

**A VISUAL AND RADAR STUDY OF
2003 SPRING BIRD MIGRATION AT THE PROPOSED
CHAUTAUQUA WIND ENERGY FACILITY, NEW YORK**

FINAL REPORT

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EXECUTIVE SUMMARY

- This report presents the results of a radar and visual study of bird migration conducted during 15 April–15 May 2003 at the proposed Chautauqua Wind Energy Facility, located in western New York. Concurrent radar and visual observations were conducted for ~4 h/day, and radar observations were conducted for ~5 h/night, throughout the study period.
- The goal of this study was to collect information that will be used to help evaluate the potential impacts of the proposed wind-energy facilities on migratory raptors and passerines during the peak spring migration period. The objectives of this study were to:
 - use radar and visual techniques to collect baseline information on flight direction, migration intensity, and flight altitude of daytime raptor and nocturnal passerine migrants at the proposed Chautauqua Wind Project area during 15 April–15 May 2003.
- In spring 2003, we recorded 3,765 individual birds (112 waterbirds, 2,578 raptors, and 1,075 landbirds) of 43 species during 115 visual sampling sessions. The five most abundant species were (in decreasing order of abundance) Broad-winged Hawk (1,059 individuals), Turkey Vulture (899), Red-winged Blackbird (355), Red-tailed Hawk (220), and Barn Swallow (138).
- We observed 10 federal- or state-listed species during spring 2003: Common Loon (19 individuals, State Species of Special Concern), Osprey (14; State Species of Special Concern), Bald Eagle (14; State and Federal Threatened Species), Northern Harrier (31; State Threatened Species), Sharp-shinned Hawk (43; State Species of Special Concern), Cooper's Hawk (41; State Species of Special Concern), Red-shouldered Hawk (6; State Species of Special Concern), Golden Eagle (7; State Endangered Species), Peregrine Falcon (2; State Endangered Species), and Common Nighthawk (1; State Species of Special Concern).
- During the day, the mean flight direction (± 1 angular deviation) of targets observed on radar was $040 \pm 49^\circ$. At night, the mean flight direction of targets observed on radar was $029 \pm 40^\circ$.
- In spring 2003, we recorded low numbers of waterfowl and landbirds and moderate–high numbers of raptors during the day. Moderate–high numbers of landbirds flew over at night in April and May; during April, waterfowl-like targets also were present at night. There was high among-day variability in movement rates for all species and times.
- Our surveillance radar observations indicated that passage rates in spring 2003 were significantly higher at night (395 ± 69 targets/km/h) than during the day (79 ± 13 targets/km/h).
- Mean daytime flight altitudes (372 ± 6 m above ground level [agl]) were significantly lower than nocturnal flight altitudes (528 ± 3 m agl). Similarly, the mean percentage of targets flying below 125 m agl was higher during the day (17.2% of all daytime targets) than at night (3.8%).
- Our vertical radar observations suggested that there was a tendency during both the day and night for birds to concentrate either over, or northwest of, the ridgeline where the proposed turbine string would be located. During the daytime, this pattern matched the pattern that we observed visually: raptors often flew over the ridgeline or the valley immediately to the north of the ridgeline and in a direction roughly parallel to the ridgeline.
- Based on our data sets, the largest pulses of migration often tended to be associated with tail winds; however, overall passage rates were not significantly different between days with tail winds and days with other winds.
- Flight altitudes during both day and night were significantly lower during periods with precipitation than without it and during periods with low ceiling heights than with high ones. Flight altitudes also were significantly lower during foggy daytime periods than during periods with no fog; in contrast, at night, birds

flew significantly higher during foggy periods. Tail winds did not affect flight altitudes during the day or the night.

- This study focused on providing information on daytime raptor and nocturnal passerine migration because the Chautauqua site is located in a known spring raptor migration corridor and because little is known about nocturnal migration in the area. We found that the Chautauqua Study Area had relatively high spring passage rates for daytime migration of raptors and for nocturnal migration of passerines. We estimated that ~5,200–5,300 raptors during peak daylight hours and ~30,000–31,000 nocturnal migrants passed through Chautauqua Wind Resource Area (at or below turbine height) during our 30-day study.

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INTRODUCTION

Jasper Energy LLC has proposed to develop a 50-megawatt (MW) wind-energy facility that will span portions of the towns of Ripley and Westfield in Chautauqua County, New York. The proposed Chautauqua Wind Energy Project is located along a ~10-km section of ridgeline above an escarpment that runs parallel to the shore of Lake Erie and lies ~6 km south of the lake (Fig. 1). The development would consist of ~34 wind turbines with a rotor diameter of 77–82 m and a total height of 118.5–121 m.

Because there are several major bird migration corridors within New York (Haugh 1972, Bellrose 1976, Bull 1985), the presence of towers and rotating wind turbines could impact both migratory and local birds in the area. Potential impacts include collisions with the meteorological towers and wind turbines and major behavioral changes of birds avoiding areas where wind turbines are operating. Studies of wind turbine-related bird impacts in the US and Europe suggest that important mortality and behavioral impacts occur in some, but not all, locations (Winkelman 1995, Anderson et al. 1999, Erickson et al. 2001). The appropriate siting of wind-energy facilities is one of the most important ways to minimize impacts to birds (Nelson and Curry 1995).

Major spring migration concentrations of raptors occur along the southern shores of the Great Lakes (Haugh 1972). The proposed Chautauqua Wind Energy Facility lies near the Ripley Hawk Watch sites, where an average of 14,000 raptors representing 18 species are observed each spring (Zalles and Bildstein 2000). Because of the proximity of this proposed wind farm to a known spring raptor concentration area and because little specific information is available on nocturnal migration near this site (Cooper and Mabee 2000), E & E requested that we conduct a visual and radar study of daytime hawk migration and a radar study of nocturnal passerine migration at the proposed Chautauqua Wind Energy Facility area during the peak spring migration period. This report presents the results of that study.

OBJECTIVES

The goal of this study was to collect information that will be used to help evaluate the potential impacts of the proposed wind energy facilities on local and migratory birds during the spring migration period. Specifically, the objectives of this study were to collect baseline information on flight direction, migration intensity, and flight altitude of daytime raptor and nocturnal passerine migrants at the proposed Chautauqua Wind Project area during 15 April–15 May 2003. An evaluation of the potential risk of the proposed wind farm to daytime raptor migrants and nocturnal passerine migrants will be presented in a separate document and is not part of this report.

STUDY AREA

The proposed wind farm will span portions of the towns of Ripley and Westfield in Chautauqua County, New York. The project area is located along a ~10-km section of ridgeline above an escarpment that runs parallel to the shore of Lake Erie (i.e., is oriented roughly southwest-to-northeast) and lies ~6 km south of the lake (Fig. 1). The Cattaraugus highlands ecozone, where the study area is located, is a component of the Allegheny Plateau physiographic province (NYSDEC 2001). The climate is dominated by cool, wet summers with an average July temperature of 71°F (22°C) and up to 20 in (~50 cm) of rainfall, and by cold, snowy winters with an average January temperature of 26°F (–3°C) and 150–200 in (i.e., ~380–500 cm) of snow. The topography of the area consists of small, rolling hills and plateaus on top of a steep ridgeline. The ridge varies in slope from over 12% in the upper portions to less than 6% in the lower portions. Elevations on the ridge where the proposed turbine string is located are ~400 m asl, and the land immediately north of the ridge slopes down to Lake Erie, which lies at 190 m asl. The majority of the ridge is covered in mature stands of hardwood forest. Flatter areas on top of the ridgeline are separated by shallow to steep ravines.

The proposed turbine corridor traverses several habitat types, including agricultural areas, forested areas, and wetlands. Agricultural areas

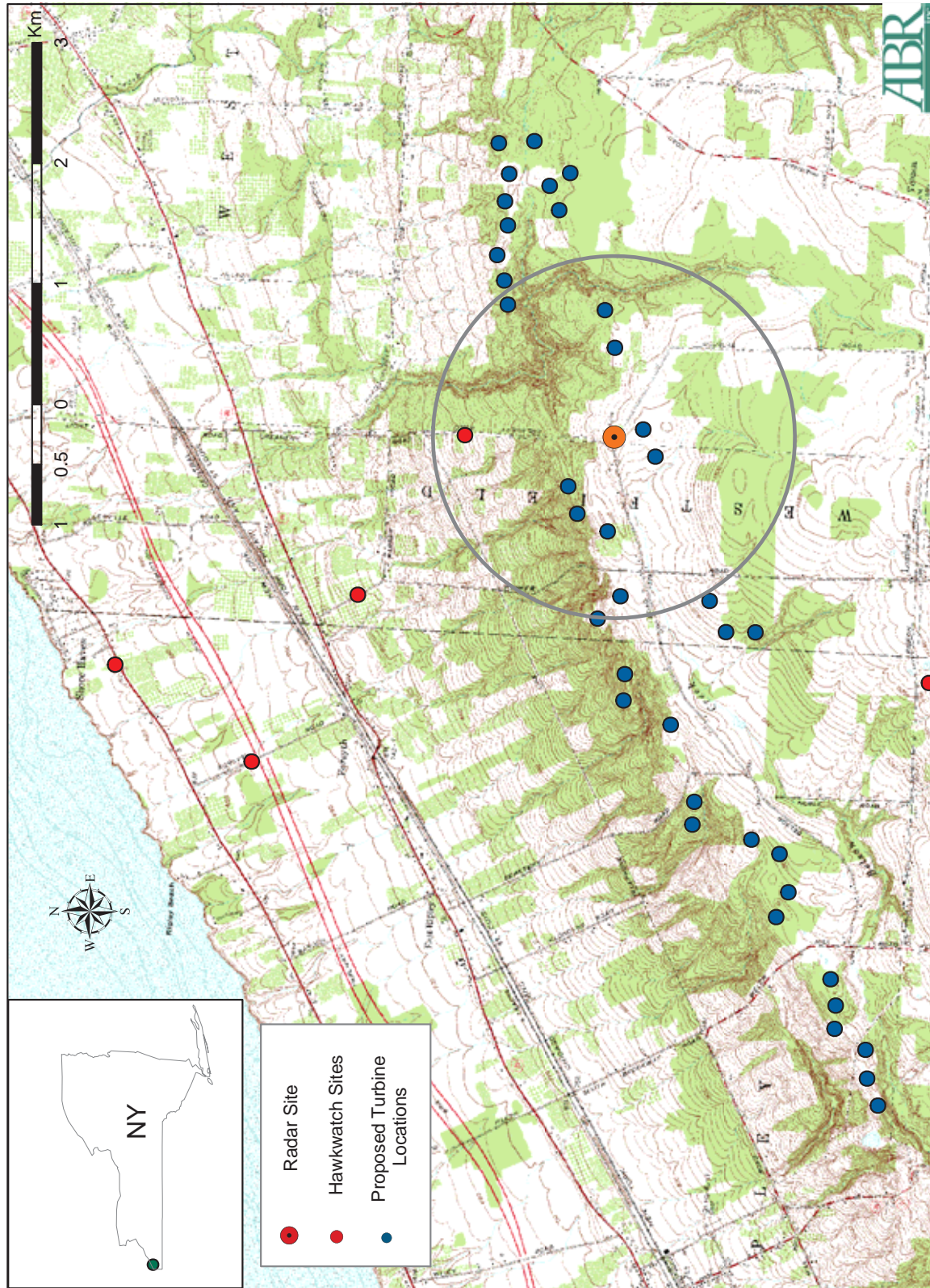


Figure 1. Map of the Chautauqua Study Area, New York, with locations of the spring 2003 radar and visual sampling sites, Ripley Hawkwatch sites, and proposed turbine locations (as of April 2003).

consist of dairy grazing, corn, alfalfa, hay, and fallow fields. Eastern hardwood stands dominate the forested areas and contain indigenous species, such as red and sugar maple, black cherry, white ash, American beech, aspen, tulip poplar, and yellow birch. There also are several conifer plantations throughout the corridor that are dominated by red pine, white pine, Scotch pine, and Norway spruce. The forested areas vary from early succession (10 to ~40 yr old to late succession (60 to ~100 yr old). Some of the forested areas have evidence of periodic mowing and thinning, with an understory plant community dominated by hardwood seedlings of the species noted above and a variety of shrubs.

Our radar and visual sampling station was located ~ 20 m south of the ~100-m-high telecommunication tower, ~50 m east of the junction of Creamery and Belson Roads (42°16'24.6"N 79°37'26.6"W). The same location is used as the Ripley Hawkwatch Station Number 5, because it provides an excellent view of the surrounding terrain.

METHODS

GENERAL SAMPLING STRATEGY

Raptors and passerines are known to migrate over the vicinity of the Chautauqua Study Area from March through May; however, the peak migration period for many common species occurs between mid-April and early May for raptors and between late April and mid-May for passerines (Haugh 1972, Bull 1985, Cooper and Mabee 2000, Zalles and Bildstein 2000, Buffalo Ornithological Society 2002). We conducted visual and radar observations of bird migration during 15 April–15 May 2003, to time our study to overlap with the migration peaks of as many raptor and passerine species as possible.

Each day, one radar observer and one visual observer sampled concurrently for ~4 h during midday between 1000 h and 1500 h, then one observer would conduct ~5 h of nocturnal migration observations (radar only) between 2100 h and 0300 h (Table 1). Our daytime sample provided coverage of what normally is the peak daily period of raptor migration, and our evening sample provided coverage of the peak period of

nocturnal migration within a night (Lowery 1951, Gauthreaux 1971, Alerstam 1990, Kerlinger 1995).

VISUAL OBSERVATIONS

DATA COLLECTION

A single observer equipped with 10X binoculars and a 20–50X spotting scope recorded data on all birds except American Crows, Rock Doves, and Starlings (see Appendix 1 for scientific names of all bird species). Each 50-min sampling session was begun at 10 min past the hour, and we recorded the following data for each flock or single bird: time; species (to lowest practical taxon); flock size; general location (>500 m north of proposed turbine string, over 1,000-m-wide transect centered on proposed turbine string, >500 m south of turbine string); closest distance to bird (in m); flight altitude above ground level (visually estimated in m agl); whether the bird/flock passed over the proposed turbine string (yes or no); and general flight direction (north, northeast, east, southeast, south, southwest, west, northwest, circling, erratic/local movements).

We estimated flight altitude and distance to birds with the aid of several reference points, including trees and artificial structures (e.g., radio towers, telephone poles) of known height and distance. Whenever possible, we checked visual estimates of altitude against altitudes measured with radar. An attempt was made to not make duplicate counts of the same individual birds within a sampling session.

