. Morrison) were given a score of 2. Birds on flight paths that took them west of the first ridge of peaks (beyond about 2.5 km) were given a score of 3. Roughly the same linear distance categories were applied to birds flying east of the hogback. Although records were not kept as to which side of the ridge the migrants passed, the vast majority passed to the west of the hogback (Frank Hein, pers. comm.).

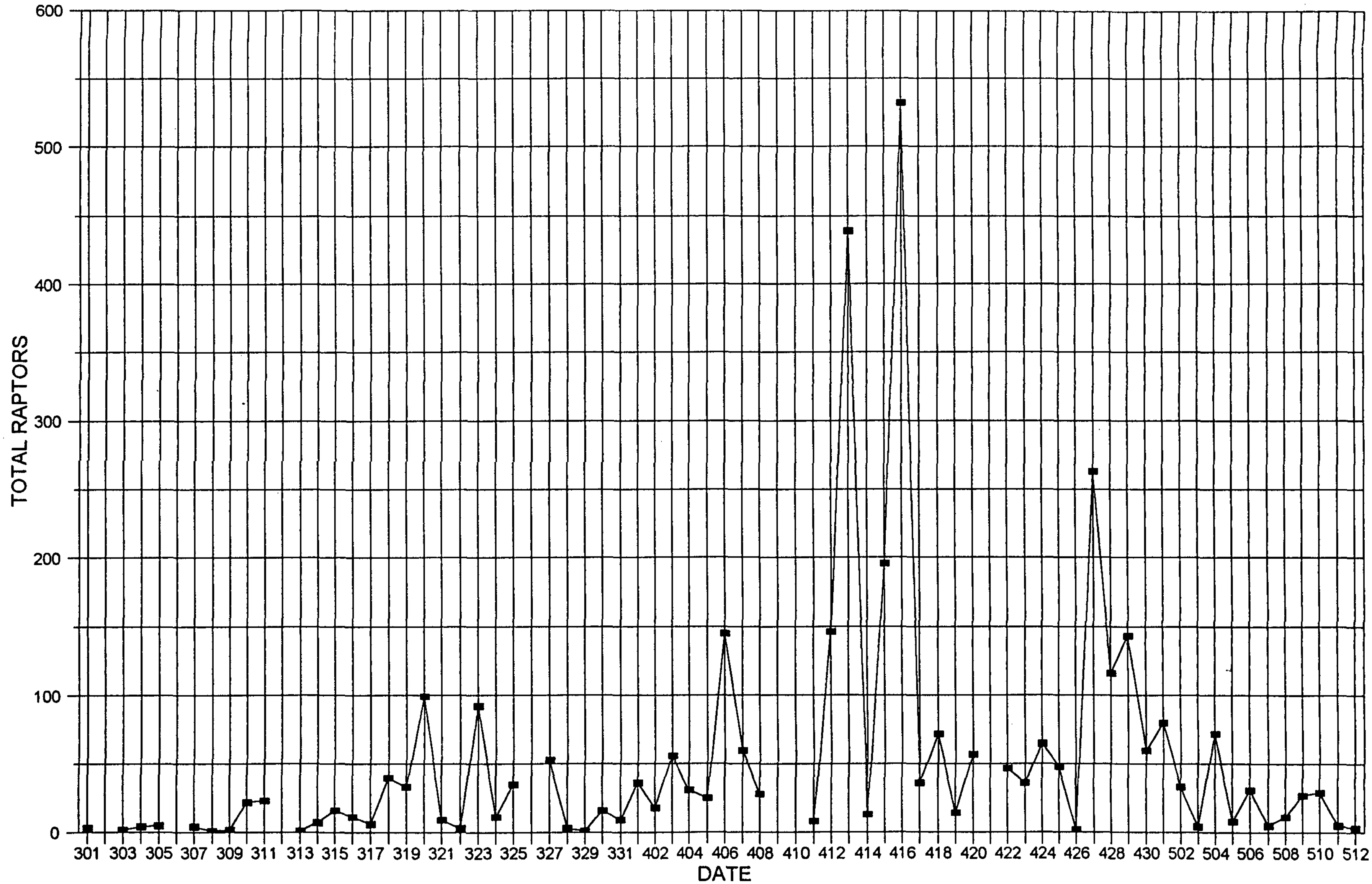
The right-hand column of Table 10 shows the percentage of migrants by species that passed by the DRRMS at distances exceeding 0.6 km (counts recorded from 3 - 27 April, inclusive). In effect, these birds were traveling on flight paths that took them within 1.5 km of the first ridge of peaks in the foothills. If these birds flew a comparable flight path along the foothills west of the wind site, they would have traveled no closer than about 3-4 km of the wind site. At this distance, only large and slow moving species would have had much chance of being detected at the NWTC. As seen in Table 10, the species of migrants that tended to be underrepresented at the Wind Site also tended to follow flight paths at the I70 hogback that placed them near the foothills. To illustrate, the eagles seen flying past the hogback were mostly (>80%) a lateral distance of about 0.6 km or more. Similarly, redtails, Cooper's and sharp-shinned hawks all tended to be poorly represented in the migrant pool recorded at the NWTC and the majority of these birds also past the hogback at lateral distances of 0.6 km or more (66% of Cooper's hawks, 56% of sharp-shinned hawks, and 70% of redtails). Conversely, kestrels tended to travel within 0.6 km of the hogback and also were detected at a reasonably high rate (12%) at the NWTC. Of course, turkey vultures also were detected at high frequency at the NWTC (23%) even though they also tended to travel along the foothills (up to 78%). The higher than expected detection rate for this species may be related to its large size (wing span of 1.7 m) and a tendency to migrate in groups (Figure 21). The low detection rates for other large bodied species such as the bald and golden eagles (wing spans of 2+ m) might be explained by the fact they do not tend to bunch up in flight and thus would be harder to detect at distances of 4 to 6 km. In the case of golden eagles, the low detection rate may have resulted because migrants were inaccurately judged to be local birds. A total of 21 golden eagles were seen over the course of the 22 observation periods in April, compared with 26 at the I70 hogback. As previously noted (Figure 19), golden eagle sightings showed an increase in April of 1995 relative to March or May, suggesting possible migrants in the area at that time.

