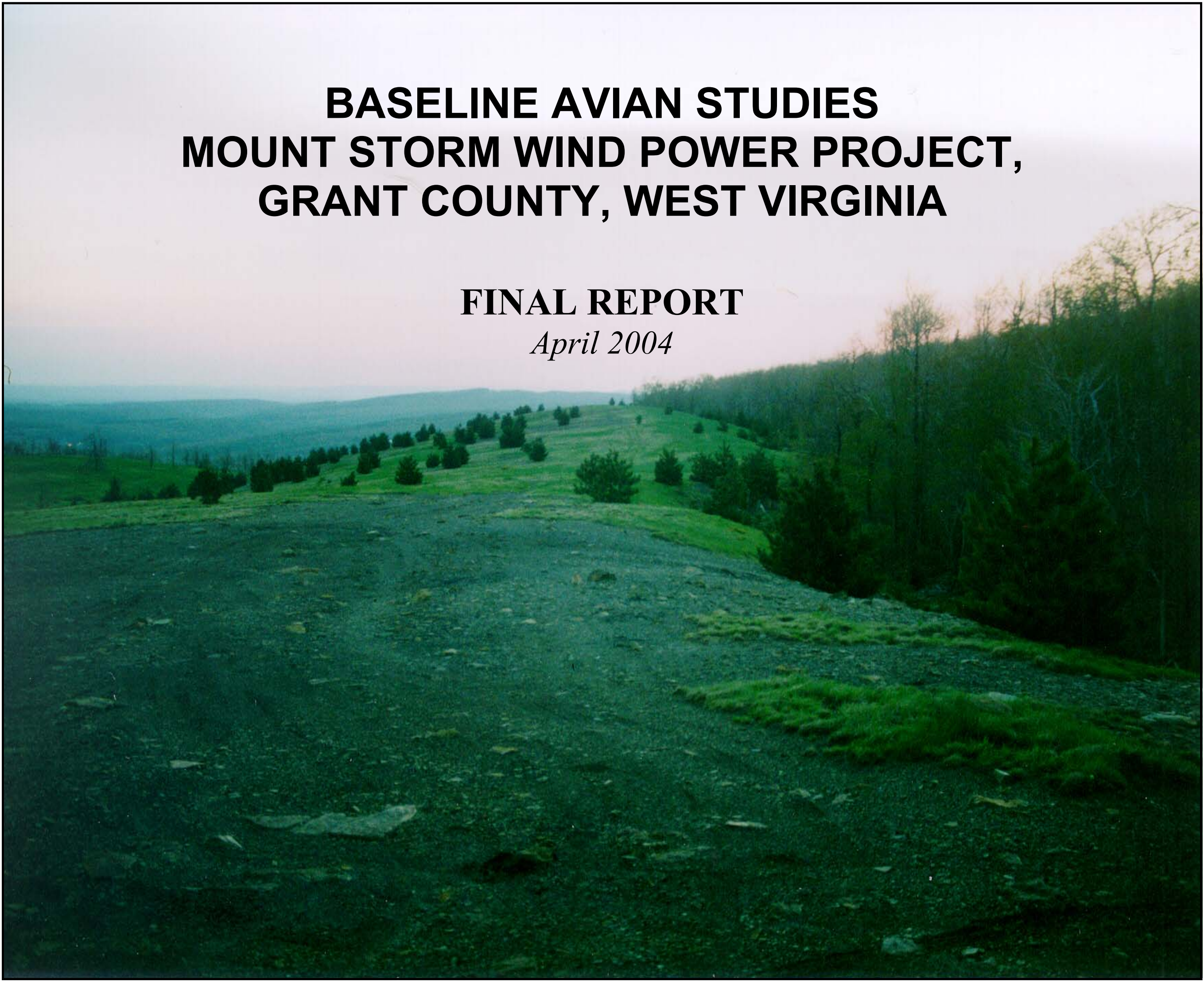

BASELINE AVIAN STUDIES
MOUNT STORM WIND POWER PROJECT, GRANT COUNTY, WEST VIRGINIA

FINAL REPORT

April 2004

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BASELINE AVIAN STUDIES
MOUNT STORM WIND POWER PROJECT, GRANT COUNTY, WEST VIRGINIA

May 2003 - March 2004

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EXECUTIVE SUMMARY

NedPower Mount Storm LLC is developing a wind farm, of up to 300 MW capacity, in Grant County, West Virginia. The *Mount Storm Wind Project*, is located approximately one mile east of Bismarck, West Virginia, along the primary ridgeline of the Allegheny Front and east of Mount Storm Lake. The Public Service Commission permit issued to NedPower for development of the site contains conditions pertaining to the study of the avian resources of the site as well as those migrating over the site. Several permit conditions focused on conducting migration studies on the proposed development area to address concerns such as heavy migration areas, feeding areas, varying climatic conditions, and spatial use patterns by migrants.

Based on the permit conditions, NedPower implemented a survey protocol for a spring and fall diurnal study of migrant birds, a habitat study for golden-winged warblers, surveys for breeding raptors and wintering raptor (including bald eagles), and a fall nocturnal radar study on the proposed Mount Storm site. The avian studies were designed to characterize avian resources using the site during the spring and fall migration seasons. The study protocol was developed with input from the USFWS, expertise and comments of local ornithologists familiar with the study region, and similar studies for wind energy development throughout the U.S.

The principal goals of the studies were to (1) provide baseline information on activity of avian species in the proposed development area useful in evaluating the impact to birds from the wind power development and (2) to provide information that would help in designing a wind plant that is less likely to expose avian species to potential collisions with turbines. The avian baseline studies consisted of diurnal avian use surveys during the spring and fall migration; a nocturnal radar study during the fall migration; surveys of golden-winged warbler habitat during the spring and summer; a survey for breeding raptors and their nests during the late spring; roadside surveys for wintering bald eagles and other raptors; and surveys of common snipe and American woodcock habitat during the spring. Methodology of the surveys and data analysis for each study component is provided in the text of the report and Appendix A.

Diurnal Avian Use Surveys

Diurnal point count surveys were conducted at each of 70 fixed-point count stations approximately twice each week between April 29 and June 13 and from August 14 to October 15, 2003. Over the spring study period, a total of 1,240 10-minute point count surveys were conducted; over the fall period a total of 1,346 10-minute point count surveys were conducted.

A total of 125 avian species were observed during the fixed-point surveys. During the spring, a total of 6,818 observations of 4,757 different groups were recorded and during the fall a total of 10,889 observations of 4,605 different groups were recorded. Passerines were the most numerous group observed comprising 88.5% of all groups observed and 88.6% of the total individual birds observed in the spring and 82.0% of all groups and 82.8% of individual birds observed in the fall. Woodpeckers and raptors were the next most common groups and comprised approximately 4.6% and 2.5% of all groups and 3.3% and 3.2% of all birds observed in the spring and approximately 6.4% and 8.2% of all groups and 3.8% and 8.0% of all birds observed in the fall, respectively. Other groups such as waterfowl, waterbirds, shorebirds, rails, upland gamebirds, doves, cuckoos, swifts, and hummingbirds combined comprised approximately 4.6% of all groups and 5.0% of all individuals observed in the spring and 3.4% of all groups and 5.4% of individual in the fall.

Data was standardize to observations within 50 meters of the survey point. Avian use by species was calculated as the mean number of observations per 10-minute survey. For the spring, based on use, the five most abundant species in the study area were American crow (0.34 detections/10-minute survey), red-winged blackbird (0.33 detections/survey), red-eyed vireo (0.31 detections/survey), eastern towhee (0.29 detections/survey), and ovenbird (0.26 detections/survey). Together these species comprised 28% of all diurnal bird use recorded during the spring. For the fall, based on use, the five most abundant species in the study area were unidentified warbler (0.67 detections/10-minute survey), American crow (0.46 detections/survey), cedar waxwing (0.38 detections/survey), blue jay (0.36 detections/survey), and chipping sparrow (0.33 detections/survey). Together these species comprised 18.4% of all diurnal bird use recorded during the fall.

On average, 4.8 passerines were observed per 10-minute survey in the spring and 5.7 per 10-minute survey in the fall. In contrast, on average, approximately one woodpecker and one raptor were observed every 6-7 surveys in the spring and every 3-4 surveys in the fall. Passerines were divided into several sub-groups that somewhat reflected taxonomic order. In the spring, sparrows were the most abundant passerine subgroup, followed by warblers, corvids, thrushes, vireos, and blackbird/orioles. In the fall, warblers were the most abundant subgroup followed by sparrows, corvids, waxwings, thrushes, and finches.

Spatial Use

During the spring, passerine use was slightly higher in the far northern and central portions of the study area and lowest in the southern portion and area just north of Highway 42. Species richness (number of species per survey) was also highest in the northern portion of the area as well as the central portion nearest the lake. In the fall, passerine use and number of species per survey showed similar patterns, highest in the northern and central portions of the study area.

Temporal Use

For passerines, use remained fairly constant across the spring season with the highest use coming in the beginning of June. For raptors there was a slight increasing trend in use of the site as the spring progressed and for woodpeckers, use fluctuated throughout the season and was highest in late May. Frequency of occurrence (percent of surveys in which a species/group was recorded) for passerines was very high (>90%) throughout the spring but tended to drop slightly as the season progressed. Raptor frequency of occurrence was variable but, as with use, increased as the season progressed. Woodpecker frequency of occurrence was variable across the season.

Passerine use varied across the fall season with several peaks evident around September 3-4, 10, 21, 26-27, October 1, 6, and 14, 2003. The highest passerine use occurred on September 27, 2003. Frequency of occurrence for passerines was high (>80%) throughout the fall and did not show distinct pulses as with use. For raptors, use also varied with the highest peaks around September 10, 27 and October 1, 2003 and frequency of occurrence was similarly variable but higher through October than in August. For other groups the number of observations was too low to see distinct patterns. Daily use estimates during the fall allowed comparison with the fall nocturnal radar data. There was no correlation with the diurnal use estimates and nocturnal radar passages rates for either the same day or the following day.

For most groups the difference in mean use across the day (plotted by two-hour blocks) was variable and there was little difference between morning and afternoon sample periods. For passerines, mean use in the spring was highest in the morning periods and lowest in the late afternoon and evening. In the fall, mean passerine use was highest during midday but also higher in the morning than in the afternoon. Raptor use in the fall showed a distinct peak during midday, approximately 1:00 to 3:00 PM.

Weather Patterns

Avian use was calculated for periods with low cloud cover (between 0 and 25% cloud cover), medium cloud cover (between 25% and 75% cloud cover), and high cloud cover or overcast (between 75 and 100% cover) and for periods with no and some precipitation. Use for passerines and all birds combined, as expected, dropped off during precipitation events, but this difference was not significant. Passerine use also dropped off slightly during periods of high cloud cover, but not significantly so. There were no correlations between avian use and precipitation or maximum temperature recorded on site during the study period.

Vegetation Types

Vegetative cover and type were measured at each survey point and plotted according to forest cover. In general, there was a high diversity of vegetation types in the study area. Most of the more heavily forested areas occurred in the southern portion of the project area. The north and central portions are a mix of vegetation types being influenced by reclaimed coal mine, logged areas, development/residential, and powerline/pipeline/road right-of-ways. Overall, passerine use was higher in areas with the lowest canopy cover (0-20% cover), but varied when considering passerine subgroups.

Nocturnal Radar Study

Nocturnal radar surveys were conducted between approximately 2030 and 0230 each night from September 3 to October 17, 2003. During the study, one radar unit was located at the central station every night and a second radar unit was moved between two of four surrounding alternative sites. For each night sampled, approximately 6 hours of radar sampling occurred at the central station and approximately 2.5-3 hours of radar sampling occurred at each alternative station sampled that night.

Flight Direction

During the study 82% of the radar targets recorded were moving in a southerly direction and 51% of the directions were between 135^o (SE) and 225^o (SW). The overall mean flight direction for targets recorded at the central radar station was 184^o. The Allegheny Front through the project area is oriented from northeast to southwest along approximately 216^o. The mean flight direction at the central station was not significantly different from mean flight directions recorded during concurrent sampling sessions at the northern, southern, or western radar stations, but was significantly different from the mean flight direction recorded at the eastern radar station.

Flight Behavior

Of 1,733 targets at the central station that could be tracked as they approached the primary ridgeline long enough to determine a response to the ridgeline, 5.3% of targets approached and turned greater than 10° before crossing or turned and did not cross the ridge, 49.7% approached and crossed the ridge, and 45% did not approach the ridge. For the central site, mean target flight direction for targets west of the ridge did not differ from targets east of the ridge.

Passage Rates

The lowest mean nightly passage rate recorded at the central site was only 8 targets per kilometer of migratory front per hour (September 13, 2003), and the highest was 852 targets per kilometer per hour (October 5, 2003). On nine different nights, the mean hourly passage rate was greater than 400 targets per kilometer. The mean hourly passage rate for nocturnal targets within the proposed project area (northern, central, southern radar stations), was 199 targets per kilometer of migratory front. Typically the lowest passage rates occurred during the earliest hour of sampling in the evening (2100) while the highest occur an hour later (2200).

Passage rates were not significantly different between the central and the northern sampling stations for concurrent sampling sessions, but were statistically different between the central station and the western, southern, and eastern stations.

Flight Altitudes

Nightly mean flight altitude (recorded by vertical radar, 1.5 km range) ranged from 214 to 769 meters above ground level. The mean target altitude at the central site over all nights sampled was 410 meters above ground level. Mean flight altitude varied within nights and generally peaked approximately an hour after sampling began and then declined through the night. Mean flight altitude at the central station was not significantly different for concurrent sampling sessions from the northern, southern, or western radar stations but was significantly different from the eastern station.

Golden-winged Warbler Survey

Forty-five sites were visited during the roadside surveys for golden-winged warblers in a variety of reclaimed, early successional old field type settings. The area surveyed extended from Abram Creek to Stony River and included 16 reclaimed pole size (trees) areas, 11 old fields, 2 recently logged areas (cutovers), 8 brushy right-of-ways, 3 open bog-like wetlands, and 5 areas along a cleared and reclaimed pipeline corridor.

No breeding golden-winged warblers were found in the project area during the spring or summer of 2003. Four migrant golden-winged warblers were recorded during the roadside (Golden-Winged Warbler Atlas Project methods) surveys; however, no singing territorial males were located. Eleven golden-winged warblers were observed during the point count surveys. These point count stations were re-visited and surveyed with taped song playback methods, however, no responses were elicited. No territorial golden-winged warblers were observed. Vegetation types in the project area were generally considered atypical of golden-winged warbler habitat. Qualitatively, most areas surveyed appeared to be too open and lacked dense shrubs and narrow-contour, goldenrod-dominated edges. This was not empirically tested because no territorial males were observed.

Breeding Raptor Survey

Approximately 8 square miles (20 km^2) was covered during the raptor nest survey. Broadcast call surveys were conducted at 82 stations within the project area during the first week of June 2003. No active raptor nests were found during surveys. One barred owl was observed flying near the surveyor after a great horned owl call was played. The area surrounding the observation was searched, but no nest structures or obvious nest cavities were found. Two empty stick nests were observed during surveys that were likely built by American crows.

Winter Raptor and Bald Eagles Survey

Fifteen roadside surveys for wintering bald eagles and other raptors were conducted on an approximately weekly basis from November 23, 2003 to March 11, 2004. Approximately 21 miles of road around Mount Storm Lake, Stony River Reservoir, and nearby areas were driven during each survey. A total of 30 raptors were observed of 10 species including five bald eagles, eight turkey vultures, two northern harriers, one sharp-shinned hawk, two northern goshawks, two red-shouldered hawks, two red-tailed hawks, two rough-legged hawks, two American kestrels, two barred owls, and two unidentified hawks. One of the bald eagles was observed on the eastern shore of Mount Storm Lake approximately 1.0 mile from the nearest proposed turbine location. A group of four bald eagles were observed perched along the eastern shore of Stony River Reservoir approximately 1.5 miles from the nearest proposed turbine location at the southern end of the project.

Common Snipe and American Woodcock Survey

Suitable habitat for American woodcock and common snipe was visited periodically throughout the spring and both woodcock and snipe were found but not in high numbers. During the fixed-point surveys, thirteen American woodcock and four common snipe observations were made in the study area in a few locations with suitable habitat adjacent to survey points. In addition, 27 other locations (7 outside the study area), which were considered suitable for either species, were also visited. Seven woodcock and three snipe were found in these locations.

The overall goal of the avian baseline studies was to provide information and data on avian use of the site that could be used in (1) evaluating impacts to birds and (2) that could assist in designing a wind plant that would minimizes the risk to birds. In this study, both diurnal surveys and nocturnal radar surveys were combined to provide an overall risk assessment and describe potential impacts from the Mount Storm wind project. Studies at other wind plants throughout the U.S. have shown that fatalities of both resident birds (breeding and winter residents) and nocturnal migrants occur. In several studies approximately 50% or greater of casualties found were resident birds.

By comparing the overall diurnal bird use results from the study with other nearby studies (e.g. Mountaineer Wind Energy Center, Canaan Valley National Wildlife Refuge) and by assessing on-site bird use, diversity, and vegetation, the project area does not appear to contain any unique features or habitat types which concentrate spring or fall migrants and which receive far greater bird use than other sites. Due to the variety of vegetation types the project area contains substantial "edge" habitat resulting in increased avian diversity over vegetatively monotypic areas. Analysis of spatial and temporal avian use of the site did not indicate that any location, day, time of day, or season received substantially greater bird use and therefore may result in greater exposure or risk to birds.

Analysis of the nocturnal radar from within the proposed development area and adjacent areas indicates that nocturnal migrants do not concentrate their migratory flight paths along the Allegheny Front. Nocturnal target flight direction was variable and did not correlate between radar sampling sites or with the prevailing direction of the Allegheny Front. Greater than 50% of targets investigated for changes in flight direction passed over the ridgeline and continued south. Flight altitude data suggested that targets did not change their altitude in response to the ground below. Target altitude was significantly different between the central station on the Allegheny Front and the valley station to the east but was not different between stations along the primary ridgeline or the station west of the Allegheny Front. Passage rates were variable over time, date, and location supporting the general knowledge about fall migration occurring in pulses over time and space. Passage rates varied between the sampling stations along the Allegheny Front and were significantly different between the central station and the southern station. Passage rates were also significantly different between the central station and the stations to the west and east. Overall the risk to avian species from the wind plant on spring or fall migrants is not expected to be substantially different than results from other wind plants in the east.