We collected the following weather data at the beginning of each visual (and radar) sampling session: wind speed (in 5-mph [2.2 m/s] categories), wind direction (north, northeast, east, southeast, south, southwest, west, northwest, variable, calm); cloud cover (to the nearest 5%); ceiling height (agl; 1–50 m, 51–100 m, 100–150 m, 151–500 m, 501–1,000 m, 1,001–2,500 m, 2,501–5,000 m, >5,000 m); visibility (0–50 m, 51–100 m, 101–500 m, 501–1,000 m, 1,001–2,500 m, 2,501–5,000 m, >5,000 m); light condition (daylight without precipitation, daylight with precipitation, twilight without precipitation, twilight with precipitation, darkness without precipitation, darkness with precipitation); precipitation (no precipitation, fog, drizzle, light rain, heavy rain, snow flurries, light snowfall, heavy snowfall, sleet, hail); and air temperature (to the nearest 1°C). We

Table 1. Visual and radar sampling schedule at the Chautauqua Study Area, New York, during spring 2003.

Date	Visual sampling hours	Radar sampling hours
15 April	none	2100–0100
16 April	1200–1500	1200–1500; 2100–0200
17 April	1000–1500	1000–1200; 1300–1500; 2100–0200
18 April	1000–1400	1000–1400; 2100–0200
19 April	1000–1400	1000–1400; 2100–0200
20 April	1100–1500	1100–1500; 2100–0200 ¹
21 April	1100–1500	1100–1500 ¹ ; 0100–0200 ¹
22 April	1100–1500	1100–1500 ¹ ; 2100–2200 ¹
23 April	1100–1500	1100–1500; 2100–0200
24 April	1100–1500	1100–1500; 2100–0200
25 April	1100–1500	1100–1500; 2100–0200
26 April	1100–1500	1100–1500; 2100–0200
27 April	1100–1500	1100–1500; 2100–0200
28 April	1100–1500	1100–1500; 2100–0200
29 April	1100–1500	1100–1500; 2100–0200 ²
30 April	1100–1600	1100–1600; 2100–0000, 0100–0200
1 May	1000–1400	1000–1330; 2100–0200 ²
2 May	1100–1400	1100–1500; 2100–0200 ²
3 May	1100–1500	1200–1500; 2100–0200 ²
4 May	1100–1500	1100–1500; 2100–0200 ²
5 May	1100–1400	1100–1400 ¹ ; 2200–0100
6 May	1000–1400	1000–1400; 2200–0300 ²
7 May	1100–1500	1100–1500; 2200–0300 ²
8 May	1100–1500	1100–1500; 2200–0300 ²
9 May	1100–1500	1100–1500; 2200–0300 ²
10 May	1200–1600	1100–1600; 2200–0300 ³
11 May	1100–1500	1100–1500 ¹ ; 2200–0300 ¹
12 May	1100–1400	1100–1400 ¹ ; 2200–0300 ¹
13 May	1100–1400	1100–1400 ¹ ; 2200–0300 ¹
14 May	1000–1400	1000–1400; 2200–0300 ³
15 May	1000–1300	1010–1015 ¹

¹ Rain clutter made it impossible to collect radar data for at least part of the session.

² Insect contamination made it impossible to collect 3-km vertical radar data for at least part of the session.

³ Insect contamination made it impossible to collect any radar data for at least part of the session.

used an “OMNI” anemometer to measure wind speed and a hand-held thermometer to measure temperature. We visually estimated cloud cover, ceiling height, visibility, light conditions, and precipitation. We also obtained 10-min averages of wind speed and direction at 40 m agl from a meteorological tower located ~1.5 km west of our sampling station.

DATA ANALYSES

We grouped species into the following three categories for most analyses, because the number of bird species was large, species within broader groups often have similar flight behavior, and identification to species often was impossible for distant birds:

- 1) “Waterbirds,” which included all waterfowl, gulls, shorebirds, cormorants, herons, and loons;

- 2) "Raptors," which included all vultures, hawks, and falcons; and
- 3) "Landbirds," which included all swifts, woodpeckers, and songbirds (passerines).

Again, data for American Crows, Rock Doves, and European Starlings were not collected or analyzed. These species are not protected by federal or state laws and occasionally were so numerous at the study sites that they could have distracted us from searching for other species of greater interest.

We used the number of individual birds for most data summaries but, because of problems of independence among individuals within a flock, compared flocks (rather than individuals) for all statistical summaries of flight altitude and flight direction. A flock was defined as either a single bird or two or more birds flying together. Analysis of flight directions followed statistical procedures for circular data presented in Zar (1999).

RADAR OBSERVATIONS

EQUIPMENT

Our mobile laboratory consisted of a marine radar mounted on a van. In the horizontal position (i.e., in surveillance mode), the radar scanned the entire area around the lab and was used to obtain information on flight paths, passage rates, and ground speeds of birds. When turned up to the vertical position, the radar measured altitudes of flight. A description of a similar radar laboratory can be found in Gauthreaux (1985a, 1985b) and Cooper et al. (1991), and a similar vertical radar setup is described by Harmata et al. (1999). The lab was powered by four 6-V (golf cart) batteries linked in series; when fully charged, these batteries could power the lab continuously for ~10 h.

The radar unit (Furuno Model FR-1510 MKIII; Furuno Electric Company, Nishinomiya, Japan) is a standard marine radar transmitting at 9,410 MHz (i.e., X-band) through a slotted wave guide (antenna) 2 m long with a peak power output of 12 kW. The 2-m antenna was a slotted waveguide array with a beam width of 1.23° (horizontal) \times 20° (vertical) and a sidelobe of $\pm \sim 10^\circ$. This radar can be operated at a variety of ranges, from 0.5 km to 133 km. Range accuracy is 1% of the maximum range of the scale in use, or

30 m, whichever is greater. Bearing discrimination is $>2.5^\circ$ and bearing accuracy is $\pm 1^\circ$. Pulse length can be set at 0.07, 0.15, 0.5, or 1.0 μ sec, depending on the range-setting used. At shorter pulse lengths, echo definition is improved (giving more accurate information on target location and, hence, distance), whereas, at longer pulse lengths, echo detection is improved (increasing the probability of detecting a target). (An echo is a picture of a target on the radar display screen; a target is one or more birds that are flying so closely that the radar displays them as one echo on the display screen.) This radar has a digital color display with several scientifically useful features, including color-coded echoes (to differentiate the strength of return signals), on-screen plotting of a sequence of echoes (to depict flight paths), and True North correction for the display screen (to determine flight directions easily). The plotting function plotted the location of a target every sweep of the antenna; because time intervals are fixed, ground speed is directly proportional to the distance between consecutive echoes and can be measured with a hand-held scale.

Whenever energy is reflected from the ground, surrounding vegetation, and other objects that surround the radar unit, a ground-clutter echo appears on the display screen. Because ground-clutter echoes can obscure bird targets, we minimized their occurrence by elevating the forward edge of the antenna by $\sim 20^\circ$ and by parking the radar lab in locations that were surrounded fairly closely by low trees or low hills. These objects act as radar fence that shield the radar from low-lying objects farther away from the lab and that produce only a small amount of ground clutter in the center of the display screen. For further discussion of radar fences, see Eastwood (1967), Williams et al. (1972), Skolnik (1980), and Cooper et al. (1991).

Maximal distances of detection of birds by the surveillance radar depends on radar settings (e.g., gain and pulse length), body size of bird, flock size, flight profile, atmospheric conditions, and, to some extent, the amount and location of ground clutter. Flocks of waterfowl routinely are detectable out to 5–6 km, individual hawks usually are detectable to 2–3 km, and single, small passerines are detectable to 1–2 km (Cooper et al. 1991; Cooper and Mabee, unpubl. data).

DATA COLLECTION DURING THE DAY

Each of the four, 60-min diurnal radar sampling sessions consisted of: one 10-min session to collect weather data (see Visual observations above for weather data collected) and adjust the radar to surveillance mode; one 5-min session with the radar in surveillance mode (i.e., in a horizontal position) at the 1.5-km-range (pulse length = 0.3 μ sec) collecting information on migration passage rates; one 10-min session with the radar in surveillance mode at 1.5-km-range (pulse length = 0.3 μ sec) collecting information on ground speed, flight direction ($^{\circ}$), tangential range (the minimal perpendicular distance to the target when it passed closest to the lab); transect crossed (the four cardinal directions—north, south, east, and west); species (if known); number (if known); flight behavior (straight, erratic, circling); and whether or not the target crossed the proposed turbine string, for as many targets as time allowed (oftentimes there were too many targets on the radar screen at once to collect data on all of them); one 10-min session to adjust the radar to vertical mode; one 15-min session in the vertical mode at 1.5-km-range (pulse length = 0.07 μ sec) to collect fine-scale information on flight altitudes below 1,500 m agl; one 5-min session in the vertical mode at 1.5-km-range (pulse length = 0.07 μ sec) to collect fine-scale GIS information on flight altitudes below 1,500 m agl by plotting the height and distance of all targets on an acetate sheet; and one 5-min session in the vertical mode at 1.5-km-range (pulse length = 0.07 μ sec) to collect information on the passage rates of migrants below 140 m agl (in the lower altitudes up to ~15–20 m above the maximum proposed turbine height). During the day, the vertical radar was oriented so that it collected data along a southeast-to-northwest transect line that was perpendicular to the main axis of raptor migration.

DATA COLLECTION AT NIGHT

Each of the five, 60-min nocturnal radar sampling sessions consisted of: one 10-min session to collect weather data (see Visual observations) and adjust the radar to surveillance mode; one 5-min session with the radar in surveillance mode at the 1.5-km-range (pulse length = 0.3 μ sec) collecting information on migration passage rates; one 10-min session with the radar in surveillance

mode at 1.5-km-range (pulse length = 0.3 μ sec) collecting information on ground speed, flight direction ($^{\circ}$), tangential range; transect crossed (the four cardinal directions—north, south, east, and west); species (if known); number (if known); flight behavior (straight, erratic, circling); and whether or not the target crossed the proposed turbine string, for as many targets as time allowed; one 10-min session to adjust the radar to vertical mode; one 10-min session in the vertical mode at 1.5-km-range (pulse length = 0.07 μ sec) to collect fine-scale information on flight altitudes below 1500 m agl; one 5-min session in the vertical mode at 1.5-km-range (pulse length = 0.07 μ sec) to collect fine-scale GIS information on flight altitudes below 1500 m agl by plotting the height and distance of all targets on an acetate sheet; one 5-min session in the vertical mode at 1.5-km-range (pulse length = 0.07 μ sec) to collect information on the passage rates of migrants below 140 m agl; and one 5-min session in the vertical mode at 3.0-km-range (pulse length = 0.50 μ sec) to collect coarse-scale information on flight altitudes below 3000 m agl. Coarse-scale refers to the fact that it is difficult to determine exact flight altitudes with the 3-km setting, and more importantly, it is especially difficult to get accurate counts within ~100 m agl (the zone of primary interest). During the night, the vertical radar was oriented so that it collected data along an east–west transect that was perpendicular to the main axis of nocturnal migration.

Differentiating the various target types encountered (e.g., birds, bats, insects) is central to any radar study, especially with X-band radars that can detect small flying animals. Because it usually was not possible to separate bird targets from migrating bat targets, some bat targets may be included in our data. Of primary importance, however, is removing insect targets from the data. Our spring sampling season had several nights with obvious insect contamination, and the contamination generally was higher later in the survey season. We used a combination of techniques to reduce insect contamination in the data when possible and omitted sampling sessions (or whole nights) when insects severely contaminated our sample. We reduced insect contamination by (1) omitting targets with speeds <8 m/s (<~18 mph), and (2) omitting targets with poor reflectivity and/or limited range (for example,

targets that plotted erratically or inconsistently in locations with good radar coverage). The 8 m/s cut-off speed was based upon radar studies that determined that most insects have an airspeed of <8 m/s, whereas birds airspeed is usually ≥ 8 m/s (Larkin 1991, Bruderer and Boldt 2001).

We could not collect radar data during periods of rain because the electronic filtering required to remove the echoes of the precipitation from the display screen also removed bird targets. In addition, there were periods when insects became so abundant that sampling was not possible, particularly on the vertical radar (Table 1).

DATA ANALYSES

The species composition and size of a flock of birds observed on the radar usually was unknown. Therefore, the term “target,” rather than “flock” or “individual,” is used to describe birds detected by the radar.

Airspeeds of surveillance radar targets were computed by subtracting speed/direction vectors of winds at 40 m agl from the ground speed/direction vectors of each radar target. The few targets with corrected airspeeds <8 m/s (most slower targets already were excluded during field sampling) were deleted from all analyses. We analyzed flight-direction data following procedures for circular statistics (Zar 1999). Migration passage rates are reported as the mean (± 1 standard error) number of targets passing along 1 km of migratory front/hour (targets/km/h ± 1 SE). Radar data were not corrected for differences in detectability with distance. We used Wilcoxon matched pairs tests to compare mean daytime passage rates with nocturnal passage rates and altitudes (SPSS 2002).

All statistical summaries of flight altitude data were made with the 1.5-km-scale data because this scale provided adequate target resolution within 1,500 m agl, whereas the 3.0 km range did not provide adequate target resolution at low altitudes. All flight-altitude data are presented in m agl relative to the radar sampling site. Thus, the actual height above ground level for the subset of targets we detected while flying over the valley to the north of the station would actually be more than what we report, which are altitudes with respect to the sampling site.

For calculations of the daily patterns in migration passage rates and flight altitudes, we

assumed that a day began and ended at 0600 h so that a sampling night was not split between two dates. We used percent of the total nightly targets within each 1-h period to compare relative passage rates within each night, using only nights with complete sampling (i.e., with no sessions cancelled by rain or insects). To compare relative rates among hours of the night for the entire season, we then computed the mean percentage for each 1-h period.

For weather analyses, we defined tail wind conditions as days/nights when over half the sessions had winds aloft (40 m agl) blowing from 135° to 270°. We used Mann-Whitney tests to compare passage rates between days/nights with and without tail winds. We used *t*-tests to compare flight altitudes between days/nights with and without tail winds and between sessions with and without precipitation. We used *t*-tests to compare flight altitudes during sessions having a cloud ceiling height ≤ 500 m agl (low ceiling height) with flight altitudes during sessions having a cloud ceiling height > 500 m agl (high ceiling heights).

Confounding factors that decreased our sample size of the various summaries and analyses included insects and inclement weather (rain). Therefore, sample sizes sometimes vary among the different summaries and analyses. The level of significance (α) for all tests was set at 0.05.