4.4B SEASONAL TRENDS IN MIGRATION BY SPECIES

The decision to increase field observation time at the Wind Site during April was based on information from the DRRMS that the bulk of the spring migration through the Denver area occurred at this time (Frank Hein, pers. comm.). Data from the 1995 season of the Dinosaur Ridge Raptor Monitoring Station were examined to see if this same generalization held in that year. Their field observations began on 1 March and continued on a daily basis through 12 May, weather permitting (observations suspended early or skipped entirely on 7 dates because of adverse weather). Their counts of total migrants (species pooled) on a daily basis are plotted in Figure 22. As expected, the bulk of the migrants were counted in April. Indeed, most of them were counted on 8 dates in April.

Figure 21. Tendency of turkey vultures to migrate in small groups. Cottontail rabbit at the NWTC reflecting the paucity of medium-sized mammalian prey available to golden eagles at the site. Great horned owl perched on the pine ridge 100 m north of the NWTC.

Figure 22. Total number of migrants recorded by the Colorado Hawkwatch Program at the I70 Hogback on a daily basis in the spring of 1995, data supplied by Frank Hein.



In terms of specific numbers, the DRRMS recorded a total of 3522 migrants during 67 days of field observation in 1995, and 2319 or 66% were censused during 22 field days between 3 and 27 April.

While the above results support the contention that increased field efforts in April should have detected sizable numbers of migrants if they were passing near the NREL, it remained possible that sampling in April tended to undercount species with earlier or later than average migration schedules. Again, the data from the DRRMS were analyzed for seasonal trends in movements of individual species. The approach involved subdividing the 74-day field season (1 March through 12 May, inclusive) into 15-day intervals to see if any species conducted the bulk of their spring migration prior to or after the month of April. The results are summarized in Table 11. Time periods 3 and 4 roughly correspond to the dates when the Wind Site was subjected to increased monitoring for migrants. Most species peaked in their migration during April and the majority of the individual birds of these species were counted during that month. Four species showed departures from these trends. Ferruginous hawks peaked in the first two weeks of March and two-thirds of the count passed through the area during that same month. The other three species (bald and golden eagles and redtails) all peaked in the second two weeks of March with roughly half the migrants passing through the area before the 1st of April.

The above results suggested that monitoring the NWTC for migrants in April had the potential to intercept at least half the volume of individuals of each species that passed through the area. The exact proportion was estimated from the DRRMS data by comparing total migrants by species across all sampling dates against the numbers counted for the 22 dates in April when the NWTC was being monitored. As seen in Table 12, the 22 sampling dates in April encompassed about 30% of migrating golden eagles, ferruginous hawks and prairie falcons, 40% of bald eagles and broad-winged, red-tailed, and Swainson's hawks, and 50% or more of all other species.