Based on surveys for species of interest that could occur within the project area – golden-winged warbler, wintering bald eagle, American woodcock, and common snipe – the project is not expected to pose any extraordinary risk. No breeding golden-winged warblers were documented in the study area. Winter bald eagle use appears to be relatively low, variable over the winter season, and concentrated around Mount Storm Lake and Stony River Reservoir. American woodcock were documented in the project area and there may be some displacement affects if turbines are constructed in habitat suitable for American woodcocks. Common snipe was also observed in the project area, however, observations were within wetland areas which will be avoided by the project. Potential impacts to these species of interest from the project are expected to be low.

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ACKNOWLEDGMENTS

We thank NedPower Mount Storm, LLC for support and funding for this study. Jerome Niessen provided support, guidance, and valuable review of the protocol and reports. A number of field technicians provided countless hours and patience conducting the field surveys: Dollie Stover, Amy Bair, Karen Daniel, Josh Daniel, Randy Daniel, Bev Hamilton, Scott Perry, Tommy Stover, Diane Holsinger, Keith Peters, & Victor Fazio III. Concord College provided administrative support for the field crews.

1.0 INTRODUCTION

NedPower Mount Storm LLC is developing a wind farm, of up to 300 MW capacity, in Grant County, West Virginia. The *Mount Storm Wind Project* (Project), is located approximately one mile east of Bismarck, West Virginia, along the primary ridgeline of the Allegheny Front and east of Mount Storm Lake (Figure 1).

During the permitting process for the development, concern was raised over potential impacts to migratory birds. It is commonly believed that the Appalachian Mountain Range is a significant topographic feature that aids in the autumnal migration of a variety of diurnal and nocturnal migrant birds (Goodrich 1997). In addition, the Allegheny Front of the Appalachian Mountain chain is believed by some to be a significant feature, or migratory corridor, followed by significant numbers of neotropical fall migrants moving south through the eastern U.S. However, most studies of North American bird migration using methods such as radar surveillance have suggested that nocturnal migrants follow a broadfront migration pattern, flying at high altitudes where they are not affected by variation in surface topography (e.g., Lowery and Newman 1966, Able 1972, Richardson 1972, Williams *et al.* 1977 *in* Williams *et al.* 2001). Radar studies have shown that nocturnal migrants fly at a variety of altitudes and that often millions of birds may pass over a site during a migration season (Kerlinger *et al.* 1984, Gauthreaux 1991, Cooper and Mabee 2000, Johnson *et al.* 2002).

It is well known that, many of the mountain ridgelines, and in particular those along the eastern edge of the Appalachian Mountains act as migratory pathways for diurnal fall migrant raptors (Goodrich 1997). Some recent evidence suggests that nocturnal fall migrants flying at lower altitudes may be influenced by topographic features and may not follow the typical broadfront pattern (Williams *et al.* 2001). Although their study methods did not allow for observations of birds flying above 300 m, Williams *et al.* (2001) suggested that low altitude (<300 m) nocturnal fall migrants may follow routes parallel to the prevailing ridge lines in the Appalachian Mountain Range and may cross over the ridges through gaps or passes. Further, data from this study suggested that numbers of daytime migrants counted in the study area were correlated with the number of nocturnal migrants estimated from radar surveys the previous night.

Both nocturnal and diurnal surveys of avian migrants provide valuable information that may be used in evaluating risk to avian species from proposed wind power developments. Properly designed nocturnal radar studies may provide information on migration activity and characteristics and allow an estimate of the relative number of migrants moving over a potential wind plant site, when compared to other sites. Diurnal studies allow species identification, more accurate estimates of avian use of an area, and counts of birds utilizing the study area when they presumably occur more frequently within the zone of risk of wind turbines. Diurnal studies also allow identification of diurnal avian use concentration areas and where development may impact important habitat.

In addition to migrating birds, the proposed site and nearby areas (e.g. Mount Storm Lake and Stony River Reservoir) also contain potentially suitable habitat for several species of interest, including golden-winged warbler (*Vermivora chrysoptera*), American woodcock (*Scolopax minor*), common snipe (*Gallinago gallinago*), and wintering bald eagles (*Haliaeetus* *leucocephalus*). Golden-winged warbler is a neotropical migrant songbird that breeds in shrubland habitats within the Appalachian Mountain chain north into southern Canada and west though Michigan, Wisconsin and eastern Minnesota. This species has been extirpated from much of its former range throughout the northeastern U.S. The golden-winged warbler is of interest at this wind project site due to observations made during a Phase I risk assessment of the site (Canterbury 2002). American woodcock inhabit similar habitats to golden-winged warblers and common snipe are typically found in open wetlands and wet meadows. Wintering bald eagle will often concentrate around large bodies of water where abundant foraging opportunities exist (e.g., fish, waterfowl, carrion). The potential presence of woodcock, snipe and wintering bald eagles were raised as concerns by the U.S. Fih and Wildlife Service (USFWS) personnel reviewing the project.

The Public Service Commission (PSC) permit issued to NedPower for development of the site contains conditions pertaining to the study of the avian resources of the site as well as those migrating over the site. Several permit conditions focused on conducting migration studies on the proposed development area to address concerns such as heavy migration areas, feeding areas, varying climatic conditions, and spatial use patterns by migrants. Specifically, the conditions of the permit related to baseline data collection included:

(1) Prior to construction, NedPower shall conduct a Golden-winged Warbler habitat study to aid micro siting.

(2) Prior to construction, NedPower shall conduct a migration study to determine heavy migration areas; areas where birds descend to feed, etc. for use in final micro siting of turbines.

(3) Prior to or after commencing construction, NedPower shall conduct both a Spring 2003, and a Fall 2003 migration study during all local climatic conditions and all daily temporal periods.

(4) Prior to or after commencing construction, NedPower shall conduct studies to determine the spatial patterns of nocturnal migrating birds and to determine raptor behavior during the next breeding season after this Order issues, and for Winter 2003-2004 residents.

Based on these conditions, NedPower requested that Western EcoSystems Technology, Inc. (WEST) develop and implement a survey protocol for a spring and fall diurnal study of migrant birds, a habitat study for golden-winged warblers, surveys for breeding and wintering raptors, and a fall nocturnal radar study on the proposed Mount Storm site. In general, avian studies were designed to characterize avian resources using the site during the spring and fall migration seasons and meet conditions of the permit. The study protocol was developed with input from the USFWS, expertise and comments of local ornithologists familiar with the study region, and experience of WEST implementing and conducting similar studies for wind energy development throughout the U.S. Input was also solicited from the West Virginia Department of Natural Resources (WVDNR), however they did not provide comments on the draft protocol.

This final report contains results from all avian studies conducted on the site. It combines results from the spring migration studies report (Young *et al.* 2003) with additional a golden-winged warbler study, fall migration studies (diurnal and nocturnal), and winter raptor, including bald eagle, surveys.

1.1 Objectives of the Avian Baseline Study

The principal goals of the studies were to (1) provide baseline information on activity of avian species in the proposed development area useful in evaluating the impact to birds from the wind power development and (2) to provide information that would help in designing a wind plant that is less likely to expose avian species to potential collisions with turbines. Specific objectives of the studies were to:

- identify avian species using the study area during the spring and fall migration periods;
- quantitatively and qualitatively describe the relative abundance and temporal and spatial use by avian species of the study area during the diurnal period;
- identify areas of high avian use within the study area which may pose a higher risk to avian species from development;
- collect baseline data on nocturnal migration characteristics (e.g., flight direction, passage rates, flight altitudes) of birds over the study area;
- determine if nocturnal migrants concentrate along the Allegheny Front within the study area;
- describe the variation of nocturnal migration characteristics at three representative locations within the Project;
- determine what raptor species nest and the spatial distribution of raptor nests in the study area;
- determine the habitat suitability and use by golden-winged warblers;
- determine locations and relative abundance of American woodcock and common snipe in the study area; and
- determine species and locations of winter raptors, including bald eagles, in the study area.

The goals and objectives of this study are addressed by a combination of data collected at the proposed project site and from baseline and post-construction monitoring data collected at other wind project sites. The study plan was designed to address questions about bird use of the site that could be used in impact assessment and to aid in wind plant design, to the extent possible. Impact assessments can be made based on avian use, relative exposure, vegetation, and other factors at the site and by comparing with avian use, exposure, and mortality at existing wind plants. Information from the avian use evaluation can be used to augment decisions about turbine siting and wind plant design to reduce the relative risk to avian species from the development. The baseline study report also provides information that can assist in design of post construction (operational) monitoring studies.

2.0 STUDY AREA

The Project is located in Grant County, in northeast West Virginia. Grant County lies within the Allegheny Mountains physiographic region and is along the western edge of the Ridge and

Valley physiographic province (Buckelew and Hall 1994). The Allegheny Mountains are characterized by steep to rolling mountains, ridges, hills and high plateaus. The development as proposed is located on the primary ridgeline of the Allegheny Mountains known as the Allegheny Front approximately 0.5-1 mile east of Mount Storm Lake and Stony River Reservoir and approximately four miles east of Mount Storm and three miles west of Scherr. West Virginia Highway 42/93 between Bismarck and Scherr bisects the site at approximately the mid point along with several transmission line right-of-ways. Elevation of the site ranges from approximately 2,625 to 3,800 feet (800-1150 m). The site is private land used for coal mining, commercial logging, and recreation (hunting).

The historical vegetation type throughout the Allegheny Mountains was hardwood and spruce forest (Buckelew and Hall 1994). The hardwood forest type on the site consists primarily of oaks, maples, hickory species, black cherry, black and yellow birch, and beech trees (Canterbury 2002). The spruce and conifer type consists of red spruce, hemlock, and a variety of pines, including red, pitch, and Virginia, used for reclamation of abandoned surface mines (Canterbury 2002). Much of the site has been previously strip mined for coal and consists of reclaimed areas and there are a few areas of active strip mining which border the site. The deciduous forest vegetation type on site has been logged, both recently and historically and shows sign of severe ice and wind damage from recent winters. Several private cabins are scattered around the site, much of the area around Mount Storm Lake and Hwy 42/93 is developed with private residences and scattered businesses, and a large (1600 MW) coal fired power plant is located on the northwest shore of the lake approximately 2 miles west of the Project.

The primary study area includes the proposed wind power development area (i.e., locations of turbines) as authorized by the project's West Virginia Public Service Commission permit and a small buffer around this area. In general, the survey points (stations) established for the study occur within the primary study area, although, some survey routes or stations for various study components were established outside the primary study area (see Section 3.0 Methods below).

3.0 METHODS

The avian baseline studies consisted of diurnal avian use surveys during the spring and fall migration; a nocturnal radar study during the fall migration; surveys of golden-winged warbler habitat during the spring and summer; a survey for breeding raptors and their nests during the late spring; roadside surveys for winter raptors including bald eagles; and surveys of common snipe and American woodcock habitat during the spring.

3.1 Fixed-Point Surveys

The objective of the fixed-point surveys (diurnal surveys) was to estimate the spatial and temporal use of the site by birds and in particular migrants utilizing the study area during the day time periods. Point counts (variable circular plots) were conducted on the development area using methods described by Reynolds *et al.* (1980) and Bibby *et al.* (1992). The points were systematically selected to survey a spatially representative sample of topography and vegetation types in the study area (Figure 2). Vegetation at each point count was quantified using a modified James and Shugart (1970) method described below.

3.1.1 Survey Plots

Seventy survey points were established over the study area along transects running parallel to the ridgeline (Figure 2), to provide good coverage of the vegetation types and topographic features of the area and so that each point was surveying a unique area. Approximate transects locations were established based on the proposed project layout (e.g., proposed turbine strings). Each transect was divided into segments of approximately equal length and the first survey station was located at a randomly selected starting point within the first segment. The subsequent stations along each transect were systematically placed one segment length from the previous point. Final survey point locations were established in the field during project set-up and recorded by GPS (UTM) coordinates and temporarily (life of study) marked in the field.

Each survey plot was a variable circular plot centered on an observation point. All birds observed were recorded regardless of the distance from the point; however, due to variability in visibility and detectability of birds in mixed vegetation types, the survey effort for passerines was concentrated within an approximate 100 m radius circle of the point.

Survey periods at each point were 10 minutes long. The date; start and end time of the observation period; and weather information such as temperature, wind speed, wind direction, precipitation, and cloud cover were recorded for each survey. Species or best possible identification, number of individuals, sex and age class (if possible), distance from plot center when first observed, approximate height above ground, and activity (behavior) were recorded for each bird or group (flock) of birds observed.

Raptors, other large birds, any bird species of concern, large flocks, and bird species not previously recorded on site which were observed between point counts were coded as in-transit observations and recorded on an incidental observation data sheet.

3.1.2 Observation Schedule

Sampling intensity was designed to document avian use and behavior within the project area during the peak migration periods. The spring avian migration period is typically from March to June and fall migration period is typically from August through October, although, the specific migration period varies by species. For example, some groups such as blackbirds and some thrushes are early spring migrants and may move through an area in March. Shorebirds are typically early fall migrants and may begin migration as early as July. It is generally believed that the peak of the spring warbler migration is during the month of May and most have moved through the project area by mid-June and that the peak fall warbler migration is September with most having moved through the project area by mid-October. Ideally the spring sample period would be the months of April and May and the fall sample period from mid-August to mid-October. Due to the timing of permit issuance (i.e., permit conditions were not known until the Spring migration was underway), project set-up began in late April and surveys were initiated by the first of May 2003.

Surveys were conducted on an approximately daily basis from the first of May through the first two weeks of June and from mid-August to mid-October, 2003. Multiple observers were used simultaneously in the field so that all of the points could be visited at least twice a week during the survey periods. Surveys took place throughout the daytime period and during all climatic conditions occurring during the study to meet permit condition requirements. The morning period was considered the time from 30 minutes before sunrise to approximately 3 hours after sunrise and the evening period was from approximately 3 hours before sunset until 30 minutes after sunset. The survey points were divided into eight blocks of eight or nine survey points each. For each survey day, the starting point within a block was varied so that survey times for any given point varied across the season within the morning and evening periods. Logistical issues such as locked gates and weather forced some deviations from the described pattern; however, an effort was made to survey all points both early and late in the morning and evening throughout the survey periods.

3.1.3 Vegetation Sampling

Habitat features of each fixed-point location were quantified by measuring plant and other habitat variables in late June and July. The James and Shugart (1970) circular sample-plot method was employed by placing a 0.04 hectare circular plot within each point count area and recording tree diameters (diameter at breast height, dbh), number and diameter of dead snags, canopy height, aspect, percent slope, and percent canopy cover (all trees and snags) and ground cover as measured using an ocular tube. Ground cover categories included green herbaceous (grasses, shrubs, ferns), bare ground/rock, moss, woody debris (any material >4 cm diameter), water, or leaf litter. Total canopy height and percent slope were recorded with a clinometer. Plants were identified using standard field guides and Strausbaugh and Core (1977). Elevation was recorded in the field with a GPS unit, and aspect was recorded with a compass.

3.2 Nocturnal Radar Survey

The overall purpose of the nocturnal radar surveys was to estimate the spatial and temporal distribution of nocturnally migrating birds over the site by collecting baseline data on characteristics of radar targets. Specific objectives of the radar study were to: (1) collect baseline information on flight direction, migration passage rates, and flight altitude of nocturnal migrants on the project area during fall migration; (2) determine if nocturnal migrants concentrate along the Allegheny Front within the Project Area; and 3) determine if there is variation in the amount or altitude of migrants at three representative locations within the study area (i.e., along the primary ridge line) and at two locations off site. An independent report of the radar study and data analysis was prepared by ABR, Inc. (Mabee *et al.* 2004; Appendix A). Results from that report are summarized and incorporated in this final report to address the overall study goals and objectives.

Five radar sampling locations were established within or near the project area (Figure 3). The actual location of the radar units (sample points) were selected based on the constraints of radar sampling (e.g., minimization of ground interference). The same sampling protocol (below) was used at all stations sampled each night.

The mobile radar labs used for the study consisted of a marine radar unit mounted on a vehicle. The radar was X-band, transmitting at 9,410 MHz with peak power output of 12 kW. A similar radar lab is described in Cooper *et al.* (1991) and the vertical radar setup is described by Harmata *et al.* (1999).

3.2.1 Data Collection

The study period for radar sampling was approximately 45 days between early September and mid October 2003. Sampling was conducted concurrently with two radars, one stationary at the center of the primary study area (central station) and one alternating among the four additional points (Figure 3). The second non-stationary radar unit was used to provide comparable information from alternate sites located in the valley east of the main ridge (east station), the plateau west of the ridge (west station), and from two additional points in the project area along the primary ridgeline (Figure 3). The second radar was rotated among the alternate sites with two sites being visited each night. For each sampling night, approximately six hours of nocturnal migration observations were conducted from approximately 2030 to 0230 (8:30 PM to 2:30 AM). At the central site, six one-hour sampling blocks were conducted each night. Each alternate site was sampled for approximately 2-3 hours each night depending on travel time between sites and setup/takedown of the radar.

Each of the six, 60-min nocturnal radar sampling periods consisted of:

1. one 10-min session to collect weather data and adjust radar to surveillance (horizontal) mode,
2. one 5-min session with the radar in surveillance mode at 1.5-km-range collecting information on migration passage rates;
3. one 10-min session with the radar in surveillance mode at 1.5-km-range collecting information on ground speed, flight direction, flight behavior, and general location of migrants;
4. one 10-min session to collect weather data and adjust radar to vertical mode;
5. one 10-min session in the vertical mode at 1.5-km-range to collect information on flight altitudes below 1500 m; and,
6. one 5-min session in the vertical mode at 3.0-km-range to collect information on flight altitudes below 3000 m.

3.3 Golden-Winged Warbler Survey

Golden-winged warblers were documented in the study area during a Phase I risk assessment study conducted in 2002 for the project (Canterbury 2002). The golden-winged warbler has experienced declines across its historic range likely due to loss of habitat and competition with the blue-winged warbler and hybrids. The objectives of the golden-winged warbler surveys were to document numbers and breeding localities for this species in the study area. Data on the occurrence of golden-winged warblers was collected concurrently with the spring point count surveys and during the vegetation sampling (June-July 2003). Golden-winged warbler abundance was assessed with the point count surveys (see above) and Golden-Winged Warbler Atlas Project (GOWAP) methods that utilize roadside call-playback to elicit responses from territorial males (Barker *et al*. 1999, Canterbury *et al*. 1996).