CALCULATION OF NUMBER OF BIRDS IN THE WRA

To calculate the numbers of raptors (daytime) and all species (at night) flying over the Chautauqua Wind Resource Area (WRA) at or below turbine height, we needed to account for the width of the WRA relative to the predominant direction of flight. The width of the WRA was 4,132 m for the daytime migrants (that had a mean flight direction of 40°) and the width of the WRA was 5,191 m for nocturnal migrants (that had a mean flight direction of 29°). For migration rates, we used the mean number of targets observed on vertical radar below 140 m agl and 500–1000 m away from (and either side of) the sampling station as the base number of targets/h. For the daytime, we only wanted to calculate number of raptors flying over the WRA, so we corrected this rate for the proportion of radar targets that were raptors. We also corrected the daytime rate for mean flock

size of all raptors observed within 100 m of visual observers (i.e., 1.4 birds/target). At night, most radar and visual studies indicate that nocturnal passerine migrants (the most common group of bird at night) generally fly singly and not in tight flocks (Gauthreaux 1972, Kerlinger 1995), so we assumed that flock size at night was 1 bird/flock. We then multiplied the average passage rate \times height of turbine \times width of WRA \times number of days \times number of hours per day to compute number of birds flying over the WRA at or below turbine height, for the 30-d study period (see Appendices 2 and 3 for more details on the calculations).

RESULTS

SPECIES COMPOSITION

VISUAL DATA

In spring 2003, we recorded 3,765 individual birds (112 waterbirds, 2,578 raptors, and 1,075 landbirds) of 43 species during 115 visual sampling sessions (Appendix 1). The five most abundant species were (in decreasing order of abundance) Broad-winged Hawk (1,059 individuals), Turkey Vulture (899), Red-winged Blackbird (355), Red-tailed Hawk (220), and Barn Swallow (138). We observed 10 federal- or state-listed species: Common Loon (19 individuals, State Species of Special Concern), Osprey (14; State Species of Special Concern), Bald Eagle (14; State and Federal Threatened Species), Northern Harrier (31; State Threatened Species), Sharp-shinned Hawk (43; State Species of Special Concern), Cooper's Hawk (41; State Species of Special Concern), Red-shouldered Hawk (6; State Species of Special Concern), Golden Eagle (7; State Endangered Species), Peregrine Falcon (2; State Endangered Species), and Common Nighthawk (1; State Species of Special Concern). Note that it is likely that some individual birds of the listed species were local breeders (i.e., Northern Harrier, Sharp-shinned Hawk, Cooper's Hawk, and Red-shouldered Hawk) and thus were counted more than once.

RADAR DATA

Most landbirds other than tanagers, vireos, and flycatchers make call notes while they are migrating at night; these calls can be used to

identify individual species (W. Evans, Old Bird, Inc., pers. comm.). Nocturnal acoustic observations were not part of the scope of work or goals for this study, however, so were not able to collect information on the species identification of the nocturnal migrants we observed on radar. Flight behavior and/or flight speeds (corrected for wind speed and direction), however, provide some information on whether a target is a waterbird, a raptor, or a landbird. For instance, during daylight hours, raptor targets usually exhibited circling behavior on the radar. At night, flight speeds generally were higher in April than in May (Fig. 2). The flight speeds >16 m/s we observed in April suggest that waterfowl composed a sizable portion of the nocturnal targets (Bruderer and Boldt 2001) during that month. In May, flight speeds of 10–16 m/s on most nights suggested that passerines composed the majority of targets.

FLIGHT DIRECTION

Most waterbirds made local flights or were headed in a northerly direction during daylight hours in spring 2003 (Table 2). As expected, most raptors were headed in a northeasterly direction, were circling, or were making local movements. Most of the landbird flocks exhibited local movements; however there was a slight directional trend toward the north or northeast for the remainder of the flocks. During the day, the mean flight direction (± 1 angular deviation) of targets observed on radar was $040 \pm 49^\circ$ ($n = 1,256$ targets), or roughly parallel to the main axis of the turbine string. At night, the mean flight direction of targets observed on radar was $029 \pm 40^\circ$ ($n = 6,792$ targets). A large proportion of the targets during both the day (64%) and at night (55%) were traveling toward the northeast (Fig. 3), in a direction roughly parallel to the orientation of the proposed turbine string.

MIGRATION PHENOLOGY AND PASSAGE RATES

VISUAL DATA

Diurnal passage rates of waterbirds generally were low at the Chautauqua Study Area during spring 2003 (Fig. 4). The mean (± 1 SE) waterbird passage rate for the season was 1.1 ± 0.2 birds/h ($n = 30$ days). In contrast, the mean passage rate for raptors was 25.6 ± 4.7 birds/h ($n = 30$ days).

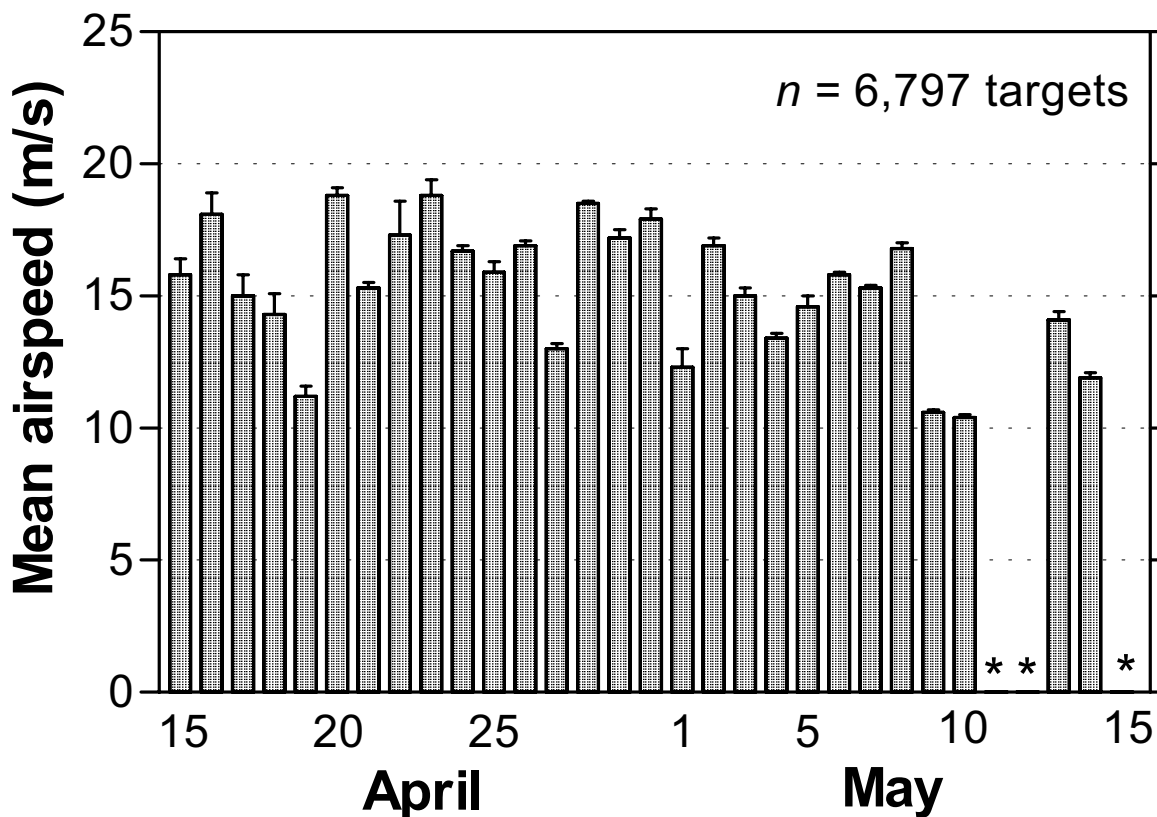


Figure 2. Nightly mean airspeeds (+ 1 SE; corrected for wind speed and direction) of targets observed on surveillance radar at the Chautauqua Study Area, New York, during spring 2003. Asterisks indicate days when sampling was not possible due to precipitation or insect contamination.

Table 2. Diurnal flight directions of waterbirds, raptors, and landbirds at the Chautauqua Study Area, New York, during spring 2003.

Flight direction	Number (%) of flocks		
	Waterbirds	Raptors	Landbirds
North	3 (4.8)	63 (5.4)	33 (9.3)
Northeast	11 (17.5)	483 (41.1)	44 (12.4)
East	3 (4.8)	64 (5.4)	14 (3.9)
Southeast	0 (0.0)	11 (0.9)	8 (2.3)
South	6 (9.5)	32 (2.7)	24 (6.8)
Southwest	4 (6.3)	42 (3.6)	18 (5.1)
West	5 (7.9)	35 (3.0)	8 (2.3)
Northwest	12 (19.0)	13 (1.1)	12 (3.4)
Local ¹	17 (27.0)	270 (23.0)	190 (53.5)
Circling	2 (3.20)	162 (13.8)	4 (1.1)
Total (n)	63	1,175	355

¹ Local refers to short, erratic flights made by birds that appeared to be local residents.

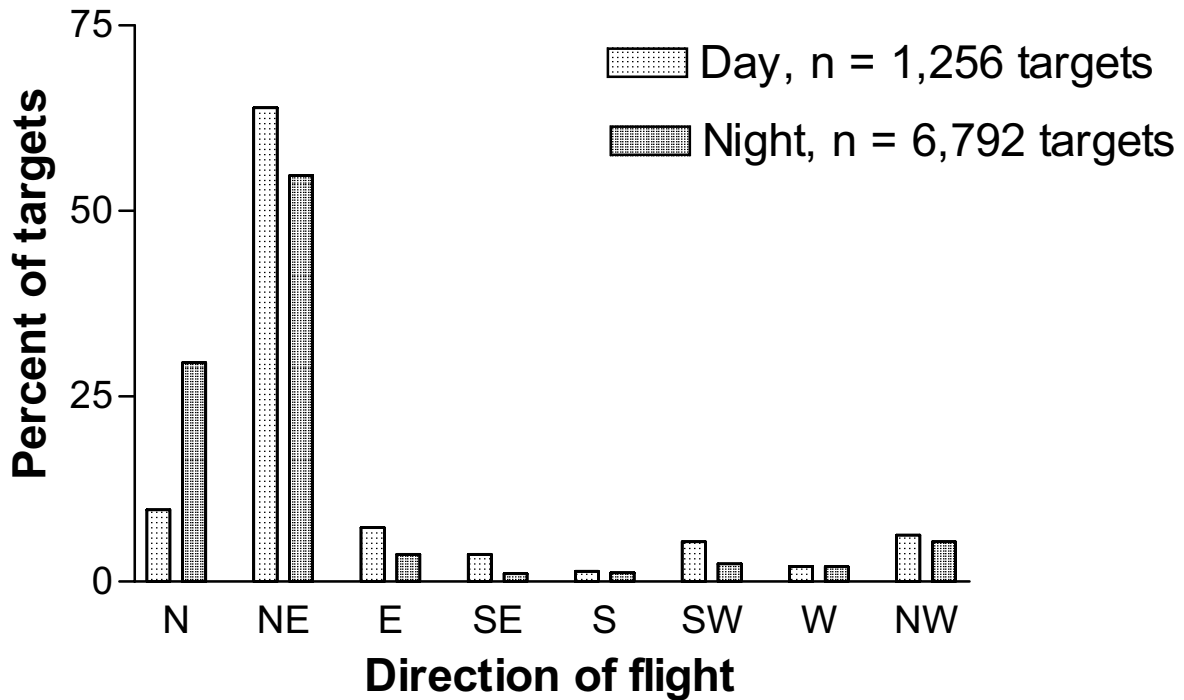


Figure 3. Diurnal and nocturnal flight directions of targets observed on radar in the Chautauqua Study Area, New York, during spring 2003.

Passage rates of raptors tended to be highest during the latter half of April (Fig. 4). The large peaks in passage rates on 19 and 21 April primarily were composed of Broad-winged Hawks and Turkey Vultures, the two most numerous bird species observed (Appendix 1). Landbird movement rates also were highly variable, with strong pulses of movement on 21 April and over several days during the second week of May (Fig. 4). The mean landbird passage rate for the season was 11.0 ± 2.2 birds/h ($n = 30$ days).

RADAR DATA

Daytime migration passage rates on surveillance radar were variable in spring 2003, ranging from 15 to 325 targets/km/h (Fig. 5). The mean daytime passage rate observed on surveillance radar was 79 ± 13 targets/km/h. Nocturnal passage rates were highly variable, ranging from 15 to 1,702 targets/km/h. The highest nocturnal passage rates occurred during the second week of May, during what probably was the peak of passerine migration. Mean nocturnal passage rates (395 ± 69 targets/km/h) were significantly

higher than were mean day rates ($Z = -4.257$, $P < 0.001$, $n = 24$ days). There were no dramatic hourly patterns in passage rates within the daytime or the nocturnal sampling periods, however (Fig. 6).

FLIGHT ALTITUDE

During daylight hours, we were able to obtain species identifications for several of the vertical radar targets (Table 3). Mean flight altitudes of individual species observed on radar ranged from 37 m agl for American Kestrel to 594 m agl for Red-shouldered Hawk. The two most numerous species, Broad-winged Hawks and Turkey Vultures, had mean flight altitudes of 384 and 121 m agl, respectively. All but 3 of the 17 species or species-groups that we obtained radar data for had mean flight altitudes above the ~125-m-high zone of the proposed turbines; however, 13 of the 17 groups had at least some individuals flying below 140 m. The overall mean flight altitude for raptors as a group was 278 ± 12 m agl ($n = 343$ targets).