Table 11. Seasonal trends in migration by species at the I70 Hogback. Data pooled by 15-day intervals. Days of field observations by time period shown in parentheses. Data provided by Frank Hein of the DRRMS. See Figure 9 for species' abbreviations.

Species	Time Period				
	3/1 - 3/15	3/16 - 3/30	3/31`- 4/14	4/15 - 4/29	4/30 - 5/12
AK	0	25	99	701	74
BE	9	15	13	3	0
BW	0	0	0	26	13
CH	1	8	122	230	55
FH	14	7	8	3	1
GE	16	26	17	17	6
ML	0	6	8	19	1
NG	1	0	0	3	0
NH	0	4	10	16	6
OS	0	0	14	45	3
PG	1	0	3	12	8
PR	2	9	5	7	9
RL	0	2	2	1	0
RT	38	277	174	140	27
SS	3	27	50	145	66
SW	0	0	0	14	7

Table 12. Seasonal totals of migrants by species as recorded at the I70 hogback and the number and percentage of birds recorded from 3 - 27 April, inclusive. Data provided by Frank Hein of the DRRMS. See Figure 9 for species' abbreviations.

Species	Total	April (3rd - 27th)	Percentage
AK	899	682	75.9
BE	40	16	40.0
BW	39	17	43.6
CH	416	307	73.8
FH	33	9	27.3
GE	82	26	31.7
ML	34	24	70.6
NG	4	3	75.0
NH	36	20	55.6
OS	62	56	90.3
PG	24	14	58.3
PR	32	10	31.2
RL	5	3	60.0
RT	656	270	41.2
SS	291	154	52.9
SW	21	9	42.9
TV	760	670	88.2
UNK	87	28	32.2
SUM	**3522**	**2319**	**65.8**

In the case of two species, the turkey vulture and kestrel, a sizable fraction of the migrants moved through the area over periods of one to several days. Such movement patterns have the potential to shape strategies for minimizing risks posed to migrating raptors by wind turbines at the NWTC. In the case of kestrels, 75 of the 85 sighted from the Wind Site (88%) were recorded during a 3-hour period on one afternoon (16 April). The DRRMS also recorded a large pulse of kestrel movement on that date, 421 individuals or 47% of the season's total being counted on that same day. In the case of turkey vultures, 103 of 156 or 66% of those sighted from the Wind Site were recorded on a 4-day period from 13 to 16 April. The DRRMS also recorded a large movement of vultures that started on 12 April and ran through 16 April. Over this 5-day period, 62% of the total for the season (471 of 760) were recorded. None of the other three abundant species of migrants (Cooper's, sharp-shinned and red-tailed hawks) showed appreciable synchrony in movement (see Table 9).

4.4C FLIGHT PATHS AND ELEVATIONS OF MIGRANTS AT THE NWTC

To determine the extent to which the towers and turbines at the Wind Site might present risks to migrating raptors, the flight paths and flight elevations of migrants were analyzed relative to features of the NWTC. Only the turkey vulture and American kestrel were sufficiently numerous to permit a quantitative assessment of movement patterns, although data for all species are presented for review. The approach with these analyses was to sort the migrants into a matrix where columns correspond to the four height intervals used in scoring flight elevations in the field (H1: 0-30m, H2: 30-80m, H3: 80-160m, H4 > 160m) and rows correspond to the four flight routes (E: east of Wind Site, FO: flight over the Wind Site, W1: flight path between 0 and 0.3 km west of Wind Site, W2: flight path between 0.3 and 3 km west of Wind Site, and W4: flight path between 3 and 6 km west of Wind Site).

As seen for turkey vultures (Table 13), only 14 of 149 birds scored for both flight route and flight elevation passed directly over the Wind Site and of these only 3 were flying at heights judged to lie below the height of the tallest met tower (80 m), 1 below the height

Table 13. Heights and flight paths of migrating turkey vultures at the NWTC in April, 1995.

Height	Flight Path					
	East	"Flyover"	West			
			<0.3 km	0.3-3 km	3-6 km	Sum
0-30m	2	1	0	2	0	5
30-80m	6	2	0	0	0	8
80-160m	29	6	6	1	22	64
> 160m	19	5	0	1	47	72
Sum	56	14	6	4	69	149

Table 14. Heights and flight paths of migrating American kestrels at the NWTC in April, 1995.