3.3.1 Observational Data

During the first few rounds of point count surveys, the overall study area was assessed for sites or habitat that could contain breeding golden-winged warblers. Results from this early assessment and information from the point counts were used to select potential locations for further sampling to locate singing males, which were to be evaluated with song-playback and territory mapping techniques. If a territorial golden-winged warbler male was located, the site was to be re-visited and observed for as long as it remained in the study area, or up to a maximum of 10 days for each male. It was the intent of the study to use spot-mapping techniques to plot territories (Bibby *et al.* 1992), determine vegetation characteristics of territories, and measure linear distance to the nearest potential turbine position.

3.3.2 Roadside/GOWAP protocols

Researchers drove and/or walked all existing roads and sampled for golden-winged warblers using standardized roadside (Barker *et al.* 1999) and GOWAP song-playback methods (Canterbury *et al.* 1996). Stops were made every 0.2 mile within areas considered suitable golden-winged warbler habitat, where observers listened for and recorded all golden-winged warblers observed during a 10-minute period. All golden-winged warbler sampling localities were geographically referenced with GPS units and plotted on a topographic map. At each roadside/GOWAP survey stop, song-playback of taped golden-winged warblers were employed according to the following system:

1. 3-minute period listening for singing territorial males;
2. 1-minute period playing taped golden-winged warbler songs;
3. 3-minute period listening for a response from a territorial male;
4. 2-minute period playing taped golden-winged warbler songs, and
5. 1-minute period listening and recording any responses.

All golden-winged warbler responses and observations (both male and female) were to be recorded.

3.3.3 Vegetation Sampling

Habitat features of golden-winged warbler territories were to be quantified by measuring plant and landscape variables at sampling points in late June and early July after golden-winged warbler young had fledged. Vegetation and standard topographic variables (e.g., aspect, elevation, slope, etc.) were to be sampled at each golden-winged warbler location similar to the methods used for the standard point count locations (see above and Canterbury *et al.* 2002).

3.4 Breeding Raptor Survey

In addition to the point count surveys that document raptor use in the study area, a survey for nesting raptors was conducted. Raptors nesting in woodland are more difficult to detect due to relatively low visibility of nests and birds compared to raptors nesting in open habitats. A number of researchers have used conspecific and interspecific pre-recorded calls to survey for nesting woodland raptors (Rosenfield *et al.* 1988, Mosher *et al.* 1990, Kennedy and Stahlecker 1993, Mosher and Fuller 1996, McLeod and Andersen 1998). Mosher and Fuller (1996) found that six species of hawks in Maryland, Ohio and Minnesota responded to great horned owl vocalizations and their vocalizations were effective for predicting abundances of nesting red-shouldered hawks, broad-winged hawks and Cooper's hawks.

The raptor survey area included the study area for the fixed-point surveys and the area within an approximately 1/4 mile buffer. Standard broadcast call methods described by Kennedy and Stahleckler (1993) and Joy *et al.* (1994) were used to solicit responses from resident raptors. Surveys were conducted from June 3-5, 2003, which coincides with the nestling stage for most of the woodland nesting raptors expected in the project area.

The entire length of all turbine strings in suitable habitat (i.e., forest) was surveyed for raptors by broadcasting great horned owl calls. Surveyors walked or drove the site and at stationary positions within suitable habitat broadcast taped great horned owl calls. Calls were played with a portable compact disc player (Lennox) and broadcast through a megaphone (Radio Shack Musical Powerhorn) attached as a speaker to the player. Volume output of the Powerhorn is approximately 94 db at 1 m. Great horned owl vocalizations were from the Peterson Field Guides: Bird Songs compact disc. Mosher *et al.* (1990) found that broadcast calls of this volume carried approximately 1 km within western Maryland forests. It was therefore assumed that broadcast calls could be heard out to at least 200-300 m. Broadcast stations were established approximately every 400-600 m along each transect within suitable habitat. At each station, the observer broadcast calls and listened/watched for responses for at least five minutes. During each broadcasting episode the observer rotated 360^{o} so that calls were directed in at least 3 directions spaced at approximately 120^{o} intervals. Stations that fell within open fields, reclaimed areas, secondary growth, or otherwise open area (e.g., logged areas, no trees) were not surveyed. In addition to great horned owl calls, red-shouldered hawk, broad winged hawk or Cooper’s hawk vocalizations were played opportunistically when the survey location was located in appropriate habitat.

3.5 Winter Bald Eagle and Raptor Survey

Wintering bald eagles will often congregate near areas of open water with readily available food sources (e.g., waterfowl, fish, carrion), and there is some evidence that bald eagles in the past have spent the winter in the vicinity of Mount Storm Lake. The primary objective of the winter raptor surveys was to estimate spatial and seasonal use and behavior by bald eagles and other raptors using the Mount Storm Lake and nearby development area during the winter months.

Beginning in late November 2003 and continuing until mid-March 2004, accessible public and private roads around Mount Storm Lake, Stony River Reservoir and near the study area were driven once per week at the slowest safe speed while visually scanning the area for raptors. Roads that provided the best coverage of the area were used to the extent possible and stopping (sampling points) points were chosen to maximize visual coverage of the entire area, especially the lakes. During each survey, observers periodically stopped in locations that provided good visibility of the lakes, their shorelines, and the uplands within the project area to scan for perched or flying eagles or other raptors. Each raptor observation was recorded to species, the behavior of the raptor was recorded, and its location was either mapped or recorded with a GPS unit, if possible.

3.6 American Woodcock and Common Snipe Surveys

Concern was raised by USFWS personnel over potential impacts to American woodcock and common snipe from the project. Therefore, habitat suitable for these species was periodically visited during the spring study period to survey for territorial or displaying males. The objective of the surveys was to determine the spatial distribution and relative abundance of these species. During the initial set-up period and first few rounds of fixed-point surveys, field personnel noted habitat that could potentially be suitable for snipe and woodcock. Based on the distribution of suitable habitat for these species, a total of 20 locations within and seven nearby locations outside the study area were visited. Each visit to an area considered suitable, occurred in the late evening hours when breeding males of these species typically perform courtship displays and are easily detected. At each of the 27 locations, observers listened for any calling snipe and/or woodcock for three minutes, played a tape of calls for two minutes, and then listened and observed for snipe and/or woodcock for five additional minutes. This resulted in a 10-min. survey at each locality. Coordinates for each locality visited were recorded with a hand-held GPS unit.

3.7 Data Compilation and Storage

An electronic database (Access) was created to store, retrieve and organize field observations. Data from field forms were keyed into electronic data files using a pre-defined format that made subsequent data analysis straightforward. All field data forms, field notebooks, and electronic data files were retained for future reference.

3.4.1 Quality Assurance/Quality Control (QA/QC)

QA/QC measures were implemented at all stages of the study, including in the field, during data entry and analysis, and report writing. At the end of each survey, field observers were responsible for inspecting their data forms for completeness, accuracy, and legibility. The study team leader reviewed data forms periodically to insure completeness and legibility; any problems detected were corrected. Any changes made to the data forms were initialed and dated by the person making the change.

Data were entered into electronic files by qualified technicians. A sample of records from the files was compared to the raw data forms to search for data entry errors. Irregular codes detected, or data suspected as questionable, were discussed with the observer and study team leader. All changes made to the raw data were documented for future reference. Any errors or suspect data identified in later stages of analysis were traced back to the raw data forms, and appropriate changes in all steps made.

3.8 Statistical Analysis and Products

Statistics/data generated for the project included the following:

- Species lists and observations by season;
- Relative use by species, species group, observation point, time of day, and habitat;
- Mean frequency of occurrence and species composition;
- Mapped relative abundance (use) by species and groups, where applicable;

- Avian flight height characteristics (mean, percent in rotor swept area);
- Percent vegetation (forest) coverage by survey point;
- Nocturnal migration characteristics (flight speed, flight direction, passage rates, flight altitude);
- Nocturnal migration site comparisons (mean passage rate, mean flight altitude; flight directions);
- Golden-winged warbler location and habitat map;
- Raptor nest map;
- Winter raptor observation map; and
- Common snipe and American woodcock location map.

The number of species seen during each point count survey was standardized to a unit area and unit time searched. The field data were examined to determine the effective radius of the survey plots and avian use by species was then calculated as the mean number of observations per 10-minute survey within 50 m of the survey point (0.78 ha plot size). Standardizing the data to a unit area and unit time allows comparison of avian use data between sample locations, time of day, and season, as well as with other study areas surveyed with the same methods.

The frequency of occurrence by species was calculated as the percent of surveys in which a particular species was observed. Species composition was represented by the mean use for a species divided by the total use for all species and multiplied by 100. Frequency of occurrence and percent composition provide relative estimates of the avian diversity of the study area. For example, a particular species may have high use estimates for the site based on just a few observations of large flocks, however, the frequency of occurrence will indicate that it occurs during very few of the surveys and therefore, may have less exposure risk from the project.

Data were plotted to illustrate differences in bird use between habitat (point count stations) and maps of bird use by observation point were developed by season. Habitats or other topographic features that appeared related to use by birds were identified to the extent possible and used to provide information on the relative risk of areas within the wind site.

Nocturnal radar data was analyzed according to methods presented in Appendix A. Radar targets recorded were screened to eliminate targets that were considered insects by computing target airspeed and eliminating those with airspeeds less than 6 meters per second. Migration passage rates were reported as the mean number of targets passing though 1 km of migratory front per hour (targets/km/hr). Flight altitude data were presented as meters above ground level (agl) relative to a horizontal plane passing through the radar unit. Target behavior was assessed through changes in target direction in relation to the primary ridge line (Allegheny Front) of the site. Targets that reacted to the ridge were those that exhibited a change in direction greater than or equal to 10 degrees.

To investigate spatial differences in migration characteristics within the site and between the site and adjacent areas, comparisons of radar data were made between the central “fixed” radar station and the four alternative stations. Project area wide characteristics were calculated by utilizing data from the three radar stations located along the primary ridge line which were all within the proposed development area. Further details of the data analysis and statistical comparison methods for the radar data are provided in Appendix A

4.0 RESULTS

4.1 Fixed-Point Surveys

Surveys were conducted at each fixed-point count station (Figure 2) approximately twice each week between April 29 and June 13 and from August 14 to October 15, 2003. Over the spring study period, a total of 1,240 10-minute point count surveys were conducted; over the fall period a total of 1,346 10-minute point count surveys were conducted.

A total of 125 avian species and an additional two unidentified bird types (best possible identification, e.g., unidentified warbler) were observed during the fixed-point surveys (Table 1). A total of 6,818 observations of 4,757 different groups[1] were recorded during the spring surveys and 10,889 observations of 4,605 different groups were recorded during the fall fixed-point surveys (Table 1). These raw counts of observations are not standardized by the number of hours of observation and provide an overall list of what was observed. These counts likely contain duplicate sightings of individual birds.

Passerines were by far the most numerous group observed comprising 88.5% of all groups observed and 88.6% of the total individual birds observed in the spring and 82.0% of all groups and 82.8% of individual birds observed in the fall. During the spring, American crow (*Corvus brachyrhynchos*), red-winged blackbird (*Agelaius phoeniceus*), eastern towhee (*Pipilo erythrophthalmus*), red-eyed vireo (*Vireo olivaceus*), and ovenbird (*Seiurus aurocapillus*) were the most numerous passerines observed. During the fall, unidentified warbler, American Crow, cedar waxwing (*Bombycilla cedrorum*), blue jay (*Cyanocitta cristata*), and chipping sparrow (*Spizella passerina*) were the most numerous passerines observed. In contrast, woodpeckers and raptors were the next most common groups and only comprised approximately 4.6% and 2.5% of all groups and 3.3% and 3.2% of all birds observed in the spring and approximately 6.4% and 8.2% of all groups and 3.8% and 8.0% of all birds observed in the fall, respectively. Other groups such as waterfowl, waterbirds, shorebirds, rails, upland gamebirds, doves, cuckoos, swifts, and hummingbirds combined comprised approximately 4.6% of all groups and 5.0% of all individuals observed in the spring and 3.4% of all groups and 5.4% of individual in the fall (Table 1).

4.1.1 Avian Use

To standardize the data for comparison between points, time of day, seasons, and other studies in similar habitats; avian use, frequency of occurrence, and species composition were calculated from observations within 50 m of the survey point. Avian use by species was calculated as the mean number of observations per 10-minute survey (Table 2). In the following discussion, references to abundance refer to estimates of use and not absolute density or numbers of individuals.

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[1] Group is defined as an observation of a species of bird regardless of number seen together. For example, a flock of eight American robins observed together is considered a group as well as an individual robin observed by itself.

For the spring, based on use, the five most abundant species in the study area were American crow (0.34 detections/10-minute survey), red-winged blackbird (0.33 detections/survey), red-eyed vireo (0.31 detections/survey), eastern towhee (0.29 detections/survey), and ovenbird (0.26 detections/survey). Together these species comprised more than one-quarter (28%) of all diurnal bird use recorded during the spring (Table 3). For the fall, based on use, the five most abundant species in the study area were unidentified warbler (0.67 detections/10-minute survey), American crow (0.46 detections/survey), cedar waxwing (0.38 detections/survey), blue jay (0.36 detections/survey), and chipping sparrow (0.33 detections/survey). Together these species comprised 18.4% of all diurnal bird use recorded during the fall (Table 3).

The number of observations for most species observed was insufficient to draw strong statistical conclusions about use of the site. Similar species were therefore grouped to increase sample sizes and decrease variability in the analyses. Averaged over the spring surveys, passerines were the most abundant group observed followed by woodpeckers and raptors, based on use estimates (Table 2). In the fall, passerines were again the most abundant group followed by raptors and then woodpeckers. On average, 4.8 passerines were observed per 10-minute survey in the spring and 5.7 per 10-minute survey in the fall (Table 2). In contrast, on average, approximately one woodpecker and one raptor were observed every 6-7 surveys in the spring and every 3-4 surveys in the fall. Passerines were divided into several sub-groups that somewhat reflected taxonomic order, however, some species were lumped based more on ecological niche (see Table 1). For example, grosbeaks and tanagers were lumped in a group and horned lark and pipit were included with the sparrows. In the spring, sparrows were the most abundant passerine subgroup, followed by warblers, corvids, thrushes, vireos, and blackbird/orioles (Table 2). In the fall, warblers were the most abundant subgroup followed by sparrows, corvids, waxwings, thrushes, and finches (Table 2).

4.1.2 Species Composition and Frequency of Occurrence

Species composition is represented by the mean use for a species divided by the total use for all species and multiplied by 100 to provide percent composition (Table 3). Frequency of occurrence was calculated as the percent of surveys in which a particular species was observed (Table 3). For example, only three species, ovenbird (23.0% of surveys), red-eyed vireo (22.6%), and eastern towhee (21.1%) were observed in more than one-fifth (20%) of the spring surveys and only American crow (17.36%), blue jay (16.6%), and eastern towhee (16.4%) were seen in more than 15% of the fall surveys. Eight other species, American crow (18.7%), tufted titmouse (*Baeolophus bicolor*) (15.0%), wood thrush (*Hylocichla mustelina*) (14.7%), song sparrow (*Melospiza melodia*) (13.3%), indigo bunting (*Passerina cyanea*) (12.9%), chipping sparrow (*Spizella passerina*) (12.4%), black-throated green warbler (*Dendroica virens*) (10.6%), and scarlet tanager (*Piranga olivacea*) 10.5%) were observed in more than one-tenth (10%) of the spring surveys, but only unidentified warbler 12.7%, and American goldfinch (9.8%) were observed in approximately 10% or more of the fall surveys. During the spring, the eleven species observed in more than 10% of the surveys made up slightly more than 40% of all spring bird use (41.2%) on the site and in the fall the five species observed in more than 10% of the surveys made up 16.7% of all fall bird use. The majority of species in both seasons were observed in less than 5% of the surveys (Table 3).

As a group, and due in part to the number of species and to the abundance of several common species, passerines comprised more than 89% of the spring avian use and more than 87% of the fall avian use on site (Table 3) and were observed in more than 91% of all spring surveys and 80% of all fall surveys (Table 3). In contrast, raptors as a group comprised approximately 3% of the spring avian use and 5% of the fall avian use of the site and were observed in approximately 7% and 13% of the surveys respectively. Woodpeckers comprised approximately 1% of the spring avian use and 2% of the fall avian use of the site and were observed in 15% and 16% of the surveys (Table 3). The remaining groups combined, comprised less than 5% of the spring avian use and less than 3% of the fall avian use recorded for the site.

4.1.3 Flight Height Characteristics

For all bird observations made during the study, approximately 25% were of birds flying. In many cases, birds were detected auditorily and were assumed to be birds perched or moving through the vegetation and not flying overhead. The proportion of observations of a bird species flying at heights that correspond with the rotor swept area of turbines provides a rough estimate of the risk of collision for that species (Table 4). The proposed turbines will likely range from 1.5 to 2.0 megawatts in size. These turbines typically have towers ranging from 65 to 70 m (approximately 213-230 feet) and associated rotor diameters ranging from 70 to 80 m (approximately 230-262 feet). Therefore, the space occupied by turbine blades typically ranges from 30 to 110 m (approximately 98-360 feet) above ground. Using the estimated distance between the ground and the tip of the blade when pointed down and the maximum height, the "zone of risk" would include the area from approximately 25 m to 115 m agl. This range is a conservative estimate that includes a small buffer of approximately 5 m on the upper and lower limits. Most of the passerines observed flying, with the exception of corvids and waxwings, were regularly observed flying less than 25 meters above the ground (Table 4). The larger birds, such as waterfowl, waterbirds, and raptors, tend to fly higher, and frequently flew greater than 25 meters high, which is within the primary zone of risk for turbine blades for most new generation turbines. As a group, 78% of the observations of flying raptors (38% of all raptor observations) were observed in the zone of risk. Only 23% of all passerines observations were of flying birds. Of these, 32% (7% of all passerine observations) were observed within the zone of risk (Table 6). These estimates only represent the proportion of observations within the area occupied by turbine rotors and in no way equate to the probability of a bird colliding with a turbine blade. Risk of collision with a turbine blade includes a variety of factors such as bird avoidance behaviors, flight speeds, flight direction, wind speed, wind direction, and location of bird in relation to blades within the rotor swept area.

4.1.4 Spatial Use

Bird use and species richness (number of species per survey) estimates by survey point were mapped across the study area for each season (Figures 4 and 5). During the spring, passerine use was slightly higher in the far northern and central portions of the study area and lowest in the southern portion and area just north of Highway 42 (Figure 4) and the number of species per survey was also highest in the northern portion of the area as well as the central portion nearest the lake (Figure 5). In the fall, passerine use and number of species per survey showed similar patterns, highest in the northern and central portions of the study area (Figures 4 and 5).