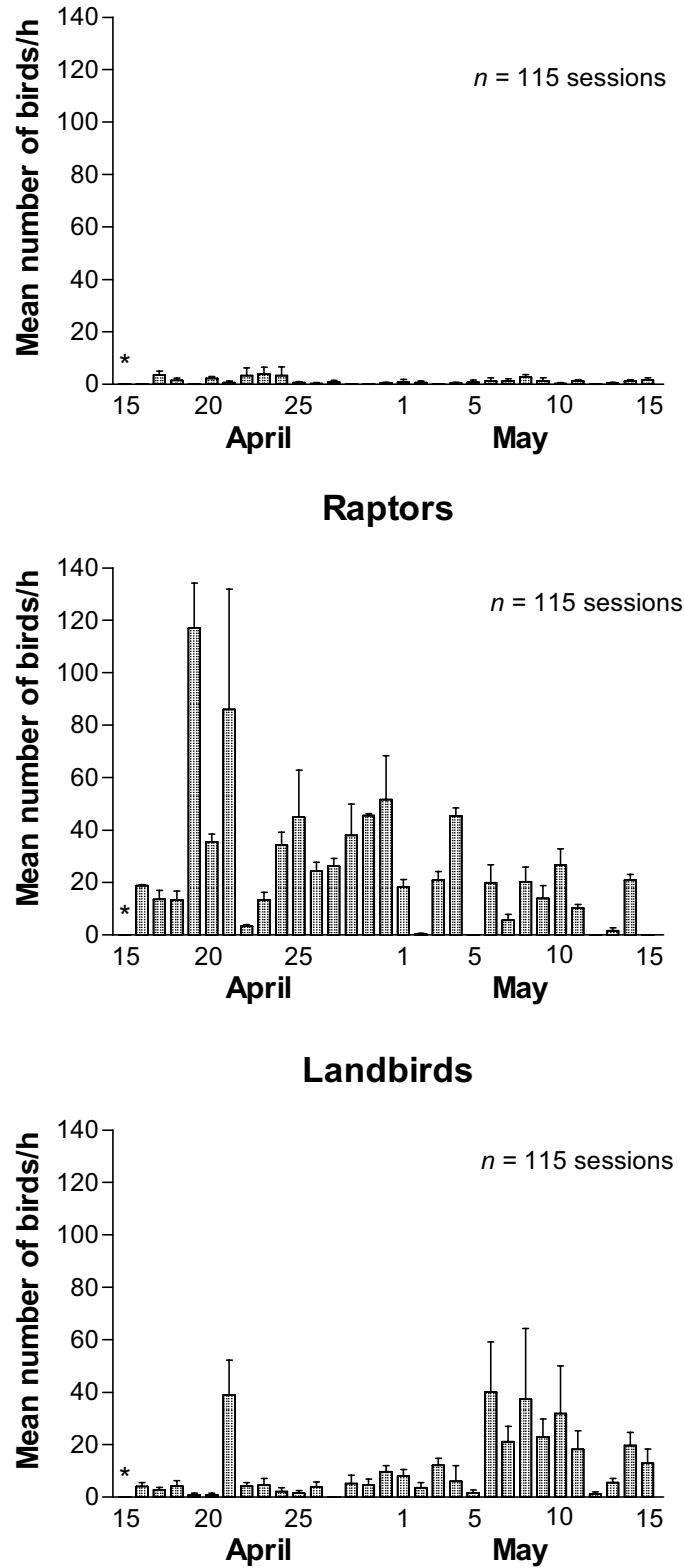


Figure 4. Mean daily diurnal passage rates (± 1 SE) of waterbirds, raptors, and landbirds observed during visual observations at the Chautauqua Study Area, New York, during spring 2003. Asterisks indicate days when sampling did not occur.

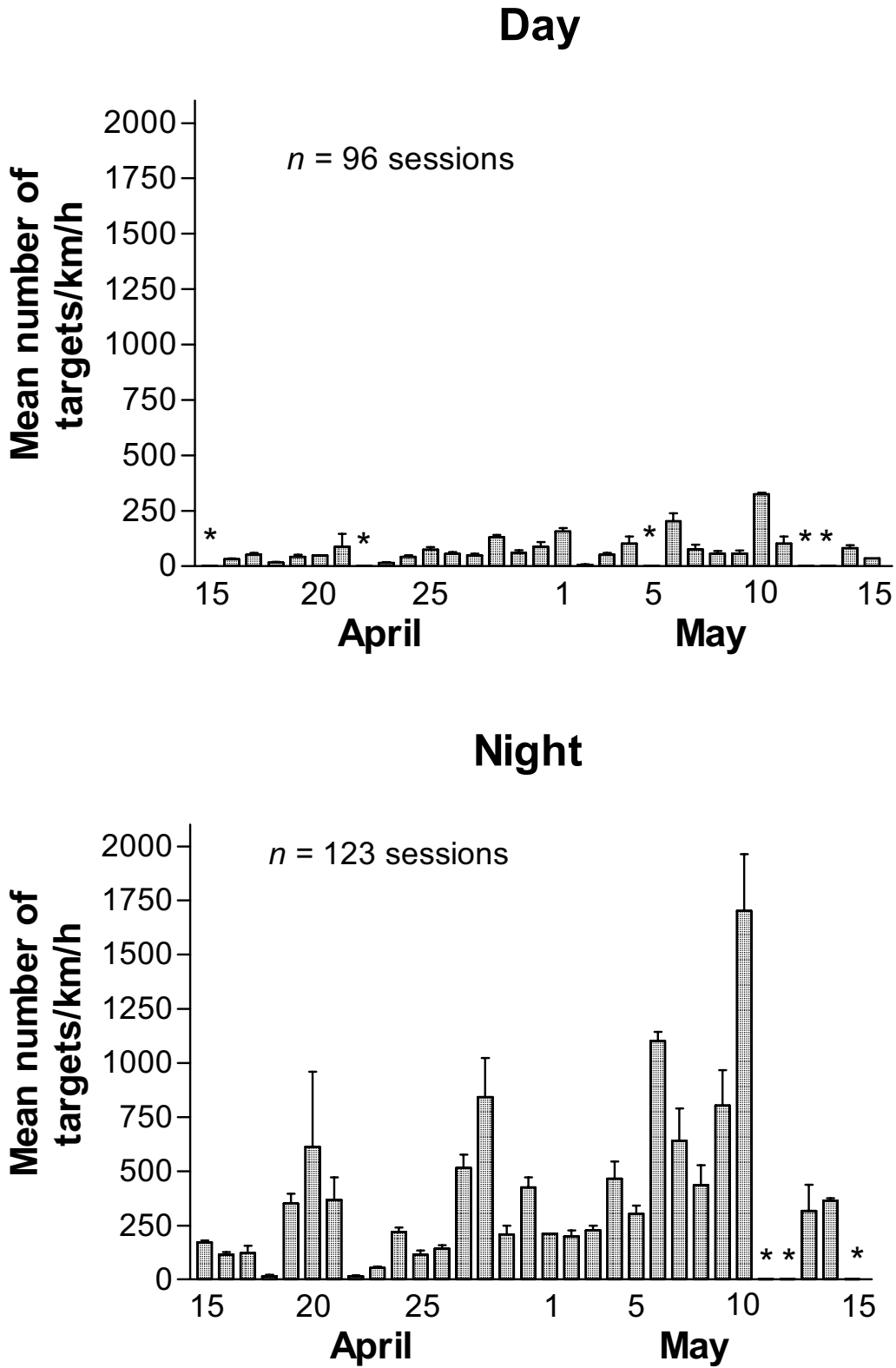


Figure 5. Diurnal and nocturnal passage rates (± 1 SE) on surveillance radar at the Chautauqua Study Area, New York, during spring 2003. Asterisks indicate days when sampling was not possible due to precipitation or insect contamination.

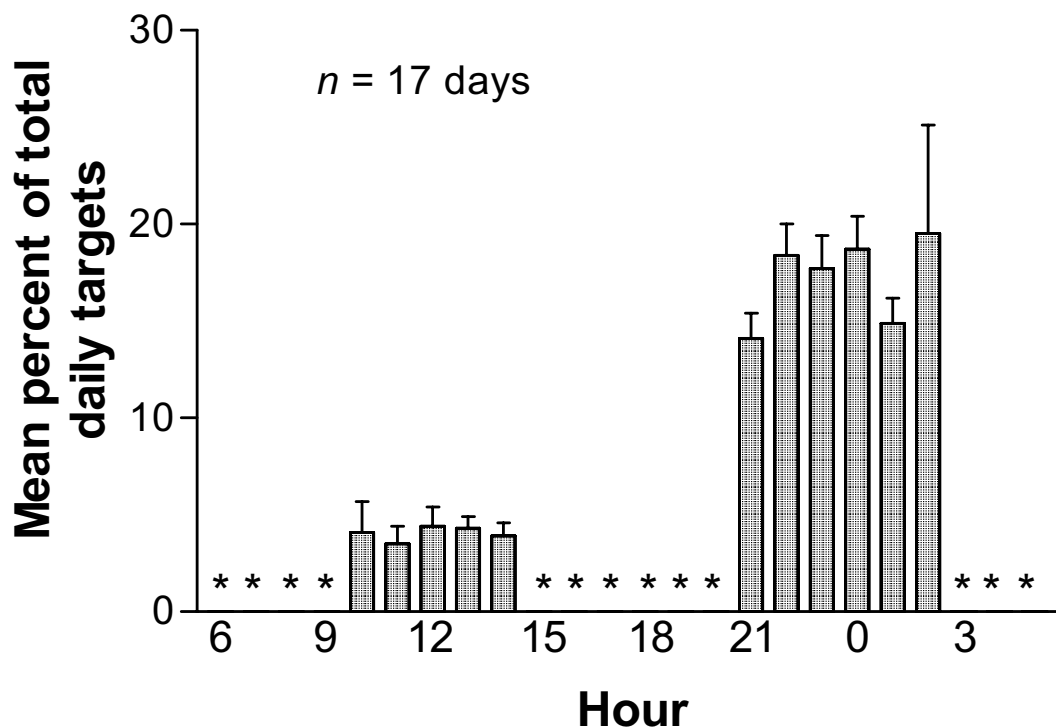


Figure 6. Mean percent of total daily surveillance radar targets (± 1 SE) by hour of the day at the Chautauqua Study Area, New York, during spring 2003. Asterisks indicate hours when sampling did not occur.

Table 3. Radar-measured flight altitudes (m agl) of birds observed in the Chautauqua Study Area, New York, during spring 2003, and number of flocks observed flying ≤ 140 m agl.

Species/species-group	Flight altitude (m agl)				Number of flocks (<i>n</i>)	Number flocks ≤ 140 m agl
	Mean	SE	Minimum	Maximum		
Common Loon	543	66	315	934	9	0
Turkey Vulture	121	12	28	504	83	63
Osprey	246	91	58	471	4	1
Bald Eagle	566	56	467	662	3	0
Northern Harrier	169	35	107	229	3	1
Sharp-shinned Hawk	148	42	58	220	4	2
Cooper's Hawk	178	93	50	181	3	2
<i>Accipiter</i> spp.	308	70	80	800	13	4
Red-shouldered Hawk	594	207	387	800	2	0
Broad-winged Hawk	384	17	73	833	172	30
Red-tailed Hawk	167	23	42	800	37	23
<i>Buteo</i> spp.	145	24	50	283	10	7
American Kestrel	37	2	35	39	2	2
Raptor spp.	267	42	70	355	7	1
Shorebird spp.	215	0	215	215	4	0
Barn Swallow	116	66	50	181	2	1
Passerine spp.	376	111	40	668	8	4

We also obtained visual-only estimates of flight altitudes for all of the species that we observed during visual sampling, however, note that these data probably are more biased to low-flying birds than the radar data and thus should be considered minimum flight altitudes (Appendix 4). For waterbirds, the mean visually estimated flight altitude was 186 ± 28 m agl (range = 1–934 m agl, $n = 56$ flocks). For raptors, the mean visually estimated flight altitude was 163 ± 4 m agl (range = 1–1,000 m agl, $n = 1,174$ flocks). For landbirds, the mean visually estimated flight altitude was 35 ± 3 m agl (range = 1–700 m agl, $n = 351$ flocks).

Mean flight altitudes observed on radar (1.5-km-range) were highly variable among both days and nights during spring 2003 (Fig. 7). Mean daytime flight altitudes (372 ± 6 m agl, $n = 1,945$ targets) were considerably lower than nocturnal flight altitudes (528 ± 3 m agl, $n = 9,755$ targets). Within a day, radar altitudes were significantly lower during daylight hours than at night ($t = -8.573$, $df = 23$, $P < 0.001$, $n = 24$ days). We also compared radar altitudes among hours of the day and again found that daytime flights were lower than evening flights but that there were no discernable hourly patterns in flight altitude within the daylight sampling hours or within the nocturnal hours (Fig. 8). The mean percentage of targets flying 1–125 m agl was higher during the day (17.2% of all daytime targets) than at night (3.8%; Appendix 5).

We also were able to collect data on the number and flight altitudes of birds along our daytime southeast–northwest vertical radar transect and along our nocturnal east–west vertical radar transect (Figs. 9 and 10). These radar data indicated that birds were flying lower during the day than at night but, more importantly, that there was a tendency during both the day and night for birds to concentrate either over or northwest of the ridgeline where the proposed turbine string would be located. During the daytime, this pattern matched the pattern that we observed visually: raptors often flew over the ridgeline or valley immediately to the north of the ridgeline and in a direction roughly parallel to the ridgeline. Note that the drop in densities beyond ~1,000 m for the radar at night probably is an artifact of effective radar range for small birds (i.e., detectability of

targets drops rapidly beyond ~1000 m from the radar), rather than lower densities of birds in those areas.

Another pattern that emerges from figures 9 and 10 is that there was a higher proportion of bird flights near ground level (i.e., in the primary zone of interest) during the day than at night. For example, of the flights below 200 m during the day, 10% were 1–50 m agl, 30% were 51–100 m agl, 33% were 101–150 m agl, and 27% were 151–200 m agl. In contrast, at night 2% were 1–50 m agl, 16% were 51–100 m agl, 34% were 101–150 m agl, and 49% were 151–200 m agl.

Our 3.0-km vertical radar sampling indicated that 82.4% of the sampling nights ($n = 17$ nights) had at least one target flying 1,500–3,000 m agl. Overall, 10.0% of all targets were flying at 1,500–3,000 m agl, and the highest-flying target was recorded at 2,842 m agl. Thus, the mean flight altitudes we report based upon the 1.5-km-range radar should be considered as minima because they do not include these birds flying >1,500 m agl.

EFFECTS OF WEATHER ON MIGRATION

It often is difficult to separate the effects of individual weather parameters on bird migration, because many parameters are strongly intercorrelated (Richardson 1978, 1990). A detailed, multivariate analysis of the effect of weather on migration passage rates was not conducted for this study, however, because it would require many more data from a variety of weather conditions and because it was beyond the scope of this study. Because wind direction is such an important factor influencing migration, however, we made a simple comparison of wind direction and migration rates. Based on our limited data sets, the largest pulses of migration tended to be associated with tail winds (i.e., from the SE, S, SW, or W; Fig. 11). Migration passage rates, however, were not significantly different between days with tailwinds and days with other winds ($U = 72.5$, $P = 0.833$, $n = 26$ days) or between nights with tail winds and nights with other winds ($U = 66.0$, $P = 0.174$, $n = 28$ nights).