Height	Flight Path					
	East	"Flyover"	West			
			<0.3 km	0.3-3 km	3-6 km	Sum
0-30m	6	27	1	2	0	36
30-80m	9	22	0	0	0	31
80-160m	7	5	0	0	0	12
> 160m	2	0	0	2	0	4
Sum	24	54	1	4	0	83

of the tallest wind turbine (30 m). Indeed, most turkey vultures recorded as migrants were on flight paths that took them 3+ km west of the wind site (69 of 149). Pooling birds in all flight path categories, only 5 (3%) were judged to be flying at elevations that would have placed them in potential contact with the tallest wind turbines on the NWTC (30 m) and 13 (9%) in potential contact with the tallest met towers (80 m).

As seen in Table 14, the kestrels presented a different pattern. Flight routes and flight elevations were available for 83 of the 85 kestrel migrants in April of 1995. Of these, 67 (81%) were flying below the height of the tallest met tower and 36 (43%) were flying below the height of the tallest wind turbine (30 m). Of the 67 migrant kestrels flying within 80 m of the ground, 49 were on flight paths that took them directly over the Wind Site. As noted earlier, most of the migrant kestrels (75 of 85) were recorded on a single date (16 April). Indeed, they all were seen within the space of about 3 hrs (1400 to 1700 hrs). Thus, the data in Table 14 may be biased in a couple ways. First, birds passing through the area but lateral to the Wind Site might easily have been overlooked because the field observers (3 present on that particular afternoon) were focused primarily on the birds passing closest to the viewing station. Second, the weather conditions on that date, overcast with light to moderate wind (averaging 7 mph and gusting to 21 mph), may have affected flight patterns in unknown ways. Most of the birds recorded on the 16th were flying due north over the site and a sizable fraction came within a dozen meters or so of towers or turbines on the site. None of the turbines were operational at the time these kestrels were seen moving through the area.

In the case of *Buteo* hawks, data were available for a total of 8 red-tailed hawks. Of these, all but one were flying above the height of the tallest met towers and only one passed directly over the Wind Site. Of seven other *Buteo* hawks, 1 broad-winged hawk passed low (under 30 m) but an unknown lateral distance from the wind site. A second broad-winged hawk flew over the Wind Site but at a height between 80 and 160 m. Two Swainson's hawks passed by at heights exceeding 160 m but positions of the flight paths were not recorded. The one rough-legged hawk recorded as a migrant flew east of the Wind Site and at an elevation between 80 and 160 m.

In contrast to the *Buteo* hawks, the few *Accipter* hawks in the sample were generally seen flying directly over the wind site (7 of 14) or along a path that took them within 300 m of the west edge of the Wind Site (an additional 3 birds). In addition, their flight elevations were generally lower than those of *Buteo* hawks. Thus, 6 of 14 accipters in the sample were flying at heights of 80 m or less, while an additional 3 were between 1 and 2 met towers (80 to 160 m).

Of the four "unidentified" falcons (prairie or peregrine) noted in the sample of migrants, all had flight paths that took them wide of the Wind Site and all were flying at heights that exceeded 80 m above ground (3 of the 4 were judged to be at heights exceeding 160 m).

Two raptor species were noted in the migrant sample that had not previously been censused in early phases of the present study. On 16 April, a lone merlin flew due north over the NWTC at a height of about 10 m above ground. In addition, migrating osprey were noted on 4 different dates. None of them flew directly over the site, although two of the four were judged to be flying at a height within 80 m of the ground. The height of one of the four probably exceeded 500 m.

4.4D NUMBER OF MIGRANTS AS A FUNCTION OF WEATHER

As evident from Figure 22, the volume of movement of raptors and vultures was highly variable from day to day, even during April when the majority of migrants passed through the area. One hypothesis to explain such variation is that the birds were responding to day-to-day variation in weather patterns. To evaluate this hypothesis, total movement of raptors and vultures on a daily basis (3 through 27 April 1995) was examined for correlation with meteorological data being gathered at the RFETS (Monthly Environmental Monitoring Report). Meteorological data were available for 11 variables as listed in the first column of Table 15. These weather variables were examined for

Table 15. Product-moment correlation coefficients between meteorological variables and total counts of raptors and vultures on the same day (t = 0), the following day (t = +1), and the preceding day (t = -1, hogback only).