4.1.5 Temporal Use

In the spring, the survey data was categorized in to blocks of 5 days to look at use across the spring season (Figure 6). Grouping the data in to 5-day blocks equalized the survey effort across time. For most species groups other than passerines, raptors, and woodpeckers, the number of observations was too low to show distinct patterns (Figure 6). For passerines, use remained fairly constant across the spring season with the highest use coming in the beginning of June. For raptors there was a slight increasing trend in use of the site as the spring progressed and for woodpeckers, use fluctuated throughout the season and was highest in late May (Figure 6). Frequency of occurrence for passerines was very high (>90%) throughout the spring but tended to drop slightly as the season progressed. Raptor frequency of occurrence was variable but, as with use, increased as the season progressed. Woodpecker frequency of occurrence was variable across the season.

In the fall, efforts were made to conduct some surveys in the study area every day. Use was plotted by day across the fall season (Figure 6). Passerine use varied across the fall season with several peaks evident around September 3-4, 10, 21, 26-27, October 1, 6, and 14, 2003. The highest passerine use occurred on September 27, 2003. Frequency of occurrence for passerines was high (>80%) throughout the fall and did not show distinct pulses as with use. For raptors use also varied with the highest peaks around September 10, 27 and October 1, 2003 and frequency of occurrence was similarly variable but higher through October than in August. For other groups the number of observations was too low to see distinct patterns. Plotting use by day during the fall allowed comparison with the fall nocturnal radar data (see below). During the radar study nocturnal passage rates were variable but there were nine nights when passage rates exceeded 400 targets per kilometer of migratory front per hour (see Figure 4, Appendix A). There was no correlation with the diurnal use estimates and nocturnal passages rates for either the same day [R= -0.1752 n=36] or the following day [R= -0.1030 n=35].

Mean use was also plotted by two-hour block to look at daily temporal variation (Figure 7). For most groups the difference in mean use across the day was variable and there was little difference between morning and afternoon sample periods (Figure 7). For passerines mean use in the spring was highest in the morning periods and lowest in the late afternoon and evening (Figure 7). In the fall, mean passerine use was highest during midday but also higher in the morning than in the afternoon (Figure 7). Raptor use in the fall showed a distinct peak during midday, approximately 1:00 to 3:00 PM (Figure 7).

4.1.6 Weather Patterns

Basic weather observations were recorded at the time of each point-count survey. Avian use was calculated for periods with low cloud cover (between 0 and 25% cloud cover), medium cloud cover (between 25% and 75% cloud cover), and high cloud cover or overcast (between 75 and 100% cover) (Figure 8) and for periods with no and some precipitation (Figure 9). The use estimates for most species groups were low enough that calculated differences were very slight. Use for passerines and all birds combined, as expected, dropped off during precipitation events, but this difference was not significant. Passerine use also dropped off slightly during periods of high cloud cover, but not significantly so.

A simple weather station was set up on the site to record precipitation and maximum and minimum daily temperature. There were no correlations between avian use and precipitation [R= -0.0141 n=88] or maximum temperature [R= -0.1208 n=88] recorded on site.

4.1.7 Vegetation Types

Vegetative cover and type were measured at each survey point and plotted according to forest cover (Figure 10). In general, the map reflects the high diversity of vegetation types in the study area. Most of the more heavily forested areas occurred in the southern portion of the project area. The north and central portions are a mix of vegetation types being influenced by reclaimed coal mine, logged areas, development/residential, and powerline/pipeline/road right-of-ways.

Passerine use varied depending on forest canopy cover for both seasons (Figure 11). Open survey points were defined as those points with less than 20% of the ground covered by overhead vegetation. Overall passerine use was higher in areas with the lowest canopy cover (0-20% cover), although some of this difference could be due to increased visibility in open areas. This pattern varied when considering passerine subgroups (Figure 11). For example, for the titmouse/chickadee and creeper/nuthatch passerine subgroups, which are closely associated with trees, higher use was observed in areas with high canopy cover.

4.2 Nocturnal Radar Survey

Nocturnal radar surveys were conducted nightly between September 3 and October 17, 2003. During this period five nights were not sampled due to weather constraints. During the study period one radar unit was located at the central station every night and a second radar unit was rotated between four surrounding alternative sites (Figure 3). During each sampling night the second radar unit was moved between two of the surrounding sites. For each radar sampling night, approximately 6 hours of radar sampling occurred at the central station and approximately 2.5-3 hours of radar sampling occurred at each adjacent station. Radar surveys occurred between approximately 2030 and 0230 each night.

The following narrative is a summary of the results of the radar studies relevant to the goals and objectives of the overall baseline studies. A detailed report of the radar study methods, results, and further discussion of the surveys is presented in Appendix A (Mabee *et al.* 2004). Because the central site was sampled on all nights during the study, much of the analysis was based on the data from that site. For some of the overall wind project analyses, data from the northern, central, and southern sites were combined as all three of these sampling stations were located in the proposed wind project development area.

4.2.1 Flight Direction

During the study 82% of the radar targets recorded were moving in a southerly direction and 51% of the directions were between 135° (SE) and 225° (SW) (Appendix A, Figure 3). The overall mean flight direction for targets recorded at the central radar station was 184°. The prevailing ridgeline (Allegheny Front) through the project area is oriented from northeast to southwest along approximately 216° (see Figure 3).

The mean flight direction at the central station was compared with concurrent sampling sessions from the four alternative radar stations. That is, for nights and times when the central station and the northern station, for example, were sampled concurrently, the mean flight directions were statistically compared. The mean flight direction at the central station was not significantly different from mean flight directions recorded at the northern, southern, or western radar stations, but was significantly different from the mean flight direction recorded at the eastern radar station (Appendix A, p. 13, Table 3).

4.2.2 Flight Behavior

Target flight behavior was investigated by tracking target paths as they approached the primary ridgeline of the project area and noting changes in the path direction. Of 1,733 targets at the central station that could be tracked long enough to determine a response to the ridgeline, 5.3% of targets approached and turned greater than 10^o before crossing or turned and did not cross the ridge, 49.7% approached and crossed the ridge, and 45% did not approach the ridge. Of the 1,733 targets, 54.5% crossed the primary ridge and 45.4% did not cross or approach the ridge (Appendix A, Table 1). For the central site, mean target flight direction for targets west of the ridge did not differ from targets east of the ridge (Appendix A, p. 10).

4.2.3 Passage Rates

The mean nightly passage rate was highly variable during the study (Appendix A, Figure 4). The lowest mean nightly passage rate recorded at the central site was only 8 targets per kilometer of migratory front per hour (September 13, 2003), and the highest was 852 targets per kilometer per hour (October 5, 2003). On nine different nights, the mean hourly passage rate was greater than 400 targets per kilometer (Appendix A, Figure 4).

The mean hourly passage rate for nocturnal targets at the central station over all nights sampled was 241 targets per kilometer of migratory front (Appendix A, p. 10). The mean hourly passage rate for nocturnal targets within the proposed project area (northern, central, southern radar stations), was 199 targets per kilometer of migratory front (Appendix A, p. 14).

Passage rates at the central site varied significantly over hours of the night. Typically the lowest passage rates occurred during the earliest hour of sampling in the evening (2100) while the highest occur an hour later (2200) (Appendix A, Figure 5).

Similarly to flight direction, mean hourly passage rates were compared between the central station and the four alternate stations by comparing data collected during concurrent sampling sessions. Passage rates were not significantly different between the central and the northern sampling stations for concurrent sampling sessions, but were statistically different between the central station and the western, southern, and eastern stations (Appendix A, Table 3). In general, passages rates recorded at the four alternate stations were less than the central station.

During the fall of 2003, both diurnal point count surveys and nocturnal radar surveys were conducted on the site from September 3 to October 15. During this period, the diurnal avian use estimates were not correlated with the nocturnal passage rates from the night before [R(squared)=0.0106; R= -0.1030 n=3]. Use for any given day-time point count surveys between September 3 and October 15 did not indicate periods of heavy nocturnal migration activity.

4.2.4 Flight Altitudes

The mean target altitude as recorded by vertical radar in the 1.5 km range at the central site over all nights sampled was 410 meters above ground level (Appendix A., p. 10). Mean flight altitude varied among nights at the central site and ranged from 214 to 769 meters agl. Mean flight altitude also varied within nights and generally peaked approximately an hour after sampling began (similar to passage rates) and then declined through the night (Appendix A, Figure 7).

When categorized by 100 m intervals, the highest percentage of targets (15.6%) as recorded by vertical radar in the 1.5 km range, occurred from 101-200 meters agl and the lowest percentage (0.1%) occurred from 1401-1500 meters agl (Appendix A, Table 2). For nights when vertical radar data was recorded in the 3.0 km range, on average, 8.2% of targets occurred above 1,500 meters agl (Appendix A, p. 13). The highest target recorded during the study at the central site was at 2,880 meters agl.

Mean flight altitudes were also compared between the central station and the four alternate stations during concurrent sampling sessions. Mean flight altitude at the central station was not significantly different from the northern, southern, or western radar stations but was significantly different from the eastern station (Appendix A, p. 13, Table 3).

4.3 Golden-Winged Warbler Survey

No breeding golden-winged warblers were found in the project area during the spring or summer of 2003. Four migrant golden-winged warblers were recorded during the roadside/GOWAP surveys; however, no singing territorial males were located. Forty-five sites were visited during the roadside surveys in a variety of reclaimed, early successional old field type settings. The area surveyed extended from Abram Creek to Stony River mostly on the west side of the project area (Figure 12). The area east of the project is predominantly deciduous woods or grassy fields and drops into a valley up to 500 m below the elevation of the project area. Areas surveyed included 16 reclaimed pole size (trees) areas, 11 old fields, 2 recently logged areas (cutovers), 8 brushy right-of-ways, 3 open bog-like wetlands, and 5 areas along a cleared and reclaimed pipeline corridor. The 45 sampling points also included areas outside the proposed project area (Figure 12), because (1) a few golden-winged warblers (early migrants or potentially late breeders) were discovered in these areas in 2002 (Canterbury 2002), (2) a lack of territorial males within the project area, and (3) for assessing nearby suitable habitat for occupancy and comparing the habitats on the project site with adjacent surrounding areas.

Vegetation types in the project area were generally atypical of golden-winged warbler habitat. Qualitatively, most areas surveyed appeared to be too open and lacked dense shrubs and narrow-contour, goldenrod-dominated edges. This was not empirically tested because no territorial males were observed. Vegetation analyses comparing areas with and without territorial pairs could not be performed because of the lack of territorial pairs.

During the roadside surveys, only four migrant golden-winged warblers were recorded. All four of these were migrant males that were not subsequently found on repeat visits. Two of the migrants were recorded at the southern end in open wetland habitats (Helmick Run) and both birds responded weakly and with only a single, brief look for another bird to taped broadcast calls. The other two birds were observed on reclaimed areas outside the project boundaries (west and south of Mount Storm Lake and the project area) and also responded weakly to taped calls.

In addition to the roadside survey locations, 11 golden-winged warblers were observed during the point count surveys. These point count stations were re-visited and surveyed with taped song playback methods, however, no responses were elicited. No territorial birds were observed. In addition, 14 localities where golden-winged warblers were found during the 2002 Phase I Avian Risk Assessment for the project (Canterbury 2002) were also surveyed. One golden-winged warbler was noted at these localities in 2003; a female was seen on July 15, 2003 on a site outside the project boundaries.

4.4 Raptor Nest Survey

Approximately 8 square miles (20 km^2) was covered during the raptor nest survey [total study area ~12 square miles (31 km^2)]. Broadcast call surveys were conducted at 82 stations within the project area during the first week of June 2003. Weather conditions were monitored so that surveys would be conducted during optimal conditions for eliciting responses from resident raptors. Foggy conditions were present for the first two days of surveys, with clear skies present the third day, but wind speeds were low enough that acoustic conditions were considered good. Surveys were not conducted during periods of rain to increase detection probabilities and to decrease the potential of disturbing nesting birds during inclement weather.

No active raptor nests were found during surveys. One barred owl (*Strix* varia) was observed during surveys. The barred owl was observed flying after a great horned owl call was played. The area surrounding the detection was searched, but no nest structures or obvious nest cavities were found. Two empty stick nests were observed during surveys. It was impossible to determine with certainty what species built the structures, however, based on relative size of the nests they were likely built by American crows.

4.5 Winter Raptor and Bald Eagle and Raptor Survey

Fifteen roadside surveys for winter raptors were conducted on an approximately weekly basis from November 23, 2003 to March 11, 2004. The focal species for the surveys was bald eagle, which has been observed during the winter months in the vicinity of Mount Storm Lake. Approximately 21 miles of road around Mount Storm Lake, Stony River Reservoir, and nearby areas were driven during each survey (Figure 13). A total of 30 raptors were observed of 10 species including five bald eagles, eight turkey vultures (*Cathartes aura*), two northern harriers (*Circus cyaneus*), one sharp-shinned hawk (*Accipiter striatus*), two northern goshawks (*Accipiter gentilis*), two red-shouldered hawks (*Buteo lineatus*), two red-tailed hawks (*Buteo jamaicensis*), two rough-legged hawks (*Buteo lagopus*), two American kestrels (*Falco sparverius*), two barred owls, and two unidentified hawks. One of the bald eagles was observed on the eastern shore of Mount Storm Lake approximately 1.0 mile from the nearest proposed turbine location. A group of four bald eagles were observed perched along the eastern shore of Stony River Reservoir approximately 1.5 mile from the nearest proposed turbine location at the southern end of the Project (Figure 13).

4.6 American Woodcock and Common Snipe Surveys

USFWS personnel requested that habitat targeted surveys be conducted for American woodcock and common snipe. Suitable habitat for these species was visited periodically throughout the spring and both woodcock and snipe were found but not in high numbers. During the fixed-point surveys, thirteen American woodcock and four common snipe observations were made on the study area in a few locations with suitable habitat adjacent to survey points (Table 1). In addition, 27 other locations (7 outside the study area), which were considered suitable for either species, were also visited. Seven woodcock and three snipe were found in these locations (Figure 14).

5.0 DISCUSSION AND SUMMARY

The Public Service Commission permit issued to NedPower for development of the wind farm contains conditions pertaining to the study of resident and migrant birds at the site. The permit conditions focused on conducting studies on the proposed development area to address concerns such as high bird use areas and collecting site-specific data to help in micro-siting turbines (See Section 1.0 Introduction). In light of these conditions, the overall goal of the avian baseline studies was to provide information and data on avian use of the site that could be used in (1) evaluating impacts to birds and (2) that could assist in designing a wind plant that would minimize the risk to birds. The following discussion attempts to put the study results in the perspective of addressing the study goals and permit conditions.

In this study, both diurnal surveys and nocturnal radar surveys were combined to provide an overall risk assessment and describe potential impacts from the Mount Storm wind project. Studies at other wind plants throughout the U.S. have shown that fatalities of both resident birds (breeding and winter residents) and nocturnal migrants occur. In several studies approximately 50% or greater of casualties found were resident birds (see Young *et al.* 2003; Johnson *et al.* 2002, Erickson *et al.* 2003b).

5.1 Avian Use and Species Diversity

Use estimates (number of observations per 10-minute survey) provide a relative measure of the abundance of species or groups of species in the study area. Because individual birds could not be distinguished one from another, counts do not reflect absolute numbers of individuals; rather, they provide an estimate of avian use of the study area. For example, if one American robin was observed during five surveys, it is unknown if this was the same bird seen five times or five different birds seen once. However, these data provide an index of how often robins occur in the study area, and thus the relative magnitude of their exposure to the wind farm, an indirect measure of the species' risk of being affected by the project.

For most species recorded during the spring and fall surveys, use estimates were relatively low, due primarily to few observations of each species. For example, on average in the spring one American crow, one red-winged blackbird, and one red-eyed vireo were observed every three 10-minute surveys and one eastern towhee and one ovenbird were observed every 4 surveys.

These were the five most common species on the site during the spring based on the use estimates. During the fall the five most common species were unidentified warbler and American crow which on average were observed every two 10-minute surveys and cedar waxwing, blue jay, and chipping sparrow which were observed approximately every three surveys. The vast majority of the species in both the spring and fall were observed far less often, however, on average, nearly 5 passerines were observed every 10-minute survey in the spring and nearly 6 passerines were observed every survey in the fall. The low individual species use but higher overall group estimates reflect high species diversity for the area. Only 11 species were observed in more than 10% of all spring surveys (1,240 total surveys) and only five species were observed in more than or approximately 10% of the fall surveys (1,346 total surveys).

The wide variety of vegetation types in the study area likely accounts for the species diversity. The study area is a mosaic of vegetation types including open grass fields, reclaimed coal mine areas in various successional vegetative states, palustrine wetlands, deciduous forest, logged areas, residential/developed patches, and cleared corridors of powerlines, pipelines, rural roads, and state highways. The survey points were established in a fashion that allowed extensive coverage of the study area and observation in all vegetation types present. Avian use and diversity was highest in the northern most portion of the study area (see Figure 4 and 5) in both spring and fall, corresponding to the area with the least forested cover, and the most extensive edge (forest-open area interface) habitat. The observation point with the highest use estimate in the spring was located next to a created wetland in a reclaimed mined area. Due to the openness, visibility in the north portion of the study area was better at some points, also likely increasing the number of birds observed. However the edge effect and multiple vegetation types increased the diversity of species observed and all data was standardized to only observations within 50 m of the point for the analyses, regardless of vegetation type. In general, the survey points within the forested types had less species diversity and lower use estimates (see Figures 4, 5, and 10) and did not appear to be a significant location for spring migrants through the study area. While there was variation in spatial use of the site, no one location stood out as receiving far greater bird use than others.

There are few comparable studies of bird use of areas in the region of the wind project. Some short-term baseline studies were conducted at the Mountaineer Wind Energy Center west of the site (Kerlinger 2003); however, the field methods were substantially different making it difficult to make quantitative comparisons of bird use from the two sites. In general, though, many of the same species were recorded at both sites. The Mountaineer site is predominantly in deciduous woodland vegetation types with fewer open habitats (e.g., logged or mined areas) so there were fewer open-land bird species recorded at that site. The overall species diversity is probably greater at Mount Storm due to the wider range of vegetation types present.