Flight altitudes during both day and night were significantly lower during sessions with precipitation than without it and during sessions with low ceiling heights than with high ones

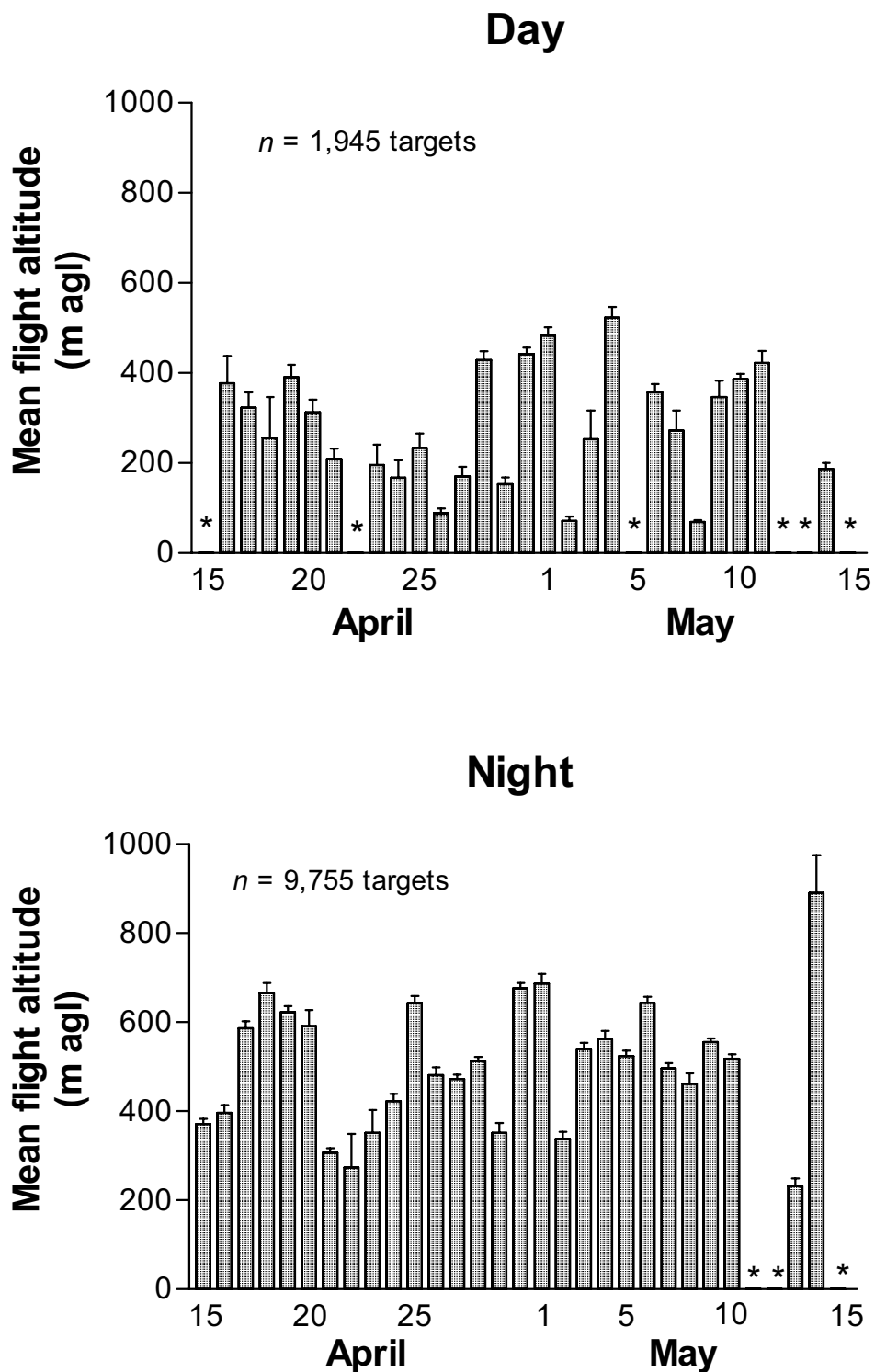


Figure 7. Mean (± 1 SE) daytime and nocturnal flight altitudes of bird targets detected by 1.5-km-range radar for each sampling date at the Chautauqua Study Area, New York, during spring 2003. Asterisks indicate dates when sampling was not possible due to precipitation or insect contamination.

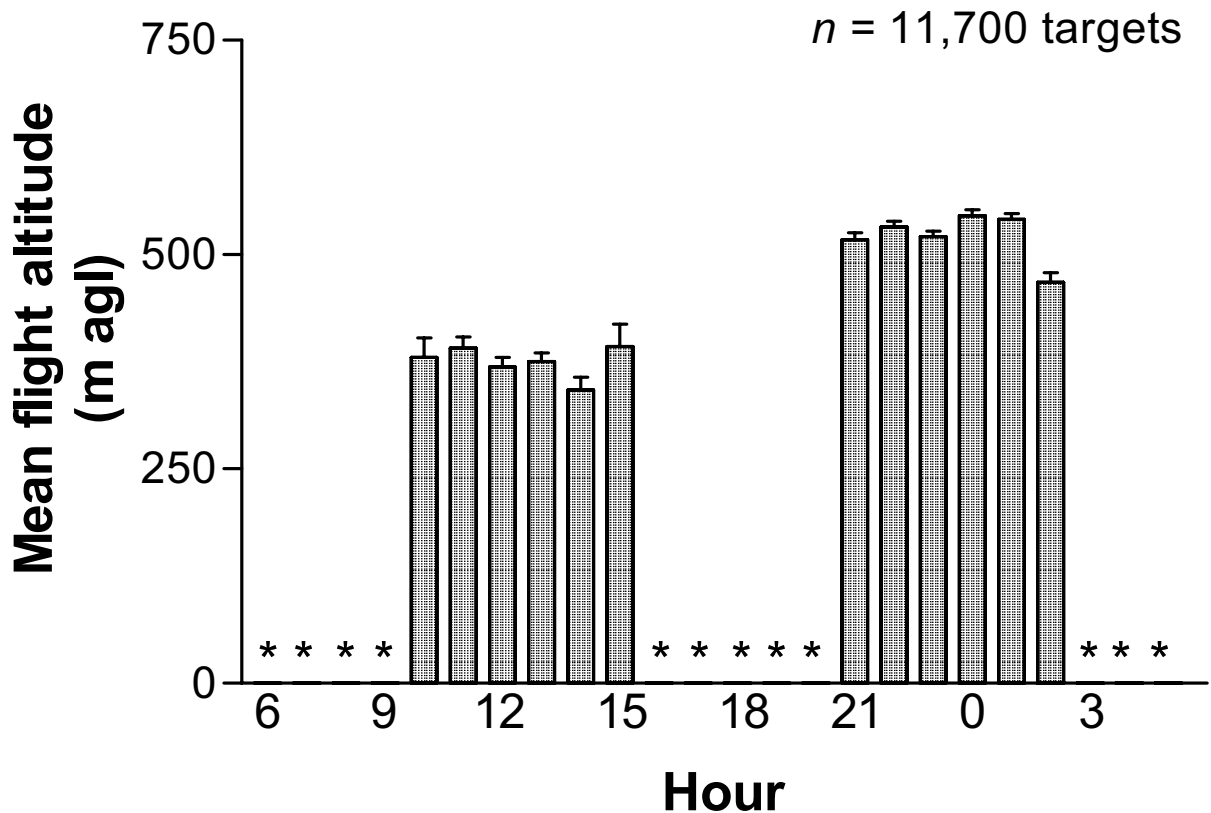


Figure 8. Mean (± 1 SE) flight altitude of bird targets detected by 1.5-km-range radar for each hour of the sampling day at the Chautauqua Study Area, New York, during spring 2003. Asterisks indicate hours when sampling did not occur.

(Table 4). Flight altitudes also were significantly lower during foggy daytime sessions than during sessions with no fog; in contrast, at night, birds flew significantly higher during foggy sessions. Tail winds did not affect flight altitudes during the day or the night.

NUMBER OF BIRDS IN THE WRA

We estimated that ~5,200–5,300 raptors during peak daylight hours and ~30,000–31,000 nocturnal migrants passed through Chautauqua Wind Resource Area (at or below turbine height) during our 30-day study (Appendices 2 and 3). Note that both the day and night numbers are based upon our sampling which was designed to capture the peak daily times of raptor migration and nocturnal migration, and we applied these peak

rates to an 8-h day for the raptor count and to all night hours for the count of nocturnal migrants.

DISCUSSION

Relative to other locations we have studied in New York (i.e., at Wethersfield [~100 km northeast of this study site; Cooper and Mabee 2000] and near Carthage [~20 km east of Watertown and ~300 km northeast of the study site; Cooper et al. 1995b]), we observed low numbers of waterfowl and landbirds and moderate–high numbers of raptors during the day. Moderate–high numbers of landbirds flew over at night in April and May, and there also were waterfowl-like targets present at night during April. There was high among-day variability in movement rates for all species and times.

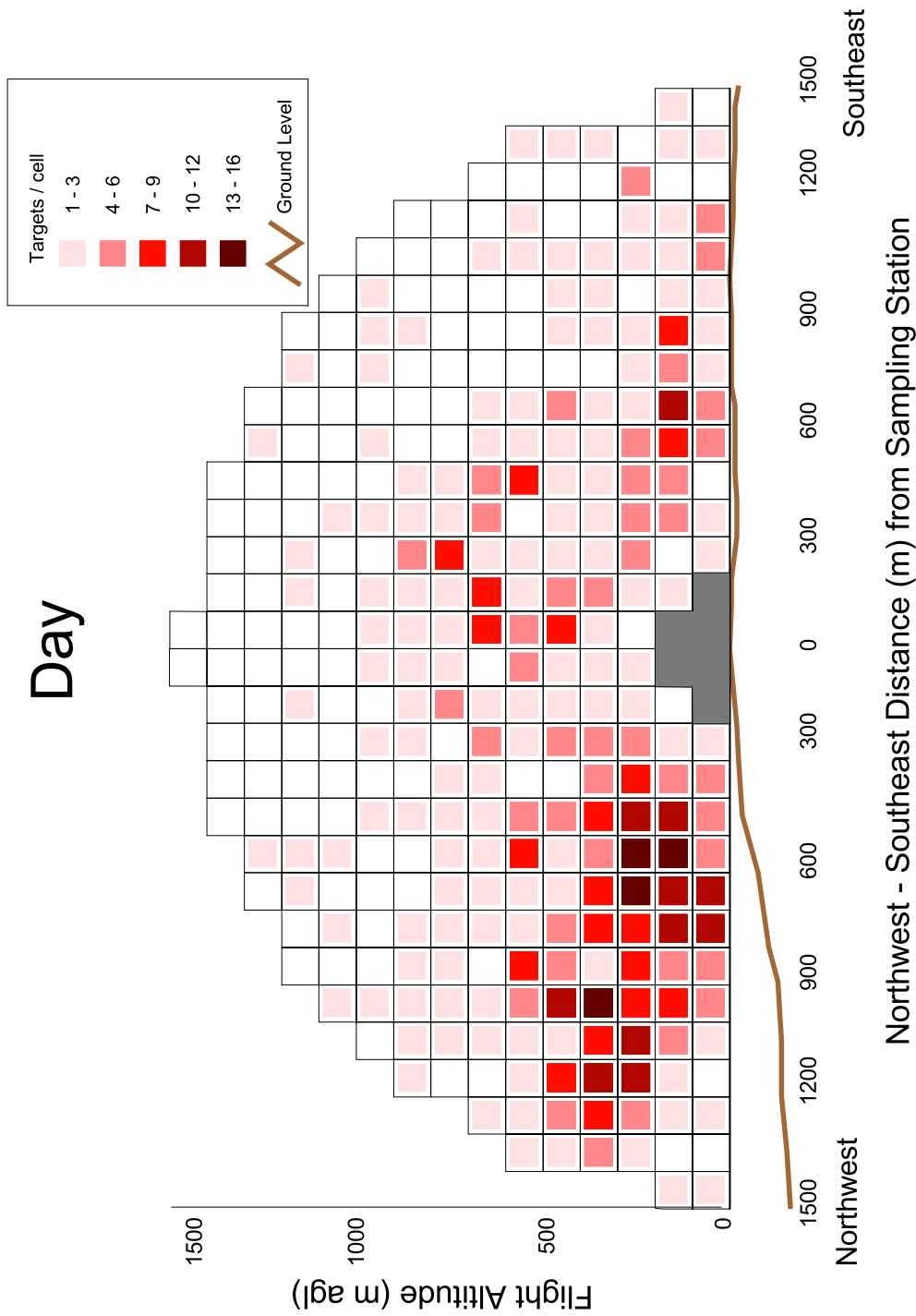


Figure 9. Distribution of daytime flight altitudes (actual counts, relative to the height of the sampling station) of targets detected by vertical radar along a 3-km, southeast-northwest transect at the Chautauqua Study Area, New York, during spring 2003. The grey zone in the center of the figure is the area where radar sampling was not possible due to ground clutter. The proposed turbine heights extend up to 121 m above the brown line representing ground level.

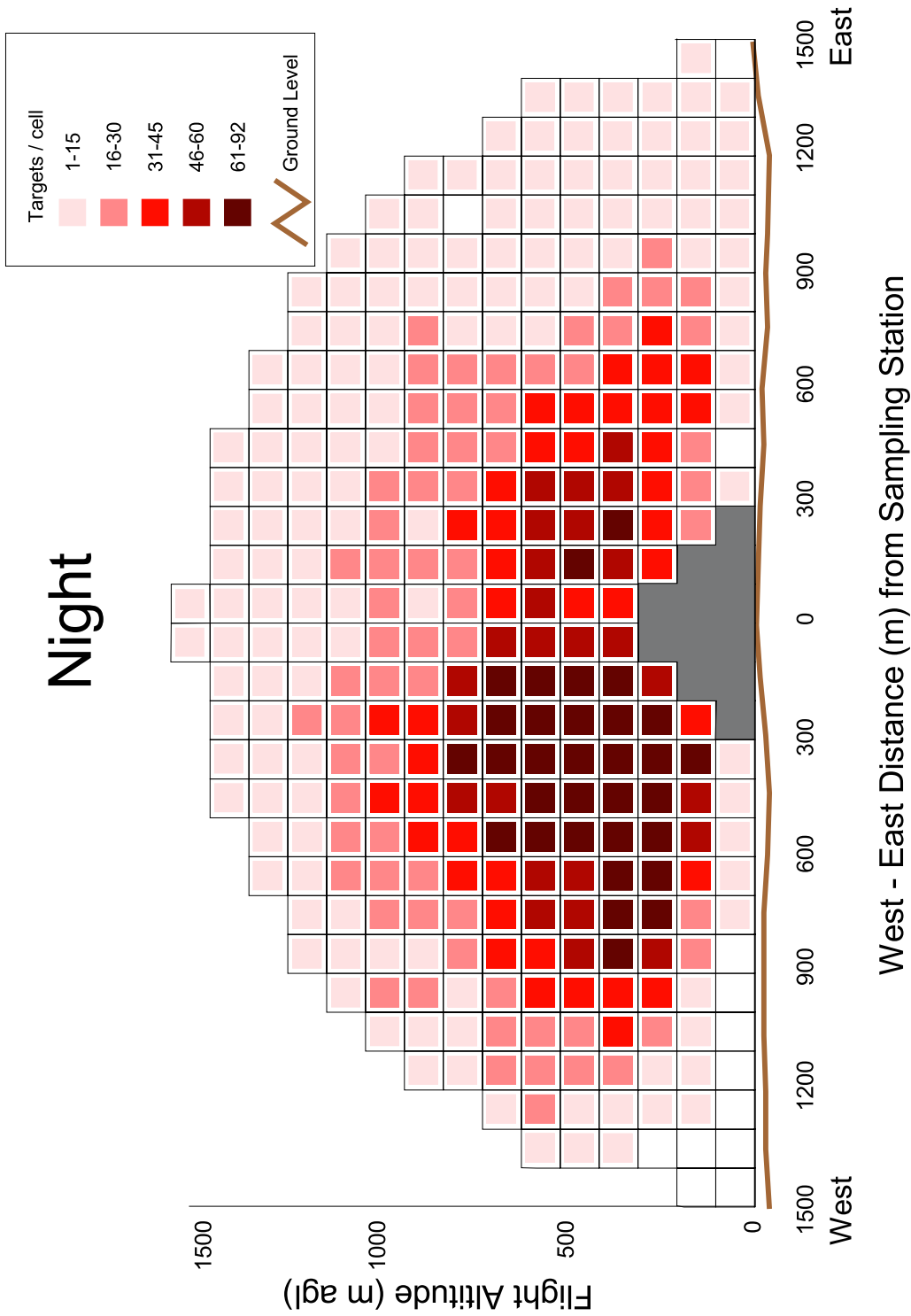


Figure 10. Distribution of nocturnal flight altitudes (actual counts, relative to the height of the sampling station) of targets detected by vertical radar along a 3-km, east-west transect at the Chautauqua Study Area, New York, during spring 2003. The grey zone in the center of the figure is the area where radar sampling was not possible due to ground clutter. The proposed turbine heights extend up to 121 m above the brown line representing ground level.