Meteorological	NREL		HOGBACK		
Variables	t = 0	t = +1	t = 0	t = +1	t = -1
High Temp	-.016	-.045	.105	-.096	-.016
Low Temp	.121	.003	.137	-.040	.138
Mean Temp	-.034	-.029	.122	-.079	.036
Relative Hum.	.121	.042	.057	.010	.062
Wind Speed(Ave)	-.072	.153	-.111	.202	.558*
Wind (Peak)	-.154	.152	-.168	.281	.394
Barometric Pres.	.089	.035	.165	.040	.450
Solar Radiation	-.326	-.004	-.146	.070	-.310
Precipitation	.483*	-.174	.279	-.236	.277
Peak PPT	.472*	-.103	.220	-.173	.135
Snow	.401	-.155	.220	-.309	.406

*Probability of correlation resulting from chance association less than 5%.
Peak PPT refers to peak precipitation within a 15-minute interval.

association with daily counts of raptors and vultures at the NWTC (NREL) and the I70 hogback (HOGBACK). The effects of local weather patterns on raptor and vulture migration may be varied, affecting the current volume of movement or setting up conditions that may alter movements on the day(s) before or the day(s) after. For example, a day with precipitation might be preceded or followed by days with winds favorable to migration. In an effort to detect such possible "short-range" effects of weather on raptor and vulture movements, weather variables were tested for association with the volume of migrants recorded for the same date ($t = 0$), the day following ($t = +1$), and the day preceding ($t = -1$, tested for I70 hogback only).

As seen in Table 15, the total volume of raptor and vulture movement on a day to day basis in April showed little or no association with meteorological variables. The analysis revealed three marginally significant correlations (5% level of confidence). Migrant numbers at NREL were positively correlated with total precipitation and peak precipitation (per 15 minutes), themselves positively correlated ($r = .931$, $P < .01$). In addition, migrant numbers at the hogback were positively correlated with average wind speed on the following day. Still, the biological importance of these three trends remains doubtful. Inspection of the scattergrams (not shown) revealed that statistical significance of each trend was based largely on the position of one or two data points. Moreover, two to three significant trends would be expected in this analysis on the basis of chance alone, simply because 55 correlation tests were performed and the level for rejecting chance as the basis for the association was 5%. In short, the data do not support the contention that day to day fluctuations in migrant numbers at the hogback or the NWTC were related to proximate weather conditions, at least as measured at the RFETS.

5.0 Discussion

Wind resources tend to attract raptors and also offer preferred locations for placing wind turbines for power generation (National Avian-Wind Power Planning Meeting, 1994). The NWTC is no exception. Based on meteorological data from the Rocky Flats Environmental Technology Site (Monthly Environmental Monitoring Reports), winds in the area average 8 to 10 mph in all months of the year and maximum gusts regularly exceeding 60 mph (peak wind guest of 93 mph for the 17 months of the present study).

The number of raptor species seen in the vicinity of the NWTC also appears to be high. Sixteen species were observed during 17 months of field observations at the NWTC and 18 species are known to migrate along the Front Range of the Rocky Mountains in the spring (data from the Dinosaur Ridge Raptor Migration Site, 1995). Included in the list are two species listed as threatened or endangered under the Federal Endangered Species Act, the bald eagle and peregrine falcon, respectively. Both these species are listed as threatened by the State of Colorado. In addition, both the Swainson's and ferruginous hawks are known to nest in the general vicinity (Andrews and Righter, 1992) and also pass through the area on migration (DRRMS, 1995). Both have been mentioned as candidates for listing under the ESA (Tate, 1986; Knopf, 1988).

Concerns have been raised about the risks posed to raptors by the presence of wind turbines (Orloff and Flannery, 1992; National Avian-Wind Power Planning Meeting, 1994; Predatory Research Group, 1995). The origins of these concerns are traceable in large part to evidence of potentially significant raptor mortality at the Altamont Pass Wind Resource Area (WRA) in California, an 189 sq. km area with over 7000 wind turbines. Annual mortality at the WRA has been estimated at 200 to 400 raptors per year (Orloff and Flannery, 1992). Based on comparison of observed abundance and observed mortality at the WRA, golden eagles appeared to be at greatest risk, followed by red-tailed hawks and American kestrels. Most of these mortalities were attributed to collisions with turbine blades (Orloff and Flannery, 1992). Primarily in response to the evidence of raptor mortality at the WRA, decisions about where to locate wind turbines must consider how these facilities may impact birds of prey (National Avian-Wind Power Planning Meeting, 1994). Prior to phasing in a series of new wind turbines at the National Wind Technology Center, the National Renewable Energy Laboratory requested the present study to determine the extent of raptor use of the area, the potential for raptor collisions with wind turbines, the significance of any such mortality for raptor populations, and possible management steps that could help shape a raptor-safe environment at the NWTC. These questions form the basis for the present discussion.