The Canaan Valley National Wildlife Refuge (CVNWR) in Tucker County southwest of Mount Storm has conducted breeding bird point count survey for all birds at up to 64 points spread along 11 transects with similar survey methods for the past 4 years (see USFWS 2000, 2002, 2003). While the total area of the CVNWR is much larger than the Mount Storm site, the diversity of vegetation types covered is similar (i.e., forested and open areas), however vegetation communities at CVNWR are protected from disturbance (i.e., no mining or logging). Overall, fewer species are typically recorded at CVNWR, however, each survey point is usually only surveyed once in June when presumably most migrants have passed through the area. Similarities exist in the species recorded at both sites, for example, with the exception of ovenbird, the five most common species at Mount Storm in the spring (American crow, red-winged blackbird, eastern towhee, and red-eyed vireo) are in the ten most common species at CVNWR (see USFWS 2003). Comparisons of the two studies indicate that the Mount Storm site does not present any unique characteristics from the bird community standpoint and appears to be typical of higher elevation Appalachian Mountain communities.

Two conditions of the development permit were to study bird use over all daily time periods and all weather conditions. To address these conditions, surveys were conducted throughout the daytime period, during periods of inclement weather, and a nocturnal radar study was conducted in the fall. In general, fewer birds were observed during the afternoon/evening surveys but the difference was not statistically significant. Variation in diurnal use across the spring season was low. There was a slight overall drop in diurnal bird use in the late spring but the trend was not significant. During the fall, diurnal use was more variable and there appeared to be several waves of migrants that moved through the area consistent with the pulsed nature of fall avian migration. As would be expected, bird use was lower during surveys with precipitation and heavy cloud cover, though these changes in use were not significant. The season and daily temporal use patterns for the site do not suggest that any one time period or date receives substantially greater bird use and should be avoided during construction or operation of the project.

Overall the diurnal avian spatial use information does not suggest that any one location or site would result in greater impacts to birds over other sites within the development area. Avian use in relation to vegetation cover does suggest some variation in potential impacts. Species use and diversity was greatest in areas with greater edge habitat, which would presumably mean that more birds in these areas would be at greater risk.

5.2 Nocturnal Migration

The two primary purposes of the nocturnal migration radar study were to (1) collect baseline data on fall migrants passing over the site that could be used to describe nocturnal migration characteristics at the site and (2) to address some site specific questions such as whether migrating birds tended to congregate along the Allegheny Front or if there were spatial differences in nocturnal migration characteristics within the site as well as between the site and nearby locations (off ridge sites). The primary metrics that were calculated from the nocturnal radar data were target passage rates, target flight direction, and target flight altitudes.

Overall, nocturnal passage rates for targets recorded during the radar study were variable across dates, time of night, and stations. Similar to the diurnal surveys, this information supports the knowledge of pulsed fall migration events that are probably influenced by a number of factors including species, date, and weather conditions. The overall mean passage rate for the three radar stations on the project area for the study period was 199 targets per kilometer per hour Mean nightly passage rates ranged from 8 to 852 targets per kilometer per hour. This is similar to passage rates recorded for other radar studies conducted in the eastern U.S. from which results have been reported. For three sites studied in New York with similar radar methods (Cooper *et al.* 1995, Cooper and Mabee 2000), average passage rates were from 122 to 225 targets per kilometer per hour and mean nightly passage rates ranged from 0 to 850 targets per kilometer per hour (Mabee, 2004, pers. comm).

Flight directions of targets recorded during the study varied between nights and stations but were generally in a southerly direction (see Appendix A, Figure 3). For example, at the central station, mean flight direction varied from 177° to 207° for the various concurrent sampling periods with the other stations (see Appendix A, Table 3). The mean direction for targets for all nights sampled varied from 184° at the central station to 219° at the western station (Appendix A, Table 3). Overall, target flight direction did not appear to be influenced by the prevailing direction of the primary ridgeline (Allegheny Front) through the project area (~ 216°).

A working hypothesis for this study was that if birds were migrating south and following the direction of the ridgeline, then targets would pass through the project area (and the radar sampling areas) along a path parallel to the ridgeline or that those targets that approached the ridge within the study area would change direction and follow or respond to the ridge in some fashion. In general, no patterns were discernable from the flight path data to support this hypothesis. Of the targets that were tracked long enough to measure a response to the ridge, approximately one-half (49.6%) approached the ridge and simply crossed over without changing direction by more than 10°; approximately 5% of the targets changed direction more than 10° when they approached the ridge before crossing over; approximately 45% of the targets followed tracks which did not approach the ridgeline within the area sampled (i.e., flew parallel to the ridge or were on a path that would not cross the ridge on the radar screen); and only 0.3% of the targets followed tracks that approached but did not cross the ridge (i.e., turned and flew parallel or away from the ridge).

To further investigate the question of whether nocturnal migrants concentrated along the Allegheny Front, the study design utilized a paired-plot approach with concurrent sampling sessions at the central station and two alternate stations on any given night (see Figure 3). If birds followed or concentrated along the ridgeline, no differences between stations in a line along the ridge (i.e. northern, central, southern) would be expected. There were significant difference between the passage rates recorded at the central station and the western, southern, and eastern stations but not between the central and the northern station. The difference between the central ridge station and the eastern valley station was confounded by factors such as an elevation difference of greater than 500 meters because the eastern site was located in the first deep valley east of the Allegheny Front.

It is assumed that the flight altitude of targets passing over a site can be used as an indication of relative risk by estimating the number of targets that might pass through the zone of risk (e.g., the rotor swept area of turbines). Because targets of birds and migrating bats are not distinguishable on the radar monitor, the number of birds flying through the zone of risk is likely an overestimate. The percentage of targets by height category (100 meter intervals) represents a maximum because some targets flew above 1.5 kilometers agl. During each sampling block (1 hour), the radar was adjusted to sample in the 3.0 kilometer range for a five minute period. For nights when sampling was effective to 3.0 km, on average, 8.2% of targets flew above 1.5 kilometers. Also, because target flight altitude was measured relative to the radar unit, the true agl could be higher or lower, depending on the topography below the target. The horizontal distance out from the radar unit sampled was 1.5 kilometers. In most cases the radar station was situated in a high spot to minimize ground clutter (see Figure 3 for contour lines around each station). Targets recorded that were out away from the unit may have been at higher agls than recorded and based on the flight altitude data, targets do not appear to adjust their altitude to the ground level below them (e.g., they did not appear to increase altitude as they approached the ridge or drop down into the valley after crossing the ridge).

In summary, the information from the radar study does not suggest that the Allegheny Front substantially influences migration direction and thus does create a concentration ("leading" edge) of nocturnal migrants by birds following the ridge. Passage rates fell within the range of other sites studied in the eastern U.S., target directions did not suggest that birds followed the ridge line, there were significant differences between radar stations along the ridge line, and flight altitude data did not suggest that targets were following the topographic contours of the earth below them. The weight of evidence suggests that the Allegheny Front does not exert a strong influence on the behavior of nocturnal fall migrant birds in the study area.

5.3 Other Species of Concern

5.3.1 Golden-Winged Warbler

At this time, the proposed Mount Storm Wind Project area does not appear suitable for breeding golden-winged warblers. Consequently, without a viable breeding population, impact and conservation plans from turbine site development for golden-winged warblers does not appear necessary at this time.

The absence of breeding golden-winged warblers on the project site and, perhaps, locally in the Mount Storm area may be due primarily to lack of appropriate nesting microhabitat. Habitats in the study area appeared generally atypical of golden-winged warblers but this was not empirically tested. Areas with habitat features making them potentially suitable for golden-winged warblers appeared too open and lacked dense shrubs and narrow-contour, goldenrod dominated edges typical of occupied habitat. The species is known to occur locally in suitable habitat in Grant County (Buckelew and Hall 1994, Canterbury, unpubl. data). Examination of an aerial photograph revealed little secondary successional habitat for golden-winged warbler, except for right-of-ways and some minelands. Most minelands are in grassland stages of secondary succession and reclamation, which is considered too early in the successional stages for golden-winged warbler occurrence. The rights-of-way areas appear to lack shrub cover necessary for breeding golden-winged warblers. Through continued recovery, reclaimed minelands may become suitable in the future. Right-of-ways are usually actively managed and maintained as clear areas and may never develop suitable golden-winged warbler habitat.

5.3.2 Breeding Raptors

No active raptor nests were located on site and the project is not likely to displace nesting raptors. The survey was conducted mainly in forested areas, but included some open areas interspersed with the forest vegetation types. The lack of nesting raptors is presumably due to the lack of good raptor nesting habitat (e.g., mature deciduous tree stands) and possibly due to large scale disturbances nearby, such as coal mining, the power plant, or logging. For example, the deciduous woods near the southern end of the project had some of the older stands with larger and taller trees. This area appeared to be the better raptor nesting habitat in the project, but was adjacent to an active coal mine where there is presumably more disturbance from large machinery and human presence. The majority of the deciduous forest vegetation type located in the study area is comprised of even aged stands interspersed with open area (e.g, reclaimed mines, logged areas, rights-of-way, residential/developed areas). Much of the forest type in the study area has also been damaged by ice and wind with the result that the crowns of trees are broken or dead. It is likely that some of the raptors seen during the point count surveys were breeding raptors with nests located outside the study area and possibly in areas with less disturbance factors such as mining and logging.

5.3.3 Wintering Bald Eagles and Raptors

A variety of raptors were observed in the vicinity of the Project during the winter months (late November to late March) but not in large numbers. While bald eagles do occur in the area during the winter their occurrence appeared to be sporadic and in low numbers. Only five bald eagles were observed, four of which were observed perching in a tree near Stony River Reservoir. The recent draining of Stony River Reservoir south of Mount Storm Lake for coal mining may contribute to reduced habitat suitability of the area for bald eagles, which are known to concentrate around large water bodies. The project is not expected to result in take of a wintering bald eagle.

5.3.4 American Woodcock and Common Snipe

American woodcock generally occur in wet thickets such as alder swales, moist woodlands, and early successional open areas like old orchards with grassy understory. Common snipe occupy peat bogs, marshes, and wet meadows. Habitat for both species is found in the general project area and they were recorded on site during spring surveys. Common snipe are more closely associated with wetlands. Since the project will avoid impacting wetlands, loss of snipe habitat will be minimal. Impacts to American woodcock habitat from the project may be more extensive, depending on the final project layout. Woodcock will occur in logged or cut over areas and some of the sites where they were recorded appeared to have been recently (within the past 10 years) logged. Development in these areas could result in loss of woodcock habitat.

It is likely that American woodcock breed locally in the project area, as they were observed conducting courtship displays in some areas. The breeding status of common snipe on site is less definitive as habitat appears to be more limited. The common snipe recorded on sight could have been migrants or transients occupying suitable habitat. Neither species was recorded in large numbers. According to the West Virginia Breeding Bird Atlas, American woodcock is a confirmed breeder and common snipe a possible breeder in Grant County (Buckelew, Jr. and Hall 1994). Both species have been recorded breeding in the Canaan Valley southwest of the project. Construction of the wind plant could result in the displacement of some breeding American woodcock but it is not expected to impact breeding common snipe.

5.4 Risk of Turbine Collision

5.4.1 Diurnal Migrants

Risk of impacts from wind development is a combination of species use (occurrence) and behavior. Behavior includes the propensity of the species to fly within the area occupied by the turbine rotor blades and its ability to avoid collisions with turbine blades. An objective of the study was to identify areas of high avian use, suggesting a potentially higher risk from development without avoidance behavior considerations. To the extent possible, an estimated flight height was recorded for birds observed flying during the surveys; although, in some cases observation above 25 meters was difficult due to the vegetation type (e.g., deciduous forest). The vast majority of flying birds were observed below 25 meters above ground level. When considering all observations of passerines, the most common group of birds, only 32% of flying birds (7% of all passerine detections) were observed in the zone of influence (25-115 m above ground). In most cases, passerines occupying the site during the daytime periods in the spring and fall are either actively foraging in the vegetation or, in the spring, establishing breeding territories. These diurnal behaviors presumably put these birds at less risk of collision with turbines.

Raptors are often thought of as a group at relatively higher risk from wind power development (Anderson *et al.* 2000, Orloff and Flannery 1992). Studies at wind projects in the west, and particularly in California, have reported numerous fatalities for some raptor species (see Erickson *et al.* 2001). Spring and fall raptor use in the study area was relatively low. In the spring, on average only one raptor was observed every seven surveys and in the fall one raptor every three surveys. The majority of raptor use (71%) was from turkey vultures in both seasons. There was no evidence that the Allegheny Front was a heavily used raptor migration route. During the winter there appeared to be light and sporadic use of the areas around Mount Storm Lake (approximately 1.5 miles west of the Project) by bald eagles and several other species including some northern breeding species (rough-legged hawk, northern goshawk). Overall winter raptor use of the project area was low.

Raptor mortality has been low at other newer generation wind plants studied. The estimate of raptor mortality at several newer generation wind plants in the mid-west and west ranged from 0 to 0.07 raptors per turbine per year (Erickson *et al.* 2001, Erickson *et al.* 2003). In addition, turkey vultures appear to be less susceptible to collision than would be expected based on their level of use (Orloff and Flannery 1992) and no rough-legged hawk or bald eagle fatalities have been reported at newer generation wind plants. One red-tailed hawk and two turkey vultures were observed as fatalities at the Mountaineer project (Kerns and Kerlinger 2004). The proposed Mount Storm wind project is not expected to result in substantial raptor mortality.

Passerines have been the most abundant avian fatality at other wind plants studied (see Johnson *et al.* 2002, Young *et al.* 2003a, Erickson *et al.* 2000), often comprising more than 80% of the avian fatalities. Both migrant and resident passerine fatalities have been observed. Given that passerines make up the vast majority of the avian observations on this site, and have comprised the majority of avian fatalities at all new wind projects, it is expected passerines would make up the largest proportion of fatalities once the wind plant is in operation. It is expected that the common species such as red-winged blackbird and red-eyed vireo, would be most at risk. Several of the more common species such as ovenbird, eastern towhee, and wood thrush are typically ground nesters and presumably would be at lower risk once they are on site (i.e., outside migration events).

Because few wind plant have been constructed in the east, there is little information regarding impacts from eastern wind plants available for comparison. At the three turbines located at the

Buffalo Mountain Tennessee wind project, it was estimated that approximately 10 birds were killed per turbine per year (Tennessee Valley Authority 2002). Monitoring at the Backbone Mountain West Virginia wind project estimated that annual avian mortality was approximately 4 birds per turbine per year (Kerns and Kerlinger 2004). For the Mountaineer wind plant approximately 60% of the fatalities were believed to be nocturnal migrants.

More extensive monitoring studies have taken place at wind plants in the western U.S. A post-construction study of wind plants on Buffalo Ridge, Minnesota, (350 total turbines), was conducted from 1996 through 1999. Total annual mortality was estimated to average approximately 2.8 birds per turbine (Johnson *et al.* 2000) of which approximately 50% were considered nocturnal migrants. Based on two studies at Foote Creek Rim, Wyoming, the total annual mortality associated with 115 turbines was estimated to be approximately 1.5 birds per turbine per year (Young *et al.* 2003a, Young *et al.* 2003b) with approximately 50% considered migrants. The estimate for the Stateline Wind Plant, Washington and Oregon, for all birds was 1.7 birds per turbine per year based on the first 18 months of study (WEST and NWC 2004) with approximately 25% of the casualties considered migrants. The estimated fatality rate at the Nine Canyon Wind Project, Washington, was 3.6 birds per turbine per year based on the first year study (Erickson *et al.* 2003b), but only 17% of the observed fatalities at the Nine Canyon Project were considered likely nocturnal migrants. At 31 turbines in Kewaunee County Wisconsin, total annual bird mortality was estimated to be approximately 1.3 fatalities per turbine per year, with approximately 70% considered nocturnal migrating songbirds (Howe *et al.* 2002). There have also been two small mortality events (several birds killed in one night) reported for wind farms. For example, at Buffalo Ridge, Minnesota, fourteen migrating passerine fatalities (vireos, warblers, flycatchers) were found at two turbines during one search in May 1999 (Johnson *et al.* 2002); and 27 migrating passerine fatalities (mostly warblers) were found near three turbines and a well-lit substation after a few nights of heavy fog conditions at the Backbone Mountain, West Virginia wind project in May 2003 (Kerns and Kerlinger, 2004).

5.4.2 Nocturnal Migrants

The results from the radar study do not suggest that the Allegheny Front has a large impact on behavior of nocturnal migrants. There did not appear to be a concentration of targets correlated with the primary ridgeline that would presumably increase the risk posed by the wind farm on migrant birds. Based on the nocturnal radar data collected at the site, approximately 16% of targets passing over the central station would be below 125 meters agl increasing their risk of flying through the rotor swept area of a turbine. This is a maximum estimate though because the actual number of birds within the total targets in that zone is less than the number of targets (i.e., total likely includes migrating bats), the agl estimate is relative to the radar position and not true ground level, the percentage is based on targets sampled only in the 1.5 kilometer range (some birds occur above 1.5 kilometers), and the turbines used for the project will likely be less than 125 meters tall.

Risk can be approximated given the following assumptions: (1) the width of migratory front (east-west axis) that the project area covers is about 10 kilometers; (2) the mean passage rate is representative of migrating birds; (3) the mean passage rate for the study period is representative of the whole fall migration period; (4) the fall migration extends from August 1 to November 1; and (5) there is an average of 10 hours of nocturnal migration per night. Given these assumptions, it is estimated that approximately 1,830,800 birds may have passed over the study area during the fall migration below 1.5 kilometers agl [199 targets per kilometer per hour x 10 kilometers of migratory front x 10 hours per night x 92 nights] and approximately 292,928 (16%) would pass though the area below 125 meters agl. Further, if it is assumed that the mortality rate of the Backbone Mountain Wind Plant of 2.37 birds per turbine per fall season (Kerns and Kerlinger 2004) is applicable to this site, a 300 MW wind plant with 200 turbines built at Mount Storm could have resulted in approximately 474 bird deaths during the fall season or 0.16% of the fall migrants passing over the site under 125 meters agl.

Based on the wind farm's projected energy production, the proposed Mount Storm wind farm (300 MW) could provide electricity for about 77,000 homes (a household consumes about 10,000 kW hours per year according to the DOE). Given the above mortality, this would equal approximately 1 bird death per 162 households served during the fall season, which is relatively small when compared to other common sources of avian collision mortality (see Erickson *et al.* 2001).