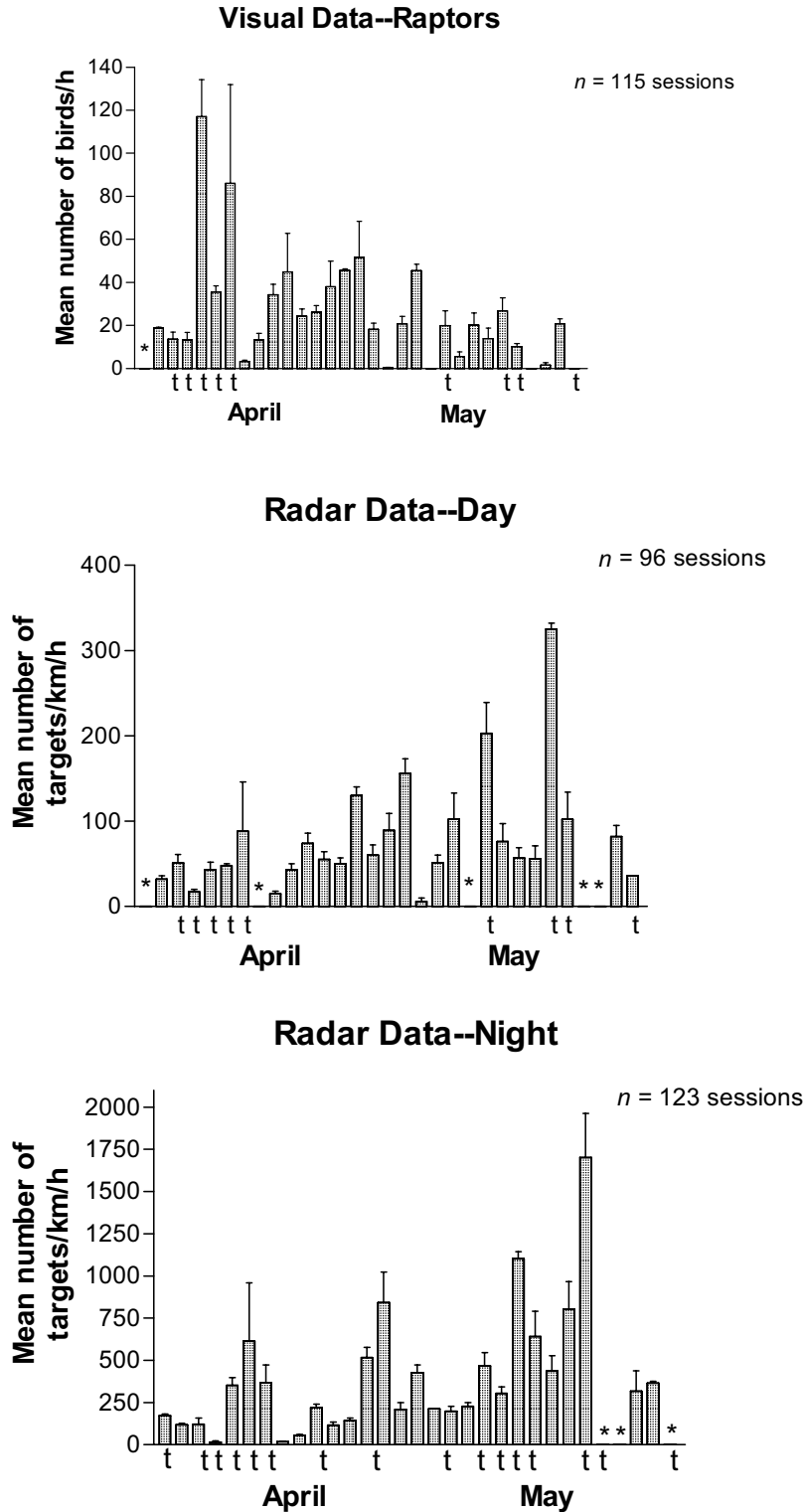


Figure 11. Daytime passage rates of raptors (± 1 SE) and diurnal and nocturnal passage rates on surveillance radar at the Chautauqua Study Area, New York, during spring 2003; t = dates with tail winds. Asterisks indicate days when sampling was not possible due to precipitation or insect contamination.

Table 4. Mean flight altitudes observed on vertical radar during different weather conditions and results of statistical comparisons of flight altitudes under different conditions during spring 2003 at the Chautauqua Study Area, New York.

Comparison	Time	Condition	Flight altitude (m agl)				
			Mean	SE	<i>n</i>	<i>t</i>	<i>P</i>
Ceiling height	Day	Low	189	23	14	-7.62	<0.001
		High	373	6	1,931		
	Night	Low	441	9	688	-10.15	<0.001
		High	534	3	9,067		
Precipitation	Day	Precip.	127	17	37	-14.20	<0.001
		No precip.	376	6	1,908		
	Night	Precip.	487	11	483	-4.57	<0.001
		No precip.	530	3	9,272		
Fog	Day	Fog	117	22	26	-11.34	<0.001
		No fog	375	6	1,919		
	Night	Fog	584	20	157	2.42	0.017
		No fog	527	3	9,598		
Wind direction	Day	Tail wind	381	11	510	0.99	0.324
		Other wind	369	7	1,435		
	Night	Tail wind	525	4	6,427	-1.54	0.123
		Other wind	535	5	3,328		

Raptors and passerines are known to migrate over the vicinity of the Chautauqua Study Area from March through May; however, the peak migration period for many common species occurs between mid-April and early May for raptors and between late April and mid-May for passerines (Haugh 1972, Bull 1985, Cooper and Mabee 2000, Zalles and Bildstein 2000, Buffalo Ornithological Society 2002). Thus, while our study was designed to bracket the major peaks in raptor and passerine migration, there is no doubt that we missed some early raptor migration and some later passerine migrants. Further, spring 2003 was unusually cold, wet, and late, all of which represent weather conditions that could have delayed migration. The timing and species-composition of bird migration that we observed generally fit with what is known for the study area during the period we were there, however.

RAPTORS

Raptors migrating during the spring were taxa of primary interest, because two of the five Ripley Hawkwatch sites (Fig. 1) are located near the

proposed facility. Each spring, an average of approximately 14,000 raptors representing 18 species are observed at the Ripley sites (Zalles and Bildstein 2000). In general, a large number of raptors migrate along the southern shore of the Lake Erie in the spring and concentrate along the lake's edge (Haugh 1972). Because no thermals form over the cold lake surface, soaring birds approaching Lake Erie must turn and follow the shoreline as a leading line. The result of this behavior is that thousands of raptors migrate along the southern shores of Lake Erie and Lake Ontario between March and May (Haugh 1972). During spring 2003, 19,298 raptors representing 18 species were observed by the Ripley Hawkwatch volunteers at the five sites (Ripley Hawkwatch, unpubl. data). Similar to our study, the most numerous species at the Ripley Hawkwatch sites were Turkey Vultures (7,782 individuals), Broad-winged Hawk (5,886), Sharp-shinned Hawks (1,695), and Red-tailed Hawks (1,332). Our counts of raptors (2,578 individuals) were lower than the Ripley Hawkwatch counts because they made observations for a larger part of the season (i.e., 8 March to ~1 June), had greater geographic

coverage extending northward to the shore of Lake Erie, and sampled for more hours per day than this study.

NOCTURNAL LANDBIRD MIGRANTS

Another species-group of primary interest was landbirds. In spring 2003, migration passage rates of nocturnal landbird migrants generally were moderate–high, and among-day variation in those rates was high. Nocturnal passage rates generally were higher at the Chautauqua Study Area than at other areas in New York where we have conducted similar radar studies. For example, the mean spring nocturnal passage rate in this study was 395 targets/km/h, compared with 41 targets/km/h at Wethersfield (~100 km northeast of this study site; Cooper and Mabee 2000) and 159 targets/km/h near Carthage (~20 km east of Watertown and ~300 km northeast of the study site; Cooper et al. 1995b). The higher migration passage rates that we observed here could partially be related to the apparent concentration of nocturnal migrants along, and just north of, the ridgeline in the Chautauqua Study Area (Fig. 10). The higher rates also could partially be related to a buildup of migrants along the south shore of the lake, similar to the raptor buildup that occurs in spring. Diehl et al. (2003) made NEXRAD radar observations and found that, while large numbers of nocturnal migrants fly over the Great Lakes, there also was some lake avoidance (which would result in a buildup of migrants flying along the front and sides of the lake and fewer birds on the far side), particularly in spring. It has been suggested that lake avoidance occurs as a matter of convenience: as the direction of travel increasingly parallels the shoreline (as we observed in spring 2003), birds may increasingly alter their flight paths to remain over land and avoid lake crossings (Alerstam and Pettersson 1977). Alternatively, as the direction becomes more perpendicular to the shoreline, birds may be more inclined to cross a lake.

LISTED SPECIES

Other birds of interest included the state or federally listed species that we observed. In spring 2003, we observed two species listed as endangered by New York state (Golden Eagle and

Peregrine Falcon), two species listed by the state as threatened (Bald Eagle [also listed as a Federally Threatened Species] and Northern Harrier), and six state Species of Special Concern (Common Loon, Osprey, Sharp-shinned Hawk, Cooper's Hawk, Red-shouldered Hawk, and Common Nighthawk). These listed species made up 4.7% of the total number of birds we observed in spring 2003 (i.e., 178 of 3,765 birds). Because there were some locally-breeding Northern Harriers, Sharp-shinned Hawks, Cooper's Hawks, and Red-shouldered Hawks in the area, it is likely that certain individuals of those species were counted more than once. Thus, our counts of those species probably are higher than the actual number of individuals that passed over the study site. Some of the threatened and endangered species were flying at altitudes below 140 m agl (i.e., within the zone of potential risk), including 1 of 2 Peregrine Falcons, 2 of 7 Golden Eagles, 2 of 14 Bald Eagles, and 17 of 31 Northern Harriers.

EFFECT OF TIME OF DAY ON PASSAGE RATES

Some birds, including loons, swans, geese, ducks, gulls, terns, and shorebirds, migrate both at night and during the day. Most small birds, including most passerines, generally migrate at night. Raptors, cranes, corvids, swallows, blackbirds, and bluebirds generally migrate during the day (Weir 1976, Gauthreaux 1978, Kessel 1984, Alerstam 1990). These general patterns also were observed at the Chautauqua site.

Our radar observations indicated that passage rates in spring 2003 were higher at night than during the day. Data from surveillance radars across North America also indicate that considerably more birds migrate at night than during the day (Gauthreaux 1975, Cooper et al. 1995b, Cooper and Mabee 2000). Several studies also have found that nocturnal migration begins to increase ~30–45 min after sunset, peaking just before midnight and declining steadily until dawn (e.g., Lowery 1951, Gauthreaux 1971). We also observed an increase in movement rates ~30–45 min after sunset but found that rates over the remainder of the night generally did not vary after that initial buildup.

FLIGHT ALTITUDE

DIURNAL FLIGHT ALTITUDE

Diurnal flight altitudes at the Chautauqua Study Area generally were higher than altitudes at other sites we have studied in New York. For instance, the mean visually-estimated flight altitude of waterbirds at Chautauqua was 186 m agl, compared with means of 23–167 m agl at three other locations in New York (Cooper et al. 1995b, Cooper and Mabee 2000). Further, mean flight altitudes of raptors were 163 m agl (visual estimate) at Chautauqua compared to 59–139 m agl (visual estimate) at the other sites. Mean visual estimates of daytime flight altitudes of landbirds were similar between Chautauqua (35 m agl) and the other sites (13–37 m agl).

Flight-altitude data from other areas varies widely. For example, geese migrate mostly at 100–1,110 m agl (Cooch 1955, Meinertzhagen 1955, Blokpoel 1974, Bellrose 1976, Ogilvie 1978, Wege and Raveling 1984). Ducks migrating during the “Grand Passage” along the Central Flyway generally fly at 460–850 m agl during the day (Bellrose and Sieh 1960). In Alaska, flight altitudes for ducks and geese are 16–300 m agl (Cooper and Ritchie 1995).

Migrating raptors in North America usually fly 200–1,100 m agl (Kerlinger 1980; Kerlinger and Gauthreaux 1984, 1985; Kerlinger et al. 1985; Heintzelman 1986), although flights below 50 m agl occur along some ridges and coastal areas and have been observed in Alaska (Kerlinger 1989; Cooper and Ritchie 1995; M. Morgante, E&E, unpubl. data).

Landbirds have been observed to migrate at low altitudes: Bingman (1980), Wiedner et al. (1992), Cooper and Ritchie (1995), and several of the sources cited by Kerlinger and Moore (1989) observed diurnal passerine migration below 150 m agl. Others report that passerines generally migrate below 1,000 m agl but that some have been observed at much greater heights (Meinertzhagen 1955, Lack 1960, Eastwood and Rider 1965, Gauthreaux 1972, Williams et al. 1977, Kerlinger and Moore 1989).

It is likely that our visual samples and others at the various Hawkwatch sites are biased to low-flying birds because visual observers tend to miss higher-flying birds (Meinertzhagen 1955;

Kerlinger and Gauthreaux 1984, 1985; Kerlinger et al. 1985). For example, the substantial difference between visual estimates of flight altitude (163 ± 4 m agl) and radar-measured flight altitudes (278 ± 12 m agl) of raptors observed in this study probably occurred because of the visual bias. Because of the visual bias, visual counts also are likely to be lower than the actual number of birds flying past the station.