Raptors are generally defined as any members of the order Falconiformes (vultures, eagles, kites, hawks, harriers, falcons) or Strigiformes (owls). Although the present study focused primarily on the diurnal species of raptors (members of the Falconiformes), we noted all sightings of owls and also looked for owl pellets at the base of towers during occasional hikes around the Center. In addition, the pine trees bordering the site on the west side were routinely searched for owls and evidence of their nest sites. A single great horned owl (*Bubo* virginianus) was occasionally seen perching on one of the poles along the east perimeter road of the NWTC at the end of late-day observation periods on various occasions. In addition, a pair of individuals of this species were regularly found perching in pines north of the NWTC in Boulder County Open Space (Figure 21). Since no more than one individual of this species was seen on the Center at any one time, we have no evidence for more than a single pair of birds in the area and no evidence of nesting on the site. Given the abundant and widespread nature of this species (Andrews and Righter, 1992) and the likelihood that only one or two pairs of great horned owls resided in the area, wind turbine impacts on this species may be disregarded.

Besides great horned owls, a long-eared owl (*Asio otus*) was observed on a single occasion in the pines north of the Center. However, subsequent checks of the area failed to turn up additional sightings of this species. Thus, the lone sighting was probably a transient. This fits with information that the habitat of the area does not conform to the normal requirements of this species (Andrews and Righter , 1992). The mixed xeric grassland with scattered and short-statured ponderosa pine on one margin of the site would also appear suboptimal in providing habitat for any of the other owl species that may be found in Colorado (Andrews and Righter, 1992). Thus, the remainder of this discussion will focus on the diurnal raptors.

The present discussion is organized around three possible issues of concern for raptor safety at the NWTC. The first issue relates to the safety of those species that were resident in the area for at least part of the year and also used the site on a regular basis for perching. The species in this category were the red-tailed hawk, prairie falcon, American kestrel, and rough-legged hawk. The second safety issue relates to species that resided in the general vicinity of the NWTC for one or more seasons of the year but rarely or never landed or foraged on the site itself. The four species in this category were the bald and golden eagles, peregrine falcon, and turkey vulture. The third possible safety issue relates to the movement of migrants through the vicinity of the NWTC and the extent to which these birds might come in contact with turbines at the NWTC. Based on intensive field observations in April of 1995, 16 species formed the migrant raptor community as detected from the NWTC and 18 species were sighted from the I70 hogback. These three areas of potential concern provide the focus for the following discussion.

5.1 SPECIES RESIDENT ON THE WIND SITE

Four species of raptors were regularly seen perching on the Wind Site during one or more seasons of the year, red-tailed hawks, prairie falcons, American kestrels, and rough-legged hawks. The first two species are year-round residents in the area, the kestrel is a spring and summer resident, and the rough-legged hawk a winter resident. Although highly variable from day to day, individuals of all four species would occasionally spend extended periods of an hour or more perched on the site. In addition, they were occasionally seen diving on prey from elevated perches on the NWTC, a behavior potentially associated with turbine collisions in the WRA studies (Orloff and Flannery, 1992). In addition, we noted a pair of kestrels investigating the cowling at the base of one of the wind turbine blades, ostensibly exploring the site for nesting opportunities. In short, each of these species has the potential for collisions with wind turbine blades. Except that large-bodied species with less maneuverability may be more vulnerable to collisions with turbine blades, the absolute risks of collisions by each species are not understood (Orloff and Flannery, 1992) and were not part of the objectives of the present study. Also, it is not clear how site management might be altered to lower collision risks for these species. Steps to reduce the prey base on the site are probably not practical or ecologically desirable but might not reduce perching in any event. The reason is that prey strikes were relatively infrequent for three of the four species (kestrels excepted) and the large number of met towers on the site might continue to attract these species in any event because of their potential attraction for loafing, conducting maintenance, or performing courtship activities.

Even allowing for the possibility that perching by these species will result in occasional mortalities, the central question is whether or not such mortalities are likely to have adverse impacts on the populations in which they reside. For these 4 species, the answer appears to be no for two reasons. First, it is highly likely that only a few individuals (2 to 6) of each species were accounting for the perch time on the NWTC during any given season. While this conclusion must be regarded as tentative in the absence of studies of individually marked birds, it is consistent with limited information we obtained on the spacing behavior of these species. Thus, both redtails and kestrels were seen to displace conspecifics from perches on the NWTC on an occasion or two, suggesting territorial defense of the area. The regularity with which individuals of each species tended to use certain perches on a day to day basis was also consistent with the idea that the same birds were making repeat visits to the site. Even if our estimates of the number of individuals using the site is off by a factor of two or three, these numbers are probably small relative to the populations of these species along the Front Range, with the possible exception of prairie falcons. Citing other sources, Andrews and Righter (1992) placed the number of breeding pairs of this species in Colorado at about 200 and the size of the wintering population at 900. On the other hand, prairie falcon use of the Wind Site was extremely low except in the fall and winter months when perch time averaged 20 to 40 minutes for a 3-hr observation period (see Figure 11). Of course, another issue is how this species reacts to wind turbines and we do not have information on that question. Additional field observations at the NWTC during the winter months when the species occurred most regularly might help to clarify how they behave around wind turbines and what their risk factor might be.