5.5 Turbine Siting

One of the primary goals of the baseline studies was to provide data that could be used to help in minimizing the risk posed by the wind farm through micro-siting of turbines. In general, the studies did not indicate that there could be substantial reduction in risk to birds by preferentially locating turbines.

- Vegetation types in the project area were not unique or pristine and were generally typical of impacted areas.
- The locations with the highest diurnal bird use and species diversity corresponded to the areas with the greatest "edge" (the forest-open area interface), which is common throughout the project area.
- No nesting raptors were found in the project area.
- No breeding golden-winged warblers were found in the project area.
- Winter bald eagle use of the area was sporadic and tended to concentrate around Stony River Reservoir and Mount Storm Lake approximately 1.5 mile west of the project.
- At the scale of the observations, the weight of evidence from the fall nocturnal radar study indicates that birds did not concentrate along the Allegheny Front.
- The fall nocturnal radar studies indicated that the site appears to have migration rates similar to and within the range of other radar studies in the eastern U.S.
- Although the fall nocturnal radar studies showed variation in passage rates among sampling stations, the results are considered equivocal because of multiple factors that could have influenced the observation pattern.
- Based on the studies there does not appear to be any risks to birds posed by the site or the proposed wind project that are not typical of newer generation wind plants.

No recommendations for micro-siting turbines are made based on the results of the studies. Based on the results of these studies, there is no evidence that the Mount Storm wind project will pose a risk to migrant birds greater that other studied wind farms.

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Table 1.

Avian species observed during fixed-point surveys.

Species/Group	Spring # of Individs	Spring # of Groups	Fall # of Individs	Fall # of Groups	Total # of Individs	Total # of Groups
Waterfowl	**104**	**37**	**386**	**31**	**490**	**68**
Canada goose	75	20	349	17	424	37
mallard	21	14	31	10	52	24
unidentified duck	0	0	1	1	1	1
wood duck	8	3	5	3	13	6
Waterbirds	**6**	**4**	**10**	**10**	**16**	**14**
American bittern	1	1	0	0	1	1
great blue heron	1	1	6	6	7	7
green heron	3	1	2	2	5	3
pied-billed grebe	1	1	2	2	3	3
Shorebirds	**59**	**44**	**45**	**34**	**104**	**78**
American woodcock	13	10	0	0	13	10
common snipe	4	2	0	0	4	2
dunlin	0	0	2	1	2	1
killdeer	41	31	40	30	81	61
semipalmated plover	0	0	1	1	1	1
solitary sandpiper	0	0	1	1	1	1
spotted sandpiper	1	1	1	1	2	2
Rails/Coots	**9**	**8**	**1**	**1**	**10**	**9**
American coot	2	1	0	0	2	1
sora	7	7	1	1	8	8
Raptors	**219**	**115**	**871**	**377**	**1090**	**492**
Kites						
Mississippi Kite	0	0	1	1	1	1
Accipiters	**5**	**5**	**35**	**33**	**40**	**38**
Cooper's hawk	1	1	17	17	18	18
northern goshawk	0	0	2	2	2	2
sharp-shinned hawk	4	4	16	14	20	18
Buteos	**32**	**25**	**126**	**70**	**158**	**95**
broad-winged hawk	8	8	77	25	85	33
red-shouldered hawk	7	6	7	7	14	13
red-tailed hawk	17	11	42	38	59	49
northern harrier	**2**	**1**	**21**	**21**	**23**	**22**
Eagles	**0**	**0**	**7**	**7**	**7**	**7**
bald eagle	0	0	5	5	5	5
golden eagle	0	0	1	1	1	1
unidentified eagle	0	0	1	1	1	1
Falcons	**1**	**1**	**56**	**38**	**57**	**39**
American kestrel	1	1	49	31	50	32
merlin	0	0	5	5	5	5
peregrine falcon	0	0	2	2	2	2
Owls	**15**	**15**	**2**	**2**	**17**	**17**
barred owl	8	8	1	1	9	9
eastern screech-owl	3	3	1	1	4	4
northern saw-whet owl	4	4	0	0	4	4

Table 1.

Avian species observed during fixed-point surveys.

	Spring		Fall		Total	
Species/Group	**# of Individs**	**# of Groups**	**# of Individs**	**# of Groups**	**# of Individs**	**# of Groups**
Vultures	**164**	**68**	**610**	**193**	**774**	**261**
black vulture	4	2	17	6	21	8
turkey vulture	160	66	593	187	753	253
Other - Raptors	**0**	**0**	**13**	**12**	**13**	**12**
osprey	0	0	9	9	9	9
unidentified raptor	0	0	4	3	4	3
Upland Gamebirds	**48**	**38**	**80**	**37**	**128**	**75**
ruffed grouse	18	18	23	19	41	37
wild turkey	30	20	57	18	87	38
Doves/Pigeons	**90**	**56**	**34**	**18**	**124**	**74**
mourning dove	89	55	34	18	123	73
rock dove	1	1	0	0	1	1
Cuckooes	**22**	**22**	**15**	**13**	**37**	**35**
black-billed cuckoo	11	11	5	5	16	16
yellow-billed cuckoo	11	11	10	8	21	19
Swifts/Hummingbirds	**6**	**3**	**6**	**5**	**12**	**8**
chimney swift	4	1	0	0	4	1
ruby-throated hummingbird	2	2	6	5	8	7
Woodpeckers	**226**	**214**	**415**	**295**	**641**	**509**
downy woodpecker	73	68	80	64	153	132
hairy woodpecker	20	20	63	55	83	75
northern flicker	71	68	180	98	251	166
pileated woodpecker	35	33	55	48	90	81
red-bellied woodpecker	19	17	10	10	29	27
red-headed woodpecker	1	1	3	3	4	4
unidentified woodpecker	0	0	6	6	6	6
yellow-bellied sapsucker	7	7	18	11	25	18
Passerines	**6030**	**4236**	**9014**	**3776**	**15044**	**8012**
Blackbirds/Orioles	**493**	**148**	**250**	**49**	**743**	**197**
Baltimore oriole	9	9	10	1	19	10
Bullock's oriole	0	0	2	2	2	2
bobolink	0	0	8	5	8	5
brown-headed cowbird	34	14	18	2	52	16
common grackle	1	1	16	2	17	3
eastern meadowlark	14	8	11	5	25	13
European starling	17	6	80	10	97	16
red-winged blackbird	416	109	90	21	506	130
rusty blackbird	2	1	0	0	2	1
unidentified blackbird	0	0	15	1	15	1
Creepers/Nuthatches	**76**	**72**	**115**	**91**	**191**	**163**
brown creeper	5	5	7	7	12	12
red-breasted nuthatch	36	36	11	11	47	47
white-breasted nuthatch	35	31	97	73	132	104

Table 1.

Avian species observed during fixed-point surveys.

	Spring		Fall		Total	
Species/Group	**# of Individs**	**# of Groups**	**# of Individs**	**# of Groups**	**# of Individs**	**# of Groups**
Corvids	**811**	**440**	**1948**	**801**	**2759**	**1241**
American crow	463	241	1080	356	1543	597
blue Jay	186	107	595	284	781	391
common raven	162	92	273	161	435	253
Finches	**194**	**76**	**386**	**169**	**580**	**245**
American goldfinch	191	73	366	161	557	234
pine siskin	0	0	1	1	1	1
purple finch	3	3	17	5	20	8
unidentified finch	0	0	2	2	2	2
Flycatchers	**190**	**163**	**227**	**178**	**417**	**341**
acadian flycatcher	0	0	2	2	2	2
alder flycatcher	3	3	0	0	3	3
eastern kingbird	2	2	3	2	5	4
eastern phoebe	44	39	134	101	178	140
eastern wood-pewee	51	37	46	40	97	77
great crested flycatcher	87	79	6	6	93	85
least flycatcher	3	3	16	9	19	12
olive-sided flycatcher	0	0	3	1	3	1
unidentified empidonax	0	0	15	15	15	15
yellow-bellied flycatcher	0	0	2	2	2	2
Gnatcatchers/Kinglet	**38**	**26**	**179**	**79**	**217**	**105**
blue gray gnatcatcher	2	2	8	6	10	8
golden-crowned kinglet	26	15	38	22	64	37
ruby-crowned kinglet	10	9	133	51	143	60
Grassland/Sparrows	**1377**	**1054**	**1666**	**703**	**3043**	**1757**
American pipit	0	0	17	5	17	5
chipping sparrow	229	165	501	126	730	291
clay-colored sparrow	0	0	1	1	1	1
dark-eyed junco	57	26	71	28	128	54
eastern towhee	368	264	375	235	743	499
field sparrow	112	99	147	42	259	141
grasshopper sparrow	81	58	23	17	104	75
horned lark	35	25	9	4	44	29
indigo bunting	148	131	63	43	211	174
lark sparrow	0	0	1	1	1	1
Lincoln's sparrow	0	0	16	9	16	9
northern cardinal	52	49	18	13	70	62
savannah sparrow	17	16	24	14	41	30
song sparrow	207	176	147	86	354	262
swamp sparrow	8	3	4	3	12	6
unidentified sparrow	0	0	7	6	7	6
vesper sparrow	42	37	174	54	216	91
white-throated sparrow	21	5	68	16	89	21
Mimids	**64**	**63**	**89**	**79**	**153**	**142**
brown thrasher	30	29	8	8	38	37
gray catbird	34	34	80	70	114	104
northern mockingbird	0	0	1	1	1	1
Swallows	**114**	**37**	**53**	**14**	**167**	**51**
barn swallow	84	29	26	6	110	35
cliff swallow	0	0	3	2	3	2

Table 1.

Avian species observed during fixed-point surveys.

Species/Group	Spring # of Individs	 # of Groups	Fall # of Individs	 # of Groups	Total # of Individs	 # of Groups
northern rough-winged swallow	28	7	7	3	35	10
tree swallow	2	1	13	2	15	3
unidentified swallow	0	0	4	1	4	1
Tanagers/Groskbeaks	**145**	**125**	**138**	**65**	**283**	**190**
rose-breasted grosbeak	19	17	82	40	101	57
scarlet tanager	126	108	56	25	182	133
Thrushs	**482**	**351**	**449**	**208**	**931**	**559**
American robin	197	99	187	67	384	166
eastern bluebird	39	26	170	63	209	89
gray-cheeked thrush	0	0	4	4	4	4
hermit thrush	53	48	20	11	73	59
Swainson's thrush	6	6	27	22	33	28
unidentified thrush	0	0	1	1	1	1
Veery	8	8	10	10	18	18
wood thrush	179	164	30	30	209	194
Titmice/Chickadees	**408**	**305**	**349**	**186**	**757**	**491**
black-capped chickadee	201	130	292	146	493	276
tufted titmouse	207	175	57	40	264	215
Philadelphia vireo	0	0	3	3	3	3
Vireos	**466**	**378**	**238**	**171**	**704**	**549**
blue-headed vireo	119	115	66	49	185	164
red-eyed vireo	335	251	146	105	481	356
solitary vireo	0	0	17	8	17	8
white-eyed vireo	6	6	5	5	11	11
yellow-throated vireo	6	6	1	1	7	7
Warblers	**993**	**875**	**2246**	**846**	**3239**	**1721**
American redstart	23	20	24	18	47	38
bay-breasted warbler	5	5	54	19	59	24
black-and-white warbler	12	12	17	14	29	26
blackburnian warbler	10	10	16	10	26	20
blackpoll warbler	14	5	72	30	86	35
black-throated blue warbler	48	42	59	50	107	92
black-throated green warbler	191	159	230	90	421	249
blue-winged warbler	0	0	2	2	2	2
Canadian warbler	1	1	8	7	9	8
Cape May warbler	5	2	39	26	44	28
ceruleon warbler	0	0	7	4	7	4
chestnut-sided warbler	69	60	34	21	103	81
common yellowthroat	102	99	101	74	203	173
Connecticut warbler	2	2	0	0	2	2
golden-winged warbler	11	9	0	0	11	9
hooded warbler	15	13	49	38	64	51
Kentucky warbler	0	0	4	4	4	4
magnolia warbler	99	95	76	44	175	139
mourning warbler	3	3	4	4	7	7
myrtle warbler	18	5	2	1	20	6
Nashville warbler	0	0	7	6	7	6
northern parula	32	32	14	14	46	46
orange-crowned warbler	0	0	2	1	2	1
ovenbird	316	284	43	41	359	325

Table 1.

Avian species observed during fixed-point surveys.

Species/Group	Spring # of Individs	Spring # of Groups	Fall # of Individs	Fall # of Groups	Total # of Individs	Total # of Groups
palm warbler	0	0	51	29	51	29
pine warbler	0	0	10	8	10	8
Tennessee warbler	3	3	55	28	58	31
unidentified warbler	2	2	1143	201	1145	203
Wilson's warbler	0	0	2	2	2	2
worm-eating warbler	4	4	8	8	12	12
yellow warbler	1	1	0	0	1	1
yellow-breasted chat	2	2	1	1	3	3
yellow-rumped warbler	0	0	109	50	109	50
yellow-throated warbler	5	5	3	1	8	6
Waxwings	**61**	**12**	**623**	**85**	**684**	**97**
bohemian waxwing	0	0	7	3	7	3
Carolina wren	38	38	9	9	47	47
cedar waxwing	61	12	616	82	677	94
Wrens	**118**	**111**	**56**	**50**	**174**	**161**
house wren	73	66	20	18	93	84
marsh wren	1	1	0	0	1	1
unidentified wren	0	0	6	6	6	6
winter wren	6	6	21	17	27	23
unidentified passerine	**0**	**0**	**2**	**2**	**2**	**2**
Other Birds	**0**	**0**	**10**	**7**	**10**	**7**
belted kingfisher	0	0	4	4	4	4
common nighthawk	0	0	6	3	6	3
unidentified bird	**4**	**2**	**2**	**1**	**6**	**3**
Total	**6823**	**4779**	**10889**	**4605**	**17712**	**9384**

Spring period = April 29 – June 13, 2003
Fall period = August 14 – October 15, 2003

Table 2.

Estimated mean use (number of observations per 10-minute survey) for each species observed within 50m of the survey point.

Species/Group	*Spring Use* *mean*	*Spring Use* *st dev*	*Fall Use* *mean*	*Fall Use* *st dev*	*Overall Use* *mean*	*Overall Use* *st dev*
Waterfowl	**0.071**	**0.154**	**0.122**	**0.564**	**0.113**	**0.430**
Canada goose	0.045	0.121	0.092	0.527	0.087	0.404
mallard	0.019	0.073	0.027	0.112	0.022	0.078
wood duck	0.008	0.040	0.004	0.026	0.005	0.021
Waterbirds	**0.005**	**0.028**	**0.005**	**0.016**	**0.005**	**0.016**
American bittern	0.001	0.005	-	-	0.000	0.001
great blue heron	0.001	0.007	0.004	0.013	0.003	0.010
green heron	0.003	0.022	0.001	0.005	0.001	0.008
pied-billed grebe	0.001	0.005	0.001	0.005	0.001	0.004
Shorebirds	**0.036**	**0.117**	**0.013**	**0.047**	**0.019**	**0.058**
American woodcock	0.005	0.016	-	-	0.002	0.005
common snipe	0.002	0.010	-	-	0.001	0.005
killdeer	0.028	0.102	0.012	0.044	0.016	0.052
solitary sandpiper	-	-	0.000	0.002	0.000	0.002
spotted sandpiper	0.001	0.007	0.000	0.002	0.000	0.003
Rails/Coots	**0.010**	**0.056**	**0.001**	**0.006**	**0.003**	**0.020**
American coot	0.002	0.013	-	-	0.001	0.005
sora	0.008	0.054	0.001	0.006	0.003	0.020
Raptors	**0.148**	**0.220**	**0.354**	**0.479**	**0.303**	**0.356**
Kites						
Mississippi Kite	-	-	0.000	0.002	0.000	0.002
Accipiters	**0.002**	**0.009**	**0.016**	**0.031**	**0.012**	**0.021**
Cooper's hawk	0.001	0.007	0.006	0.017	0.005	0.012
northern goshawk	-	-	0.002	0.009	0.001	0.006
sharp-shinned hawk	0.001	0.005	0.008	0.022	0.006	0.014
Buteos	**0.019**	**0.064**	**0.045**	**0.108**	**0.038**	**0.082**
broad-winged hawk	0.005	0.022	0.024	0.100	0.019	0.071
red-shouldered hawk	0.004	0.013	0.003	0.015	0.004	0.012
red-tailed hawk	0.011	0.047	0.018	0.038	0.016	0.033
northern harrier	**0.004**	**0.030**	**0.010**	**0.032**	**0.008**	**0.025**
Small Falcons	**0.001**	**0.005**	**0.030**	**0.081**	**0.022**	**0.058**
American kestrel	0.001	0.005	0.029	0.079	0.021	0.057
merlin	-	-	0.002	0.008	0.001	0.005
peregrine falcon	-	-	0.001	0.006	0.001	0.004
Owls	**0.010**	**0.029**	**-**	**-**	**0.005**	**0.014**
barred owl	0.008	0.028	-	-	0.004	0.014
eastern screech-owl	0.001	0.006	-	-	0.001	0.003
northern saw-whet owl	0.001	0.007	-	-	0.000	0.002
Vultures	**0.112**	**0.216**	**0.251**	**0.357**	**0.218**	**0.262**
black vulture	0.003	0.018	0.006	0.036	0.003	0.014
turkey vulture	0.109	0.206	0.245	0.356	0.214	0.261
Other - Raptors						
osprey	-	-	0.000	0.003	0.000	0.002

Table 2.

Estimated mean use (number of observations per 10-minute survey) for each species observed within 50m of the survey point.