We did not observe any patterns in flight altitudes of radar targets among diurnal hours, but others have found that flight altitudes of migrating raptors are highest during midday when development of thermals is greatest (Kerlinger et al. 1985). It is likely that we did not observe this increase in flight altitudes because our radar data set included many non-soaring birds that do not depend upon thermal updrafts to migrate. For example, when our radar data set was limited to raptors only, flight altitudes were higher during 1300–1359 h (346 ± 26 m agl, $n = 93$ targets) and 1500–1559 h (340 ± 49 m agl, $n = 34$) than during 1000–1059 h (229 ± 60 m agl, $n = 13$), 1100–1159 h (240 ± 21 m agl, $n = 61$), 1200–1259 h (244 ± 25 m agl, $n = 68$), or 1400–1459 h (233 ± 21 m agl, $n = 74$).

NOCTURNAL FLIGHT ALTITUDE

We do not believe that it is appropriate to directly compare nocturnal flight altitudes between Chautauqua (mean = 528 m agl) with flight altitudes measured at the other sites we have studied in New York (Cooper et al. 1995b, Cooper and Mabee 2000), because those studies used different methods and equipment. Other radar studies besides the Chautauqua study have found that nocturnal migration usually occurs below 600 m agl, however (Bellrose 1971; Gauthreaux 1972, 1978, 1991; Bruderer and Steidinger 1972; Cooper and Ritchie 1995; Kerlinger 1995). Large kills of birds at tall, manmade structures also indicate that large numbers of nocturnal migrants fly <500 m on at least some nights (Avery et al. 1980). In contrast, others have found that peak nocturnal densities extend over a broad altitudinal range below ~2,000 m (Harper 1958 *in* Eastwood 1967; Graber and Hassler 1962; Nisbet 1963; Bellrose and Graber 1963; Eastwood and Rider 1965; Bellrose 1967; Blokpoel 1971; Richardson 1971, 1972; Blokpoel and Burton 1975). We

suspect that differences between the two groups of studies are due to differences in location, species-composition of migrating birds, and perhaps weather conditions. It also has been suggested that limitations in equipment and sampling methods of some previous radar studies may have been responsible for their overestimation of the altitude of bird migration (Able 1970, Kerlinger and Moore 1989). For example, the radars used by Bellrose and Graber (1963), Blokpoel (1971), and Nisbet (1963) could not detect birds below 450 m, 370 m, and 180 m agl, respectively. In contrast, our vertical radar could detect targets down to ~10 m above ground level. Given the number of birds we observed below 180 m agl, we believe that the data we collected for this study more accurately reflect actual flight altitudes than those studies that used radar that did not detect birds below 180 m agl.

We found that flight altitudes were higher at night than during the day. Although a few studies have found that flight altitudes of birds are higher during the day (e.g., Bellrose and Sieh 1960, Gauthreaux 1972), most have found that flight altitudes are higher at night (e.g., Lack 1960, Eastwood and Rider 1965, Bruderer and Steidinger 1972, Gauthreaux 1978, Buurma and Bruderer 1990). We did not observe any patterns in flight altitude among hours of the night, but others have found that flight altitudes of migrating birds are not constant and vary within a night and are highest near or just before midnight, declining slowly until dawn (Graber and Hassler 1962, Nisbet 1963, Able 1970, Bellrose 1971, Richardson 1971, Blokpoel and Burton 1975, Buurma and Bruderer 1990). This behavior probably explains why more birds are killed at tall obstacles after midnight than before midnight (Weir 1976).

Similar to our other migration studies in New York and elsewhere (Cooper and Ritchie 1995; Cooper et al. 1995a, 1995b; Cooper and Mabee 2000; Mabee and Cooper 2002), we recorded large among-day variation in nocturnal flight altitudes. This variation probably reflected changes in both species-composition and vertical structure of the atmosphere and weather. Among-day variation in the flight altitude of migrants across the Gulf of Mexico is considerable and primarily is related to changes in the vertical structure of the atmosphere (Gauthreaux 1991). Those birds appear to fly at

altitudes at which favorable winds minimize the energetic cost of migration. Kerlinger and Moore (1989) have concluded that atmospheric structure is the primary selective force determining the height at which migrants fly.

EFFECTS OF WEATHER ON MIGRATION

EFFECTS OF WEATHER ON MIGRATION PASSAGE RATES

It is a well-known fact that general weather patterns and their associated temperatures and winds affect migration (Richardson 1990). In the Northern Hemisphere, air moves counterclockwise around low-pressure systems and clockwise around high-pressure ones. Thus, winds are warm and southerly when the area is affected by a low to the west or a high to the east and cold and northerly in the reverse situation. Clouds, precipitation, and strong, variable winds are typical in the centers of lows and near fronts, whereas weather is usually fair with weak or moderate winds in high-pressure areas. Numerous studies in the Northern Hemisphere have shown that, in spring, most bird migration tends to occur in the eastern parts of lows, the western or central parts of highs, or in intervening transitional areas. In contrast, cold fronts, which are accompanied by northerly (unfavorable) winds and colder temperatures, tend to slow migration in spring (Lowery 1951; Gauthreaux 1971; Able 1973, 1974; Blokpoel and Gauthier 1974; Richardson 1990).

A detailed analysis of the effect of weather on migration passage rates was not conducted for this study because it would require many more data from a variety of weather conditions. Because wind direction is such an important factor influencing migration in the vicinity of this proposed wind farm (Haugh 1972; W. Evans, pers. comm.), however, we made a simple comparison of wind direction and migration rates and found that the largest pulses of diurnal and nocturnal migration often occurred on days with tail winds. Overall, however, migration passage rates were not significantly different between days with tail winds and days with other winds. It is likely that a combination of small sample sizes and different conditions further south along the migration route contributed to these contradictory results.

UNUSUAL CIRCLING PATTERN DURING FOGGY NIGHT

On the night of 7 May 2003, we observed unusual circling behavior by birds under foggy conditions. When radar sampling began at 2200 h, nocturnal migration rates were fairly high, and there was a heavy fog layer at the sampling station. At that time, many of the birds that we observed within ~800 m of the radar sampling site were flying in a circling pattern around the site. Circling continued until ~0000 h, when the fog dissipated and one could see patches of clear sky. The flight paths were then northerly, linear tracks until the fog again became dense at 0200–0300 h, and the circling resumed. We speculate that the circling could have occurred because birds were attracted to, and disoriented by, the flashing white strobe light on the telecommunications tower near our sampling station. This type of circling behavior around lights under foggy conditions has been observed elsewhere (Cochrane and Graber 1958, Larkin and Frase 1988) and it has been suggested that it could lead to nocturnal bird kills at tall, lit towers. It is doubtful that much mortality would have occurred on the night of 7 May 2003, however, because mean flight altitude that night (i.e., 496 ± 12 m agl) was far above the proposed facility heights. Further, no dead birds were found the next morning below the ~100-m-high telecommunications tower that is located near the radar sampling site (M. Morgante, E&E, unpubl. data).

EFFECTS OF WEATHER ON FLIGHT ALTITUDE OF BIRDS

Most studies (except for Bellrose 1971) have found that clouds influence flight altitude, but the results are not consistent among studies. For instance, some studies (Bellrose and Graber 1963, Blokpoel and Burton 1975) found that birds flew both below and above cloud layers, whereas others (Nisbet 1963, Able 1970) found that birds tended to fly below clouds. Radar observations at the Chautauqua Study Area indicated that flight altitudes during both the day and night were lower during periods of low (< 500 m agl) cloud ceilings than during periods of high (> 500 m agl) cloud ceilings or clear skies.

Gauthreaux (1978) found that daytime migrants flew lower when visibility was poor and

when there was dense cloud cover and drizzle. Kessel (1984) noted that cranes in east-central Alaska flew lower during “bad flying weather” than in “good flying weather.” We found that flight altitudes during both day and night were lowest during periods with precipitation. Flight altitudes at Chautauqua also were lower during foggy conditions than clear conditions during the day but at night were higher during foggy conditions. We suspect that the reason nocturnal flights were higher during the foggy conditions is because the birds were flying above what appeared to be a fairly thin layer of ground fog on several nights.

Radar studies have shown that wind is a key factor in migratory flight altitudes (Alerstam 1990). The birds fly mainly at heights where head winds are minimized and tail winds are maximized. Thus, as a rule of thumb, bird migration takes place at low altitudes in head winds and at higher altitudes in tail winds, if winds of all layers are heading in the same direction. Our data from Chautauqua do not fit with this general pattern, in that there was no difference in flight altitudes between tail winds and other winds during spring 2003. We cannot explain this difference; perhaps it is an artifact of the sample sizes of different wind conditions that we experienced.

Although the ability of weather to influence migration passage rates and flight altitudes of nocturnal birds has been established in many studies, it will require additional field data under a greater variety of weather conditions throughout the full migratory season to build predictive models that would identify those conditions that would put nocturnal migrants at risk of collision with wind turbines. Large kills of migratory birds have not been documented at wind power developments, but they have sporadically occurred at other, taller structures (e.g., guyed and lighted towers >130 m high) in many places across the country during periods of heavy migration, especially on foggy, overcast nights in fall (Weir 1976, Avery et al. 1980, Evans 1998; Erickson et al. 2001). Recently, however, 27 nocturnal spring migrants (passerines) were killed on one foggy spring night, when they collided with turbines near a brightly lit substation at the Mountaineer wind power development on Backbone Mountain in West Virginia (Kerns and Kerlinger 2004).

CONCLUSIONS

This study focused on raptor and nocturnal songbird migration because the Chautauqua site is located in a known spring raptor migration corridor and because little is known about spring nocturnal migration in the area. We found that the Chautauqua Study Area has higher spring daytime migration of raptors and spring nocturnal migration of passerines than other locations that have been studied in New York (i.e., at Wethersfield [~100 km northeast of this study site; Cooper and Mabee 2000] and near Carthage [~20 km east of Watertown and ~300 km northeast of the study site; Cooper et al. 1995b]). We estimated that ~5,200–5,300 raptors during peak daylight hours and ~30,000–31,000 nocturnal migrants passed through Chautauqua Wind Resource Area (at or below turbine height) during our 30-day study. Mean daytime flight altitudes (372 m agl) were significantly lower than nocturnal flight altitudes (528 m agl), and the mean percentage of targets flying below 125 m agl was 17% during the day and 4% at night. We observed a tendency during both the day and night for birds to concentrate either over, or northwest of, the ridgeline where the proposed turbine string would be located. These types of data will be used for an evaluation of the potential risk of the proposed wind farm to daytime raptor migrants and nocturnal passerine migrants that is presented in a separate document.

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Appendix 1. Daily counts and scientific names of all species observed visually at the Chautauqua Study Area, New York, during spring 2003.

Species	16-Apr	17-Apr	18-Apr	19-Apr	20-Apr	21-Apr	22-Apr	23-Apr	24-Apr	25-Apr
Common Loon (<i>Gavia immer</i>)		8			7				1	
Great Blue Heron (<i>Ardea herodias</i>)		2	2							1
Turkey Vulture (<i>Cathartes aura</i>)	30	51	23	75	48	11	5	33	42	45
Snow Goose (<i>Chen caerulescens</i>)										
Canada Goose (<i>Branta canadensis</i>)			2			2	10	3		
Goose spp.								7		
Duck spp.								3	10	
Waterfowl spp.										1
Waterbird spp.										
Osprey (<i>Pandion haliaetus</i>)				2	1					
Bald Eagle (<i>Haliaeetus leucocephalus</i>)				1	1					
Northern Harrier (<i>Circus cyaneus</i>)	3			2		1	2	2	1	3
Sharp-shinned Hawk (<i>Accipiter striatus</i>)	4		2	3	5					
Cooper's Hawk (<i>Accipiter cooperii</i>)	1	1	3	4	2				2	1
Accipiter spp.	5	3	6	3	3			1	1	5
Red-shouldered Hawk (<i>Buteo lineatus</i>)				5	1					
Broad-winged Hawk (<i>Buteo platypterus</i>)			1	252	41	270		1	52	70
Red-tailed Hawk (<i>Buteo jamaicensis</i>)	4	6		15		2	2	3	5	7
Rough-legged Hawk (<i>Buteo lagopus</i>)										
Buteo spp.			2	24	14				6	6
Golden Eagle (<i>Aquila chrysaetos</i>)									1	3
American Kestrel (<i>Falco sparverius</i>)			3	2	2	2	2	4	3	1
Peregrine Falcon (<i>Falco peregrinus</i>)										
Falcon spp.										
Raptor spp.		2	4						1	8
Wild Turkey (<i>Meleagris gallopavo</i>)							3			
Sandhill Crane (<i>Grus canadensis</i>)										
Killdeer (<i>Charadrius vociferus</i>)			1							
Shorebird spp.										
Herring Gull (<i>Larus argentatus</i>)										1
Gull spp.		2								

Appendix 1. (Continued).

Species	16-Apr	17-Apr	18-Apr	19-Apr	20-Apr	21-Apr	22-Apr	23-Apr	24-Apr	25-Apr
Mourning Dove (<i>Zenaida macroura</i>)		1	1				1			
Common Nighthawk (<i>Chordeiles minor</i>)								1		
Belted Kingfisher (<i>Ceryle alcyon</i>)										
Northern Flicker (<i>Colaptes auratus</i>)	2	1	1	1		2				
Woodpecker spp.		1								
Eastern Kingbird (<i>Tyrannus tyrannus</i>)										
Blue Jay (<i>Cyanocitta cristata</i>)						2				
Tree Swallow (<i>Tachycineta bicolor</i>)										
Barn Swallow (<i>Hirundo rustica</i>)		1								2
Swallow spp.			1		3				2	2
Eastern Bluebird (<i>Sialia sialis</i>)							1	2		
American Robin (<i>Turdus migratorius</i>)	1		6			2	1			
Yellow-rumped Warbler (<i>Dendroica coronata</i>)										
Scarlet Tanager (<i>Piranga olivacea</i>)										
Savannah Sparrow (<i>Passerculus sandwichensis</i>)										
Song Sparrow (<i>Melospiza melodia</i>)						1	4		2	
Sparrow spp.										1
Bobolink (<i>Dolichonyx oryzivorus</i>)										
Red-winged Blackbird (<i>Agelaius phoeniceus</i>)						86	3			
Eastern Meadowlark (<i>Sturnella magna</i>)		3		2		2			2	
Common Grackle (<i>Quiscalus quiscula</i>)			5							
Baltimore Oriole (<i>Icterus galbula</i>)										
Blackbird spp.						1		1		
American Goldfinch (<i>Carduelis tristis</i>)										
Passerine spp.	7	2				33	1	11	1	
Total	57	84	63	393	128	417	36	72	132	156

Appendix 1. (Continued).