5.2 EAGLES, PEREGRINE FALCON, AND VULTURES

The second group of species were those that were resident in the vicinity of the NWTC for part or all of the year but did not use the site for perching or foraging. These species would be the bald and golden eagles, peregrine falcon, and turkey vulture. Of these, turkey vultures may be disregarded as a species of concern at the site. Except during migration (see later), they were sighted infrequently, rarely flew over the site, and generally flew at heights considerable greater than those of the wind turbines.

In the case of peregrine falcons, we had only one confirmed sighting of this species during the 17 months of the study, a subadult seen perching on a low post 100 m north of the NWTC. Two active aeries are known to occur in the area (Jerry Craig, Colorado Division of Wildlife, pers. comm.), one in the vicinity of Eldorado Canyon and one near The Flatirons southwest of Boulder, Colorado. Recent telemetry studies of breeding peregrine falcons near Colorado Springs has indicated that daily foraging flights may extend out 30 km or more from the aerie and that foraging tends to focus in riparian habitat (Jerry Craig, pers. comm.). Thus, the NWTC would easily fall within the foraging distances of the peregrines nesting in the area but the lack of riparian habitat on the site would presumably limit its use by foraging birds. The question remains why we did not spot them passing over the site. However, their elevation above ground and speed of flight when conducting a "stealth" flight makes them extremely difficult to detect, even when specifically watching for them (Jerry Craig, pers. comm.). In short, it does not appear from our results that the presence of wind turbines at the NWTC will present risks to peregrine falcons.

The two eagle species present somewhat different situations. Golden eagles are resident in the area throughout the year and probably nest in several locations along the Front Range within a 30 km of the Wind Site (Monahan, pers. obs.). On the basis of our data, the number of individual birds seen flying over or near the Wind Site was probably on the order of 2 to 4 birds. A maximum of 8 were recorded in late February of 1994 but the accuracy of that count may be questioned (see 4.3B). Thus, our evidence suggests that we were dealing with the equivalent of one family group that included the NWTC (and perhaps the RFETS) as part of their home range. With only about 200 breeding pairs in the state (Andrews and Righter, 1992), any extra mortality could be viewed as undesirable. Besides, the species is protected under the Bald Eagle Protection Act (Orloff and Flannery,1992) which apparently does not provide for the "taking" of golden eagles by structures such as wind turbines (Predatory Research Group, 1995). Thus, the issue of golden eagle risks of collisions with turbines at the Wind Site may revolve around the question of whether or not their behavior is likely to bring them in contact with the turbines. On this point, it seems doubtful that turbines on the NWTC would present significant risks. The main reason is that the site lacks a suitable prey base to attract golden eagles, at least at the present time. Although the area supported a few cottontail rabbits near near some of the sheds and buildings on the site (Figure 21), it lacked any significant base of medium-sized prey such as ground squirrels or prairie dogs, two major prey items of this eagle species. The reason golden eagle mortalities may total upwards of 60 per year at the WRA in California is probably related to especially high populations of ground squirrels in the area (National Avian-Wind Power Planning Meeting, 1994). On the other hand, golden eagles occasionally fly over the Wind Site and some of these flyovers occur at heights that would place the birds in potential contact with wind turbines (below 30 m). The question remains whether or not golden eagles are vulnerable to collisions with turbines if they are not hunting and not trying to land on the turbines. In the latter regard, raptors appear less prone to landing on tubular-style turbines than the lattice type (National Avian-Wind Power Planning Meeting, 1994). Additional field observations might help resolve the degree to which "flyovers" by golden eagles present risks of collisions with turbines. On the basis of the present study, afternoon observations on winter days are likely to yield the greatest opportunities for observing this species from the Center.