	Spring Use		*Fall Use*		*Overall Use*	
Species/Group	*mean*	*st dev*	*mean*	*st dev*	*mean*	*st dev*
Upland Gamebirds	**0.033**	**0.057**	**0.053**	**0.092**	**0.047**	**0.066**
ruffed grouse	0.009	0.019	0.018	0.049	0.015	0.035
wild turkey	0.024	0.050	0.034	0.082	0.032	0.057
Doves/Pigeons	**0.074**	**0.197**	**0.019**	**0.046**	**0.037**	**0.074**
mourning dove	0.073	0.196	0.019	0.046	0.037	0.073
rock dove	0.001	0.007	-	-	0.000	0.002
Cuckooes	**0.022**	**0.040**	**0.009**	**0.028**	**0.014**	**0.022**
black-billed cuckoo	0.011	0.030	0.004	0.017	0.006	0.013
yellow-billed cuckoo	0.010	0.026	0.005	0.023	0.008	0.019
Swifts/Hummingbirds	**0.005**	**0.028**	**0.003**	**0.019**	**0.004**	**0.016**
chimney swift	0.003	0.027	-	-	0.001	0.008
ruby-throated hummingbird	0.002	0.010	0.003	0.019	0.003	0.014
Woodpeckers	**0.170**	**0.108**	**0.250**	**0.250**	**0.231**	**0.176**
downy woodpecker	0.050	0.067	0.052	0.077	0.055	0.061
hairy woodpecker	0.019	0.041	0.039	0.070	0.032	0.047
northern flicker	0.052	0.072	0.098	0.196	0.085	0.143
pileated woodpecker	0.027	0.044	0.036	0.060	0.034	0.050
red-bellied woodpecker	0.018	0.042	0.008	0.023	0.012	0.024
red-headed woodpecker	0.000	0.003	0.003	0.017	0.001	0.008
unidentified woodpecker	-	-	0.001	0.005	0.001	0.004
yellow-bellied sapsucker	0.003	0.011	0.012	0.034	0.010	0.024
Passerines	**4.848**	**2.157**	**5.717**	**3.809**	**5.596**	**2.978**
Blackbirds/Orioles	**0.392**	**1.140**	**0.144**	**0.382**	**0.239**	**0.562**
Baltimore oriole	0.010	0.030	0.007	0.060	0.009	0.045
bobolink	-	-	0.004	0.022	0.003	0.016
brown-headed cowbird	0.032	0.150	0.011	0.069	0.024	0.106
Bullock's oriole	-	-	0.001	0.008	0.001	0.006
common grackle	-	-	0.016	0.128	0.010	0.078
eastern meadowlark	0.011	0.047	0.007	0.042	0.008	0.032
European starling	0.013	0.071	0.033	0.179	0.028	0.135
red-winged blackbird	0.324	1.032	0.055	0.199	0.150	0.430
rusty blackbird	0.001	0.006	-	-	0.000	0.001
unidentified blackbird	-	-	0.011	0.090	0.008	0.064
Corvids	**0.597**	**0.358**	**0.939**	**0.851**	**0.862**	**0.621**
American crow	0.338	0.276	0.458	0.546	0.431	0.419
blue Jay	0.132	0.149	0.360	0.479	0.295	0.341
common raven	0.127	0.191	0.121	0.155	0.136	0.130
Creepers/Nuthatches	**0.064**	**0.076**	**0.088**	**0.129**	**0.082**	**0.090**
brown creeper	0.004	0.017	0.009	0.036	0.006	0.017
red-breasted nuthatch	0.036	0.060	0.011	0.033	0.023	0.037
white-breasted nuthatch	0.025	0.051	0.068	0.118	0.054	0.082
Finches	**0.129**	**0.199**	**0.250**	**0.378**	**0.217**	**0.274**
American goldfinch	0.127	0.200	0.238	0.348	0.208	0.251
pine siskin	-	-	0.001	0.005	0.000	0.004

Table 2.

Estimated mean use (number of observations per 10-minute survey) for each species observed within 50m of the survey point.

	Spring Use		*Fall Use*		*Overall Use*	
Species/Group	***mean***	***st dev***	***mean***	***st dev***	***mean***	***st dev***
purple finch	0.002	0.011	0.010	0.066	0.008	0.049
unidentified finch	-	-	0.001	0.007	0.001	0.005
Flycatchers	**0.186**	**0.185**	**0.155**	**0.151**	**0.171**	**0.138**
acadian flycatcher	-	-	0.002	0.012	0.001	0.005
alder flycatcher	0.004	0.019	-	-	0.002	0.009
eastern kingbird	0.002	0.014	0.002	0.011	0.002	0.009
eastern phoebe	0.042	0.095	0.077	0.122	0.072	0.104
eastern wood-pewee	0.058	0.129	0.039	0.057	0.048	0.067
great crested flycatcher	0.076	0.106	0.006	0.019	0.028	0.036
least flycatcher	0.004	0.021	0.008	0.026	0.006	0.020
olive-sided flycatcher	-	-	0.002	0.019	0.002	0.013
unidentified empidonax	-	-	0.019	0.052	0.009	0.021
yellow-bellied flycatcher	-	-	0.001	0.010	0.001	0.006
Gnatcatchers/Kinglet	**0.029**	**0.064**	**0.126**	**0.183**	**0.094**	**0.126**
blue gray gnatcatcher	0.002	0.014	0.005	0.023	0.004	0.017
golden-crowned kinglet	0.019	0.057	0.032	0.077	0.027	0.052
ruby-crowned kinglet	0.008	0.031	0.089	0.165	0.063	0.113
Grassland/Sparrows	**1.077**	**0.946**	**1.156**	**1.223**	**1.115**	**1.069**
American pipit	-	-	0.009	0.048	0.007	0.036
chipping sparrow	0.164	0.220	0.333	0.571	0.286	0.429
clay-colored sparrow	-	-	0.001	0.006	0.001	0.004
dark-eyed junco	0.039	0.103	0.059	0.159	0.056	0.110
eastern towhee	0.295	0.299	0.275	0.337	0.265	0.267
field sparrow	0.086	0.130	0.106	0.244	0.099	0.192
grasshopper sparrow	0.057	0.130	0.015	0.043	0.027	0.063
horned lark	0.027	0.093	0.007	0.030	0.013	0.043
indigo bunting	0.146	0.185	0.049	0.094	0.078	0.099
lark sparrow	-	-	0.000	0.002	0.000	0.002
Lincoln's sparrow	-	-	0.011	0.036	0.008	0.026
northern cardinal	0.043	0.068	0.013	0.035	0.023	0.029
savannah sparrow	0.018	0.047	0.013	0.034	0.015	0.030
song sparrow	0.152	0.206	0.103	0.189	0.113	0.158
swamp sparrow	0.007	0.041	0.005	0.032	0.005	0.021
unidentified sparrow	-	-	0.003	0.014	0.002	0.010
vesper sparrow	0.034	0.100	0.109	0.276	0.085	0.215
white-throated sparrow	0.009	0.039	0.044	0.109	0.034	0.078
Mimids	**0.059**	**0.100**	**0.065**	**0.130**	**0.061**	**0.090**
brown thrasher	0.024	0.053	0.006	0.021	0.012	0.030
gray catbird	0.035	0.070	0.058	0.121	0.048	0.072
northern mockingbird	-	-	0.000	0.004	0.000	0.003
Swallows	**0.071**	**0.229**	**0.023**	**0.071**	**0.038**	**0.091**
barn swallow	0.055	0.179	0.009	0.036	0.024	0.062
cliff swallow	-	-	0.001	0.012	0.001	0.009
northern rough-winged swallow	0.012	0.056	0.006	0.034	0.007	0.033
tree swallow	0.004	0.030	0.007	0.046	0.006	0.033
Tanagers/Groskbeaks	**0.140**	**0.141**	**0.091**	**0.133**	**0.112**	**0.106**
rose-breasted grosbeak	0.016	0.042	0.053	0.089	0.042	0.066
scarlet tanager	0.123	0.131	0.037	0.100	0.070	0.089
Thrushs	**0.428**	**0.354**	**0.340**	**0.422**	**0.400**	**0.337**
American robin	0.180	0.337	0.141	0.275	0.168	0.257

Table 2.

Estimated mean use (number of observations per 10-minute survey) for each species observed within 50m of the survey point.

	Spring Use		*Fall Use*		*Overall Use*	
Species/Group	***mean***	***st dev***	***mean***	***st dev***	***mean***	***st dev***
eastern bluebird	0.031	0.067	0.117	0.301	0.090	0.214
gray-cheeked thrush	-	-	0.003	0.014	0.002	0.009
hermit thrush	0.047	0.091	0.014	0.054	0.028	0.051
Swainson's thrush	0.006	0.024	0.024	0.056	0.018	0.035
unidentified thrush	-	-	0.000	0.002	0.000	0.002
Veery	0.005	0.021	0.012	0.043	0.008	0.022
wood thrush	0.159	0.170	0.028	0.050	0.085	0.098
Titmice/Chickadees	**0.316**	**0.327**	**0.259**	**0.267**	**0.294**	**0.217**
black-capped chickadee	0.147	0.252	0.208	0.251	0.193	0.189
eastern tufted titmouse	0.169	0.148	0.051	0.080	0.101	0.096
Vireos	**0.405**	**0.325**	**0.180**	**0.161**	**0.260**	**0.183**
blue-headed vireo	0.091	0.106	0.054	0.073	0.068	0.070
Philadelphia vireo	-	-	0.002	0.009	0.001	0.007
red-eyed vireo	0.306	0.294	0.105	0.129	0.175	0.157
solitary vireo	-	-	0.012	0.051	0.009	0.036
white-eyed vireo	0.005	0.020	0.006	0.029	0.005	0.015
yellow-throated vireo	0.004	0.012	0.001	0.005	0.001	0.005
Warblers	**0.800**	**0.439**	**1.483**	**1.531**	**1.295**	**1.068**
American redstart	0.020	0.061	0.014	0.032	0.016	0.034
bay-breasted warbler	0.003	0.014	0.035	0.102	0.026	0.073
black-and-white warbler	0.007	0.021	0.014	0.036	0.011	0.021
blackburnian warbler	0.006	0.020	0.014	0.045	0.011	0.025
blackpoll warbler	0.012	0.069	0.051	0.100	0.039	0.073
black-throated blue warbler	0.048	0.099	0.045	0.082	0.048	0.064
black-throated green warbler	0.119	0.103	0.183	0.293	0.169	0.183
blue-winged warbler	-	-	0.001	0.006	0.001	0.005
Canadian warbler	0.001	0.007	0.013	0.051	0.005	0.019
Cape May warbler	0.003	0.018	0.023	0.045	0.018	0.033
ceruleon warbler	-	-	0.005	0.023	0.003	0.016
chestnut-sided warbler	0.057	0.165	0.029	0.074	0.034	0.064
common yellowthroat	0.088	0.148	0.069	0.112	0.075	0.108
Connecticut warbler	0.002	0.015	-	-	0.001	0.004
golden-winged warbler	0.009	0.027	-	-	0.003	0.010
hooded warbler	0.013	0.035	0.036	0.086	0.029	0.067
Kentucky warbler	-	-	0.006	0.034	0.003	0.016
magnolia warbler	0.088	0.091	0.050	0.098	0.071	0.079
mourning warbler	0.002	0.011	0.003	0.014	0.002	0.008
myrtle warbler	0.007	0.044	0.001	0.012	0.004	0.018
Nashville warbler	-	-	0.003	0.012	0.003	0.009
northern parula	0.031	0.048	0.015	0.047	0.020	0.027
orange-crowned warbler	-	-	0.001	0.009	0.001	0.007
ovenbird	0.268	0.240	0.038	0.061	0.123	0.102
palm warbler	-	-	0.029	0.078	0.021	0.056
pine warbler	-	-	0.005	0.017	0.004	0.012
Tennessee warbler	0.003	0.015	0.038	0.096	0.028	0.069
unidentified warbler	0.003	0.016	0.673	1.240	0.467	0.880
Wilson's warbler	-	-	0.003	0.024	0.001	0.009
worm-eating warbler	0.004	0.017	0.010	0.031	0.007	0.018
yellow warbler	0.001	0.007	-	-	0.000	0.002
yellow-breasted chat	0.002	0.015	0.000	0.002	0.001	0.005

Table 2.

Estimated mean use (number of observations per 10-minute survey) for each species observed within 50m of the survey point.

	Spring Use		*Fall Use*		*Overall Use*	
Species/Group	***mean***	***st dev***	***mean***	***st dev***	***mean***	***st dev***
yellow-rumped warbler	-	-	0.072	0.124	0.049	0.082
yellow-throated warbler	0.002	0.011	0.001	0.007	0.001	0.006
Waxwings	**0.051**	**0.133**	**0.385**	**0.797**	**0.299**	**0.552**
bohemian waxwing	-	-	0.003	0.013	0.002	0.009
cedar waxwing	0.051	0.133	0.382	0.799	0.297	0.553
Wrens	**0.104**	**0.183**	**0.036**	**0.056**	**0.056**	**0.069**
Carolina wren	0.034	0.070	0.007	0.021	0.017	0.035
house wren	0.063	0.158	0.013	0.033	0.026	0.052
marsh wren	0.001	0.005	-	-	0.000	0.001
unidentified wren	-	-	0.002	0.012	0.002	0.009
winter wren	0.006	0.019	0.014	0.031	0.011	0.022
unidentified passerine	**-**	**-**	**0.000**	**0.002**	**0.000**	**0.002**
Other Birds	**-**	**-**	**0.011**	**0.049**	**0.005**	**0.023**
belted kingfisher	-	-	0.004	0.020	0.002	0.008
common nighthawk	-	-	0.006	0.045	0.003	0.022
unidentified bird	**0.007**	**0.060**	**0.001**	**0.012**	**0.003**	**0.020**

Table 3.

Estimated percent composition (mean use divided by total use for all species) and frequency of occurrence (percent of surveys species is recorded) for each species observed within 50 m of the survey point

	% Composition			% Frequency		
Species/Group	**Spring**	**Fall**	**Overall**	**Spring**	**Fall**	**Overall**
Waterfowl	**1.31**	**1.86**	**1.77**	**3.07**	**1.16**	**1.87**
Canada goose	0.82	1.40	1.36	1.76	0.41	1.04
mallard	0.35	0.41	0.34	1.07	0.84	0.84
wood duck	0.14	0.06	0.07	0.30	0.22	0.23
Waterbirds	**0.09**	**0.08**	**0.08**	**0.29**	**0.51**	**0.46**
American bittern	0.01	-	0.00	0.06	-	0.01
great blue heron	0.01	0.06	0.05	0.08	0.37	0.29
green heron	0.05	0.01	0.02	0.09	0.09	0.09
pied-billed grebe	0.01	0.01	0.01	0.06	0.06	0.06
Shorebirds	**0.30**	**0.10**	**0.31**	**2.80**	**1.04**	**1.53**
American woodcock	0.04	-	0.03	0.37	-	0.13
common snipe	0.01	-	0.01	0.12	-	0.04
killdeer	0.24	0.10	0.25	2.34	0.98	1.33
solitary sandpiper	-	0.00	0.00	-	0.03	0.02
spotted sandpiper	0.01	0.00	0.01	0.09	0.03	0.05
Rails/Coots	**0.08**	**0.01**	**0.05**	**0.88**	**0.07**	**0.31**
American coot	0.01	-	0.01	0.08	-	0.03
sora	0.07	0.01	0.04	0.80	0.07	0.28
Raptors	**2.72**	**5.39**	**4.76**	**7.30**	**13.06**	**11.73**
Kites						
Mississippi Kite	-	0.00	0.00	-	0.03	0.02
Accipiters	**0.02**	**0.14**	**0.18**	**0.19**	**1.55**	**1.13**
Cooper's hawk	0.01	0.05	0.07	0.09	0.64	0.47
northern goshawk	-	0.01	0.02	-	0.16	0.10
sharp-shinned hawk	0.01	0.07	0.10	0.10	0.76	0.55
Buteos	**0.16**	**0.38**	**0.60**	**1.34**	**2.52**	**2.19**
broad-winged hawk	0.04	0.20	0.29	0.52	0.72	0.63
red-shouldered hawk	0.03	0.03	0.06	0.33	0.34	0.35
red-tailed hawk	0.09	0.15	0.25	0.58	1.68	1.38
northern harrier	**0.03**	**0.08**	**0.13**	**0.18**	**0.98**	**0.76**
Small Falcons	**0.00**	**0.25**	**0.34**	**0.06**	**1.77**	**1.29**
American kestrel	0.00	0.24	0.33	0.06	1.67	1.22
merlin	-	0.01	0.02	-	0.17	0.12
peregrine falcon	-	0.01	0.01	-	0.07	0.05
Owls	**0.09**	**-**	**0.08**	**1.03**	**-**	**0.48**
barred owl	0.07	-	0.06	0.80	-	0.39
eastern screech-owl	0.01	-	0.01	0.10	-	0.05
northern saw-whet owl	0.01	-	0.01	0.13	-	0.04
Vultures	**0.93**	**2.09**	**3.41**	**4.56**	**8.24**	**7.35**
black vulture	0.02	0.05	0.05	0.15	0.27	0.18
turkey vulture	0.91	2.04	3.36	4.41	8.04	7.22
Other - Raptors						
osprey	-	0.00	0.00	-	0.03	0.02

Table 3.

Estimated percent composition (mean use divided by total use for all species) and frequency of occurrence (percent of surveys species is recorded) for each species observed within 50 m of the survey point

	% Composition			% Frequency		
Species/Group	**Spring**	**Fall**	**Overall**	**Spring**	**Fall**	**Overall**
Upland Gamebirds	**0.27**	**0.44**	**0.74**	**2.72**	**2.72**	**2.80**
ruffed grouse	0.07	0.15	0.24	0.90	1.50	1.34
wild turkey	0.20	0.29	0.49	1.88	1.22	1.49
Doves/Pigeons	**0.62**	**0.16**	**0.58**	**4.63**	**1.10**	**2.19**
mourning dove	0.61	0.16	0.58	4.55	1.10	2.16
rock dove	0.01	-	0.00	0.08	-	0.02
Cuckooes	**0.18**	**0.08**	**0.21**	**2.16**	**0.84**	**1.30**
black-billed cuckoo	0.09	0.03	0.09	1.13	0.39	0.58
yellow-billed cuckoo	0.09	0.05	0.12	1.02	0.45	0.72
Swifts/Hummingbirds	**0.04**	**0.03**	**0.06**	**0.25**	**0.27**	**0.28**
chimney swift	0.03	-	0.02	0.08	-	0.02
ruby-throated hummingbird	0.01	0.03	0.05	0.17	0.27	0.25
Woodpeckers	**1.42**	**2.09**	**3.62**	**15.24**	**16.35**	**16.43**
downy woodpecker	0.42	0.44	0.86	4.75	4.17	4.65
hairy woodpecker	0.16	0.32	0.50	1.91	3.27	2.81
northern flicker	0.44	0.82	1.33	4.94	5.33	5.22
pileated woodpecker	0.23	0.30	0.54	2.53	3.08	2.98
red-bellied woodpecker	0.15	0.06	0.19	1.70	0.77	1.20
red-headed woodpecker	0.00	0.03	0.02	0.03	0.32	0.15
unidentified woodpecker	-	0.01	0.02	-	0.14	0.10
yellow-bellied sapsucker	0.03	0.10	0.16	0.31	0.74	0.66
Passerines	**89.32**	**87.18**	**87.68**	**91.20**	**80.72**	**84.97**
Blackbirds/Orioles	**3.27**	**1.20**	**3.75**	**10.67**	**2.67**	**5.50**
Baltimore oriole	0.08	0.06	0.14	1.00	0.07	0.39
bobolink	-	0.04	0.05	-	0.25	0.18
brown-headed cowbird	0.27	0.09	0.37	1.06	0.12	0.46
Bullock's oriole	-	0.01	0.02	-	0.14	0.10
common grackle	-	0.13	0.15	-	0.17	0.11
eastern meadowlark	0.09	0.06	0.12	0.74	0.23	0.36
European starling	0.11	0.27	0.44	0.55	0.38	0.46
red-winged blackbird	2.71	0.46	2.35	8.30	1.36	3.84
rusty blackbird	0.01	-	0.00	0.04	-	0.01
unidentified blackbird	-	0.09	0.12	-	0.07	0.05
Corvids	**4.98**	**7.83**	**13.50**	**28.88**	**33.27**	**32.65**
American crow	2.82	3.82	6.75	18.85	17.36	18.28
blue Jay	1.10	3.00	4.62	8.05	16.64	13.95
common raven	1.06	1.01	2.13	7.27	7.98	8.16
Creepers/Nuthatches	**0.54**	**0.73**	**1.29**	**6.22**	**6.88**	**6.88**
brown creeper	0.03	0.07	0.09	0.39	0.89	0.59
red-breasted nuthatch	0.30	0.09	0.35	3.57	1.08	2.26
white-breasted nuthatch	0.21	0.57	0.84	2.29	5.11	4.15
Finches	**1.08**	**2.08**	**3.41**	**5.62**	**10.16**	**8.85**
American goldfinch	1.06	1.99	3.26	5.40	9.81	8.52
pine siskin	-	0.00	0.01	-	0.06	0.04

Table 3.