Species	26-Apr	27-Apr	28-Apr	29-Apr	30-Apr	1-May	2-May	3-May	4-May	5-May
Common Loon (<i>Gavia immer</i>)					2					
Great Blue Heron (<i>Ardea herodias</i>)									1	
Turkey Vulture (<i>Cathartes aura</i>)	47	39	40	21	48	21	1	33	33	
Snow Goose (<i>Chen caerulescens</i>)		1								
Canada Goose (<i>Branta canadensis</i>)	1	1					2			2
Goose spp.										
Duck spp.						3				
Waterfowl spp.		1								
Waterbird spp.				4	1	4		4		
Osprey (<i>Pandion haliaetus</i>)					4	3				
Bald Eagle (<i>Haliaeetus leucocephalus</i>)		3	1	1	2	1		1	1	
Northern Harrier (<i>Circus cyaneus</i>)		1	2	1	4			1	2	
Sharp-shinned Hawk (<i>Accipiter striatus</i>)	1		1	1	4	1		3	2	
Cooper's Hawk (<i>Accipiter cooperii</i>)	1	1		2	1	3		1	4	
Accipiter spp.	1	1	2	2		1		1	3	
Red-shouldered Hawk (<i>Buteo lineatus</i>)										
Broad-winged Hawk (<i>Buteo platypterus</i>)	8	16	45	94	118	13		1	48	
Red-tailed Hawk (<i>Buteo jamaicensis</i>)	14	18	8	18	15	4		26	17	
Rough-legged Hawk (<i>Buteo lagopus</i>)		1								
Buteo spp.	2	7		1	11	1			3	
Golden Eagle (<i>Aquila chrysaetos</i>)										
American Kestrel (<i>Falco sparverius</i>)	2		2							
Peregrine Falcon (<i>Falco peregrinus</i>)										
Falcon spp.										
Raptor spp.	5		24	10	4	12		1		
Wild Turkey (<i>Meleagris gallopavo</i>)										
Sandhill Crane (<i>Grus canadensis</i>)										
Killdeer (<i>Charadrius vociferus</i>)					10					
Shorebird spp.										
Herring Gull (<i>Larus argentatus</i>)										
Gull spp.										

Appendix 1. (Continued).

Species	26-Apr	27-Apr	28-Apr	29-Apr	30-Apr	1-May	2-May	3-May	4-May	5-May
Mourning Dove (<i>Zenaida macroura</i>)								2		
Common Nighthawk (<i>Chordeiles minor</i>)										
Belted Kingfisher (<i>Ceryle alcyon</i>)										
Northern Flicker (<i>Colaptes auratus</i>)	1		1							
Woodpecker spp.										
Eastern Kingbird (<i>Tyrannus tyrannus</i>)										
Blue Jay (<i>Cyanocitta cristata</i>)										
Tree Swallow (<i>Tachycineta bicolor</i>)										
Barn Swallow (<i>Hirundo rustica</i>)	5		3	4	7	5		19	7	
Swallow spp.			7			2	1			
Eastern Bluebird (<i>Sialia sialis</i>)			1							
American Robin (<i>Turdus migratorius</i>)										
Yellow-rumped Warbler (<i>Dendroica coronata</i>)										
Scarlet Tanager (<i>Piranga olivacea</i>)										
Savannah Sparrow (<i>Passerculus sandwichensis</i>)										
Song Sparrow (<i>Melospiza melodia</i>)				1			1			1
Sparrow spp.	1									
Bobolink (<i>Dolichonyx oryzivorus</i>)										
Red-winged Blackbird (<i>Agelaius phoeniceus</i>)				3	2	4	8	3		3
Eastern Meadowlark (<i>Sturnella magna</i>)				3	1		2			
Common Grackle (<i>Quiscalus quiscula</i>)										
Baltimore Oriole (<i>Icterus galbula</i>)										
Blackbird spp.										
American Goldfinch (<i>Carduelis tristis</i>)	4		5		19	1		10	8	
Passerine spp.						11				
Total	95	90	143	166	256	90	15	109	129	6

Appendix 1. (Continued).

Species	6-May	7-May	8-May	9-May	10-May	11-May	12-May	13-May	14-May	15-May	Grand Total
Common Loon (<i>Gavia immer</i>)						1					19
Great Blue Heron (<i>Ardea herodias</i>)		2									8
Turkey Vulture (<i>Cathartes aura</i>)	46	14	48	42	41	24			38		899
Snow Goose (<i>Chen caerulescens</i>)											1
Canada Goose (<i>Branta canadensis</i>)		2	4	2		3					34
Goose spp.											7
Duck spp.											16
Waterfowl spp.											2
Waterbird spp.	46	3		2						3	67
Osprey (<i>Pandion haliaetus</i>)			2		1	1					14
Bald Eagle (<i>Haliaeetus leucocephalus</i>)					2						14
Northern Harrier (<i>Circus cyaneus</i>)	1			1	1			1	2		31
Sharp-shinned Hawk (<i>Accipiter striatus</i>)	3		4	2	2	2			3		43
Cooper's Hawk (<i>Accipiter cooperii</i>)	1	2	3	4	1	2			1		41
Accipiter spp.	2			2	6	1			1		50
Red-shouldered Hawk (<i>Buteo lineatus</i>)											6
Broad-winged Hawk (<i>Buteo platypterus</i>)	2				17	1			9		1,059
Red-tailed Hawk (<i>Buteo jamaicensis</i>)	8	3	7	9	14	2			13		220
Rough-legged Hawk (<i>Buteo lagopus</i>)								3			1
Buteo spp.	2		3	2	2	1					90
Golden Eagle (<i>Aquila chrysaetos</i>)	1								1		7
American Kestrel (<i>Falco sparverius</i>)				1							24
Peregrine Falcon (<i>Falco peregrinus</i>)											2
Falcon spp.											2
Raptor spp.				1	2				1		75
Wild Turkey (<i>Meleagris gallopavo</i>)											3
Sandhill Crane (<i>Grus canadensis</i>)					1						11
Killdeer (<i>Charadrius vociferus</i>)	1		3	2	1			1	4	4	17
Shorebird spp.	3										3
Herring Gull (<i>Larus argentatus</i>)											1
Gull spp.			2								4

Appendix 1. (Continued).

Species	6-May	7-May	8-May	9-May	10-May	11-May	12-May	13-May	14-May	15-May	Grand Total
Mourning Dove (<i>Zenaida macroura</i>)	1	1				1				2	10
Common Nighthawk (<i>Chordeiles minor</i>)									1		1
Belted Kingfisher (<i>Ceryle alcyon</i>)											1
Northern Flicker (<i>Colaptes auratus</i>)											9
Woodpecker spp.											1
Eastern Kingbird (<i>Tyrannus tyrannus</i>)		4							1	1	6
Blue Jay (<i>Cyanocitta cristata</i>)	1	2		1							6
Tree Swallow (<i>Tachycineta bicolor</i>)		1	2				1				4
Barn Swallow (<i>Hirundo rustica</i>)	7	4	11	21	17	10			15		138
Swallow spp.	1			5	3	3					30
Eastern Bluebird (<i>Sialia sialis</i>)											4
American Robin (<i>Turdus migratorius</i>)		2									12
Yellow-rumped Warbler (<i>Dendroica coronata</i>)	1										1
Scarlet Tanager (<i>Piranga olivacea</i>)	1										1
Savannah Sparrow (<i>Passerculus sandwichensis</i>)				1						1	2
Song Sparrow (<i>Melospiza melodia</i>)	1			1							11
Sparrow spp.	3							1			7
Bobolink (<i>Dolichonyx oryzivorus</i>)	3	11	7	5	10	11		2	14	10	73
Red-winged Blackbird (<i>Agelaius phoeniceus</i>)	30	19	97	18	16	21	3	7	20	12	355
Eastern Meadowlark (<i>Sturnella magna</i>)	1	2	1	1	1				1		26
Common Grackle (<i>Quiscalus quiscula</i>)											5
Baltimore Oriole (<i>Icterus galbula</i>)			1								1
Blackbird spp.											2
American Goldfinch (<i>Carduelis tristis</i>)	6	16	3	5	11	2			11	2	75
Passerine spp.	31	5	2	16	47	12		3	2	1	213
Total	203	93	200	144	196	98	3	19	138	36	3,765

Appendix 2. Calculation of number of raptors flying over the Chautauqua Wind Resource Area during the entire 30-day study period, spring 2003.

Variable/parameter	Small-turbine array ¹	Large-turbine array ²
TURBINE HEIGHT		
(A) Total turbine height (m)	118.5	121
MOVEMENT RATE		
(B) Mean movement rate all species within 1 km and below 140 m (targets/h)	17.36	17.36
(C) Proportion of visual targets below 140 m agl that were raptors (within 100 m of visual observer)	0.253	0.253
(D) Size of area below 140 m agl that was sampled (m ²)	140,000	140,000
(E) Mean movement rate of birds within 140 m agl (targets/h/m ²) = (B × C)/D	0.000031	0.000031
(F) Number of raptors per target	1.4	1.4
(G) Mean number of raptors/h/m ² within 140 m agl = E × F	0.000044	0.000044
NUMBER IN WRA DURING STUDY PERIOD		
(H) Length of study period (nights)	30	30
(I) Average number of hours of peak raptor movements (h/day)	8	8
(J) Max width of study area perpendicular to mean flight direction for the season	4,132	4,132
(K) Estimated number of raptors passing through WRA below turbine height during study period = A × G × H × I × J	5,161	5,270

¹Assumes that small-turbine array consists of 34 turbines 118.5 m high, with a blade radius of 38.5 m.

²Assumes that large-turbine array consists of 34 turbines 121 m high, with a blade radius of 41 m.

Appendix 3. Calculation of numbers of nocturnal migrants (all species) flying over the Chautauqua Wind Resource Area, New York, during the entire 30-day study period, spring 2003.

Variable/parameter	Small-turbine array ¹	Large-turbine array ²
TURBINE HEIGHT		
(A) Total turbine height (m)	118.5	121
MOVEMENT RATE		
(B) Mean movement rate within 1 km and below 140 m (targets/h)	28.56	28.56
(C) Size of area below 140 m agl that was sampled (m ²)	140,000	140,000
(D) Mean movement rate within 140 m agl (targets/h/m ²) = B/C	0.000204	0.000204
(E) Number of birds per target	1	1
(F) Mean number of birds/h/m ² within 140 m agl = D × E	0.000204	0.000204
NUMBER IN WRA DURING STUDY PERIOD		
(G) Length of migratory period (nights)	30	30
(H) Average number of hours darkness (h)	8	8
(I) Max width of study area perpendicular to mean flight direction for the season	5,191	5,191
(J) Estimated number of birds passing through WRA below turbine height during migratory period = A × F × G × H × I	30,117	30,752

¹Assumes that small-turbine array consists of 34 turbines 118.5 m high, with a blade radius of 38.5 m.

²Assumes that large-turbine array consists of 34 turbines 121 m high, with a blade radius of 41 m.

Appendix 4. Visually estimated flight altitudes (m agl) of flocks of birds observed in the Chautauqua Study Area, New York, during spring 2003, and number of flocks flying ≤ 140 m agl.

Species/species-group	Mean	SE	Minimum	Maximum	Number flocks (n)	No. flocks ≤ 140 m agl
Common Loon	438	53	100	934	16	1
Great Blue Heron	61	19	5	180	8	7
Turkey Vulture	107	3	2	600	451	349
Snow Goose	100	--	100	100	1	1
Canada Goose	55	17	3	200	14	12
Goose spp.	300	0	300	300	2	0
Duck spp.	223	62	100	300	3	1
Waterfowl spp.	100	0	100	100	2	2
Waterbird spp.	37	8	10	140	16	16
Osprey	244	41	30	500	14	4
Bald Eagle	313	51	80	662	14	2
Northern Harrier	131	20	2	300	28	15
Sharp-shinned Hawk	151	20	20	500	40	23
Cooper's Hawk	104	14	15	358	36	25
Accipiter spp.	193	25	40	800	44	23
Red-shouldered Hawk	322	178	50	800	4	2
Broad-winged Hawk	278	11	30	1,000	246	51
Red-tailed Hawk	142	7	1	800	174	102
Rough-legged Hawk	250	--	250	250	1	0
Buteo spp.	193	17	10	700	50	16
Golden Eagle	186	32	100	350	7	2
American Kestrel	60	13	5	250	23	21
Peregrine Falcon	150	70	80	220	2	1
Falcon spp.	130	30	100	160	2	1
Raptor spp.	167	18	50	500	38	18
Sandhill Crane	295	203	64	700	3	2
Killdeer	9	4	1	20	6	6
Shorebird spp.	215	--	215	215	1	1
Herring Gull	120	--	120	120	1	1
Gull spp.	88	13	75	100	2	2
Mourning Dove	26	8	10	80	8	8
Common Nighthawk	80	--	80	80	1	1
Belted Kingfisher	60	--	60	60	1	1
Northern Flicker	32	4	10	50	9	9
Woodpecker spp.	25	--	25	25	1	1
Eastern Kingbird	7	3	1	15	5	5
Blue Jay	24	8	2	45	5	5
Tree Swallow	10	2	3	15	4	4
Barn Swallow	35	5	2	200	44	43
Swallow spp.	59	11	1	200	17	16

Appendix 4. (Continued).

Species/species-group	Flight altitude (m agl)				<i>n</i>
	Mean	SE	Minimum	Maximum	
Eastern Bluebird	7	2	5	10	3
American Robin	48	17	10	150	8
Yellow-rumped Warbler	20	--	20	20	1
Scarlet Tanager	20	--	20	20	1
Savannah Sparrow	2	1	1	2	2
Song Sparrow	4	--	100	100	1
Sparrow spp.	20	4	10	30	5
Bobolink	8	1	1	30	26
Red-winged Blackbird	11	3	2	120	53
Eastern Meadowlark	16	2	2	50	19
Common Grackle	18	8	10	25	2
Baltimore Oriole	15	--	15	15	1
Blackbird spp.	88	13	75	100	2
American Goldfinch	18	3	3	80	25
Passerine spp.	60	9	1	668	82
Total	136	3	1	1,000	1,581

Appendix 5. Numbers of targets observed on 1.5-km vertical radar at each 25-m interval below 200 m and cumulative percent of all targets below or within each altitude category during day and night at the proposed Chautauqua wind facility, New York, spring 2003.

Alt (m agl)	Spring, diurnal		Spring, nocturnal	
	Number	Cumulative % below or within	Number	Cumulative % below or within
0–25	4	0.2	2	0
26–50	60	3.3	22	0.2
51–75	99	8.4	71	0.9
76–100	84	12.7	108	2.0
101–125	88	17.2	175	3.8
126–150	118	23.3	208	5.9
151–175	95	28.2	270	8.7
176–200	68	31.7	281	11.6
201–1500	1329	100	8618	100
TOTAL	1945		9755	