The pattern of movement of bald eagles past the NWTC presents larger concerns. For one, the species is protected under the both the ESA and Bald Eagle Protection Act. Also, the number of individual birds passing by the Wind Site over the course of the winter is potentially significant, at least on a regional population level. From observations conducted in Eldorado Canyon, we know that at least 10 bald eagles were using that roosting area in the winter of 1994-5, and at least 6 were seen flying past the NWTC on a single afternoon in February of 1994, a maximum of 4 on any given afternoon during the winter of 1994-5. In addition, a pair of bald eagles has established a nest site at Stanley Lake, 6 km southwest of the NWTC. There are unconfirmed reports that this pair may be using the Eldorado Canyon area for roosting in January and February.

Typically, bald eagles were seen approaching the vicinity of the NWTC from east in the mid-to late afternoons during the months of October through February. Often they would fly parallel to CO 128 and at varying distances north or south of the road. A commonly used flight path (see Figure 20) had them flying 100 m or so south of CO 128. As they approached the Wind Site, birds on this latter flight path tended to follow one of two routes. Roughly half the time they would follow the north edge of the "bench" of the Rocky Flats Formation and thus veer to the north of BLDG 251 and out over the Boulder Open Space property to the north of the Wind Site (see Figure 20). When followed with binoculars, these birds were invariably heading into the Eldorado Canyon area. Alternatively, they would continue directly west along paths that would take them over some portion of the NWTC. Certainly, some of these birds were flying at or below 30 m, the height of the tallest wind turbine on the site. It is not clear if weather conditions affected these flight paths. The number of eagles detected on a given afternoon correlated weakly or not at all with weather variables such as average wind speed, cloud cover, and temperature (max, min or average). Flights over the wind site were sufficiently infrequent that their relationship with weather could not be assessed.

The potential risks posed to bald eagles by the construction of wind turbines at the NWTC requires further investigation. Daily viewing from 1400 hours til dusk over the course of the wintering period from mid-October through February would provide a clearer picture of the number of birds using this movement corridor and the particular kinds of weather conditions that cause some birds to move directly across the Wind Site at low altitudes. Alternatively, the risk to eagles would be minimized if the operation of wind turbines could be suspended during late-afternoons in the months of November through February.

5.3 MIGRANTS

The third category of potential risks to raptors at the Wind Site concerns the extent to which migrants come in close proximity to the Wind Site in the spring or fall. On the basis of 9 hours of field observation time each week, the results for the spring and fall of 1994 did not reveal an any sizable increase in movements of raptors through the vicinity of the NWTC. We were picking up a few new species in the spring and fall but just an occasional individual or two. Duplicating the field sampling procedures of the Dinosaur Ridge Raptor Migration Station established that migrants do pass near the NWTC in April (no comparable data for fall) and that only a small fraction of the birds seen flying past Dinosaur Ridge in April can be detected from the NWTC. While the number of migrants detected at the NWTC in April of 1995 was 12% of the volume detected at the I70 hogback, much of that volume was accounted for by turkey vultures that were flying routes considerably west (2 to 6 km) of the Wind Site. The balance of the migrants were mostly American kestrels. Unlike the turkey vultures, the kestrels tended to fly directly over the NWTC and many of them were flying within 30 m of the ground. Thus, in terms of turbine risks to migrants, kestrels appear to be the only species where any appreciable number of individuals had the potential for contact with wind turbine blades. Of course, the magnitude of the risk would also depend on how kestrels react to rotating blades. Almost all of the kestrels counted by us at the NWTC were recorded in one 3-hour period on 16 April 1995. The day was overcast with light winds and the four turbines on the Wind Site were not active. Thus, we did not have an opportunity to evaluate the reaction of these birds to moving turbines. On the same day that we saw the flux of kestrels migrating through the vicinity of the Wind Site, nearly 500 kestrels were counted at the DRRMS. While kestrels are certainly an abundant species, the possibility of large numbers flying through the Wind Site would justify measures to minimize any potential risks of collisions. Placing color patterns on the turbine blades might be one solution encourage avoidance behavior (National Avian-Wind Power Planning Meeting, 1994). Another approach would be to receive early warning from the field people operating the DRRMS on those few days when large volumes of kestrels are moving through the area and than to take any steps possible to close down turbine operations. This approach might have practical difficulties from an engineering standpoint but might serve as a safety margin if such kestrel movements are a regular spring occurrence.

The question remains as to why our counts of migrants at the NWTC were so much lower than at the I70 hogback, especially considering their close proximity (roughly 10 km) and placement (roughly north to south). The answer seems to be that the NWTC is about twice the distance from the foothills as the DRRMS. If the birds are mainly flying routes that track the foothills, their flight paths would generally take them too far west to be detected by us at the NWTC.

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