Estimated percent composition (mean use divided by total use for all species) and frequency of occurrence (percent of surveys species is recorded) for each species observed within 50 m of the survey point

	% Composition			% Frequency		
Species/Group	**Spring**	**Fall**	**Overall**	**Spring**	**Fall**	**Overall**
purple finch	0.02	0.08	0.13	0.22	0.24	0.24
unidentified finch	-	0.01	0.01	-	0.11	0.09
Flycatchers	**1.55**	**1.29**	**2.68**	**13.70**	**11.81**	**12.44**
acadian flycatcher	-	0.01	0.01	-	0.17	0.07
alder flycatcher	0.03	-	0.02	0.38	-	0.16
eastern kingbird	0.02	0.02	0.03	0.22	0.12	0.15
eastern phoebe	0.35	0.64	1.13	3.53	5.85	5.42
eastern wood-pewee	0.48	0.32	0.76	3.87	3.43	3.65
great crested flycatcher	0.64	0.05	0.45	6.56	0.56	2.54
least flycatcher	0.03	0.07	0.10	0.36	0.55	0.46
olive-sided flycatcher	-	0.02	0.02	-	0.08	0.05
unidentified empidonax	-	0.16	0.14	-	1.87	0.90
yellow-bellied flycatcher	-	0.01	0.01	-	0.15	0.09
Gnatcatchers/Kinglet	0.24	1.05	**1.48**	**2.10**	**5.86**	**4.58**
blue gray gnatcatcher	0.02	0.04	0.06	0.19	0.29	0.26
golden-crowned kinglet	0.16	0.27	0.42	1.18	2.05	1.65
ruby-crowned kinglet	0.06	0.74	0.99	0.73	3.69	2.77
Grassland/Sparrows	**8.99**	**9.65**	**17.48**	**44.34**	**34.12**	**36.31**
American pipit	-	0.08	0.11	-	0.27	0.20
chipping sparrow	1.37	2.77	4.49	12.53	8.26	**9.36**
clay-colored sparrow	-	0.01	0.01	-	0.08	0.05
dark-eyed junco	0.32	0.49	0.87	2.38	2.44	2.61
eastern towhee	2.46	2.30	4.15	21.22	16.40	17.00
field sparrow	0.72	0.89	1.55	7.62	3.67	4.54
grasshopper sparrow	0.48	0.12	0.42	4.47	1.17	2.14
horned lark	0.23	0.05	0.20	1.84	0.29	0.74
indigo bunting	1.22	0.41	1.22	12.93	3.51	6.17
lark sparrow	-	0.00	0.00	-	0.03	0.02
Lincoln's sparrow	-	0.09	0.12	-	0.57	0.41
northern cardinal	0.36	0.11	0.35	3.97	1.02	1.96
savannah sparrow	0.15	0.11	0.23	1.65	0.76	1.02
song sparrow	1.27	0.86	1.77	13.32	6.13	7.78
swamp sparrow	0.05	0.05	0.08	0.26	0.49	0.29
unidentified sparrow	-	0.02	0.03	-	0.26	0.19
vesper sparrow	0.28	0.91	1.34	2.93	3.71	3.42
white-throated sparrow	0.07	0.37	0.53	0.19	1.15	0.85
Mimids	**0.50**	**0.54**	**0.95**	**5.47**	**5.43**	**5.36**
brown thrasher	0.20	0.05	0.20	2.31	0.59	1.22
gray catbird	0.30	0.49	0.75	3.54	5.03	4.35
northern mockingbird	-	0.00	0.01	-	0.05	0.04
Swallows	**0.59**	**0.19**	**0.60**	**2.32**	**0.63**	**1.18**
barn swallow	0.46	0.07	0.37	1.95	0.25	0.80
cliff swallow	-	0.01	0.02	-	0.07	0.05
northern rough-winged swallow	0.10	0.05	0.11	0.40	0.25	0.29
tree swallow	0.03	0.06	0.10	0.18	0.11	0.13
Tanagers/Groskbeaks	**1.17**	**0.76**	**1.75**	**11.67**	**4.36**	**7.05**
rose-breasted grosbeak	0.14	0.44	0.65	1.48	3.08	2.48
scarlet tanager	1.03	0.31	1.10	10.63	1.62	4.95
Thrushs	3.57	2.83	**6.27**	**26.51**	**15.06**	**20.02**

Table 3.

Estimated percent composition (mean use divided by total use for all species) and frequency of occurrence (percent of surveys species is recorded) for each species observed within 50 m of the survey point

	% Composition			% Frequency		
Species/Group	**Spring**	**Fall**	**Overall**	**Spring**	**Fall**	**Overall**
American robin	1.50	1.18	2.64	7.66	4.88	5.91
eastern bluebird	0.26	0.98	1.42	2.06	4.11	3.43
gray-cheeked thrush	-	0.03	0.03	-	0.33	0.21
hermit thrush	0.39	0.12	0.44	3.86	0.75	2.11
Swainson's thrush	0.05	0.20	0.28	0.63	2.00	1.52
unidentified thrush	-	0.00	0.00	-	0.03	0.02
Veery	0.04	0.10	0.12	0.53	1.18	0.79
wood thrush	1.32	0.23	1.34	14.69	2.78	7.94
Titmice/Chickadees	**2.64**	**2.16**	**4.61**	**22.05**	**13.02**	**17.19**
black-capped chickadee	1.23	1.73	3.03	9.72	9.95	10.35
eastern tufted titmouse	1.41	0.43	1.58	15.02	3.76	8.42
Vireos	**3.38**	**1.50**	**4.07**	**29.96**	**12.65**	**18.99**
blue-headed vireo	0.76	0.45	1.07	8.88	4.02	5.89
Philadelphia vireo	-	0.02	0.02	-	0.20	0.14
red-eyed vireo	2.55	0.87	2.74	22.70	7.75	13.08
solitary vireo	-	0.10	0.13	-	0.55	0.39
white-eyed vireo	0.04	0.05	0.08	0.48	0.62	0.51
yellow-throated vireo	0.03	0.01	0.02	0.35	0.06	0.15
Warblers	6.67	12.37	**20.29**	**50.08**	**38.00**	**42.94**
American redstart	0.17	0.12	0.25	1.71	1.06	1.29
bay-breasted warbler	0.02	0.29	0.41	0.26	1.16	0.91
black-and-white warbler	0.06	0.12	0.17	0.71	1.22	0.95
blackburnian warbler	0.05	0.12	0.17	0.63	0.94	0.77
blackpoll warbler	0.10	0.42	0.61	0.51	2.39	1.77
black-throated blue warbler	0.40	0.38	0.75	4.18	3.84	4.06
black-throated green warbler	0.99	1.53	2.65	10.65	7.38	9.06
blue-winged warbler	-	0.01	0.01	-	0.10	0.07
Canadian warbler	0.01	0.11	0.08	0.09	1.14	0.49
Cape May warbler	0.02	0.19	0.28	0.09	1.56	1.13
ceruleon warbler	-	0.04	0.05	-	0.25	0.18
chestnut-sided warbler	0.48	0.25	0.53	4.92	1.91	2.56
common yellowthroat	0.74	0.57	1.17	8.55	4.88	6.03
Connecticut warbler	0.02	-	0.01	0.24	-	0.07
golden-winged warbler	0.07	-	0.05	0.79	-	0.28
hooded warbler	0.11	0.30	0.46	1.10	2.64	2.19
Kentucky warbler	-	0.05	0.05	-	0.61	0.31
magnolia warbler	0.74	0.41	1.11	8.49	3.07	5.52
mourning warbler	0.02	0.03	0.04	0.24	0.30	0.24
myrtle warbler	0.06	0.01	0.06	0.20	0.07	0.14
Nashville warbler	-	0.03	0.04	-	0.32	0.23
northern parula	0.26	0.13	0.32	3.09	1.51	2.01
orange-crowned warbler	-	0.01	0.01	-	0.05	0.04
ovenbird	2.24	0.32	1.93	23.00	3.71	10.98
palm warbler	-	0.24	0.33	-	1.54	1.12
pine warbler	-	0.04	0.06	-	0.39	0.28
Tennessee warbler	0.02	0.32	0.44	0.28	1.95	1.49
unidentified warbler	0.02	5.62	7.32	0.26	12.75	8.69
Wilson's warbler	-	0.03	0.02	-	0.32	0.12
worm-eating warbler	0.03	0.08	0.11	0.38	1.01	0.69

Table 3.

Estimated percent composition (mean use divided by total use for all species) and frequency of occurrence (percent of surveys species is recorded) for each species observed within 50 m of the survey point

	% Composition			% Frequency		
Species/Group	**Spring**	**Fall**	**Overall**	**Spring**	**Fall**	**Overall**
yellow warbler	0.01	-	0.00	0.09	-	0.02
yellow-breasted chat	0.01	0.00	0.01	0.18	0.03	0.07
yellow-rumped warbler	-	0.60	0.77	-	3.13	2.18
yellow-throated warbler	0.02	0.01	0.02	0.20	0.03	0.10
Waxwings	**0.43**	**3.21**	**4.68**	**1.39**	**5.07**	**4.23**
bohemian waxwing	-	0.02	0.03	-	0.19	0.13
cedar waxwing	0.43	3.19	4.65	1.39	4.88	4.11
Wrens	**0.87**	**0.30**	**0.87**	**9.58**	**3.18**	**5.06**
Carolina wren	0.29	0.06	0.26	3.42	0.67	1.67
house wren	0.53	0.11	0.41	5.72	1.13	2.31
marsh wren	0.00	-	0.00	0.06	-	0.02
unidentified wren	-	0.02	0.02	-	0.21	0.16
winter wren	0.05	0.12	0.17	0.56	1.17	0.95
unidentified passerine	**-**	**0.00**	**0.00**	**-**	**0.02**	**0.02**
Other Birds	**-**	**0.09**	**0.08**	**-**	**0.68**	**0.32**
belted kingfisher	-	0.04	0.03	-	0.43	0.19
common nighthawk	-	0.05	0.05	-	0.25	0.13
unidentified bird	**0.06**	**0.01**	**0.05**	**0.18**	**0.07**	**0.10**

Table 4.
Flight height characteristics of bird species/groups observed during the fixed-point surveys.

Species/Group	Number birds flying	Number groups flying	Percent of birds flying	<25m	25-115m	> 115m
Waterfowl	**173**	**22**	**35.31**	**36.42**	**43.93**	**19.65**
Canada goose	154	15	36.32	38.31	39.61	22.08
mallard	10	3	19.23	0.00	100.00	0.00
unidentified duck	1	1	100.00	0.00	100.00	0.00
wood duck	8	3	61.54	50.00	50.00	0.00
Waterbirds	**5**	**5**	**31.25**	**20.00**	**80.00**	**0.00**
American bittern	1	1	100.00	0.00	100.00	0.00
great blue heron	4	4	57.14	25.00	75.00	0.00
green heron	0	0	0.00	N/A	N/A	N/A
pied-billed grebe	0	0	0.00	N/A	N/A	N/A
Shorebirds	**19**	**15**	**18.27**	**78.95**	**21.05**	**0.00**
American woodcock	0	0	0.00	N/A	N/A	N/A
common snipe	0	0	0.00	N/A	N/A	N/A
dunlin	2	1	100.00	0.00	100.00	0.00
killdeer	17	14	20.99	88.24	11.76	0.00
semipalmated plover	0	0	0.00	N/A	N/A	N/A
solitary sandpiper	0	0	0.00	N/A	N/A	N/A
spotted sandpiper	0	0	0.00	N/A	N/A	N/A
Rails/Coots	**2**	**1**	**20.00**	**100.00**	**0.00**	**0.00**
American coot	2	1	100.00	100.00	0.00	0.00
sora	0	0	0.00	N/A	N/A	N/A
Raptors	**534**	**265**	**48.99**	**17.04**	**78.09**	**4.87**
Kites						
Mississippi Kite	1	1	100.00	0.00	100.00	0.00
Accipiters	**29**	**27**	**72.50**	**41.38**	**58.62**	**0.00**
Cooper's hawk	10	10	55.56	70.00	30.00	0.00
northern goshawk	2	2	100.00	100.00	0.00	0.00
sharp-shinned hawk	17	15	85.00	17.65	82.35	0.00
Buteos	**71**	**47**	**44.94**	**9.86**	**81.69**	**8.45**
broad-winged hawk	36	20	42.35	5.56	91.67	2.78
red-shouldered hawk	9	8	64.29	11.11	77.78	11.11
red-tailed hawk	26	19	44.07	15.38	69.23	15.38
northern harrier	**15**	**14**	**65.22**	**73.33**	**26.67**	**0.00**
Eagles	**5**	**5**	**71.43**	**0.00**	**80.00**	**20.00**
bald eagle	4	4	80.00	0.00	75.00	25.00
golden eagle	0	0	0.00	N/A	N/A	N/A
unidentified eagle	1	1	100.00	0.00	100.00	0.00
Falcons	**20**	**13**	**36.36**	**35.00**	**65.00**	**0.00**
American kestrel	16	9	32.00	31.25	68.75	0.00
merlin	4	4	80.00	50.00	50.00	0.00
peregrine falcon	0	0	0.00	N/A	N/A	N/A
Owls	**0**	**0**	**0.00**	**N/A**	**N/A**	**N/A**
barred owl	0	0	0.00	N/A	N/A	N/A
eastern screech-owl	0	0	0.00	N/A	N/A	N/A
northern saw-whet owl	0	0	0.00	N/A	N/A	N/A

Table 4.

Flight height characteristics of bird species/groups observed during the fixed-point surveys.

Species/Group	Number birds flying	Number groups flying	Percent of birds flying	<25m	25-115m	> 115m
Vultures	**382**	**148**	**49.35**	**13.87**	**81.15**	**4.97**
black vulture	9	5	42.86	0.00	100.00	0.00
turkey vulture	373	143	49.54	14.21	80.70	5.09
Other - Raptors	**11**	**10**	**84.62**	**9.09**	**90.91**	**0.00**
osprey	7	7	77.78	0.00	100.00	0.00
unidentified raptor	4	3	100.00	25.00	75.00	0.00
Upland Gamebirds	**7**	**7**	**5.47**	**71.43**	**28.57**	**0.00**
ruffed grouse	6	6	14.63	83.33	16.67	0.00
wild turkey	1	1	1.15	0.00	100.00	0.00
Doves/Pigeons	**12**	**7**	**9.68**	**33.33**	**66.67**	**0.00**
mourning dove	11	6	8.94	36.36	63.64	0.00
rock dove	1	1	100.00	0.00	100.00	0.00
Cuckooes	**2**	**2**	**5.41**	**50.00**	**50.00**	**0.00**
black-billed cuckoo	0	0	0.00	N/A	N/A	N/A
yellow-billed cuckoo	2	2	9.52	50.00	50.00	0.00
Swifts/Hummingbirds	**8**	**5**	**66.67**	**50.00**	**50.00**	**0.00**
chimney swift	4	1	100.00	0.00	100.00	0.00
ruby-throated hummingbird	4	4	50.00	100.00	0.00	0.00
Woodpeckers	**147**	**72**	**22.93**	**80.95**	**19.05**	**0.00**
downy woodpecker	21	14	13.73	76.19	23.81	0.00
hairy woodpecker	5	5	6.02	60.00	40.00	0.00
northern flicker	94	33	37.45	88.30	11.70	0.00
pileated woodpecker	10	9	11.11	80.00	20.00	0.00
red-bellied woodpecker	6	5	20.69	100.00	0.00	0.00
red-headed woodpecker	1	1	25.00	100.00	0.00	0.00
unidentified woodpecker	1	1	16.67	100.00	0.00	0.00
yellow-bellied sapsucker	9	4	36.00	11.11	88.89	0.00
Passerines	**3499**	**895**	**23.26**	**68.02**	**31.98**	**0.00**
Blackbirds/Orioles	**245**	**39**	**32.97**	**68.98**	**31.02**	**0.00**
Baltimore oriole	0	0	0.00	N/A	N/A	N/A
Bullock's oriole	0	0	0.00	N/A	N/A	N/A
European starling	82	9	84.54	59.76	40.24	0.00
bobolink	6	3	75.00	50.00	50.00	0.00
brown-headed cowbird	18	5	34.62	61.11	38.89	0.00
common grackle	15	1	88.24	100.00	0.00	0.00
eastern meadowlark	8	2	32.00	100.00	0.00	0.00
red-winged blackbird	116	19	22.92	71.55	28.45	0.00
rusty blackbird	0	0	0.00	N/A	N/A	N/A
unidentified blackbird	0	0	0.00	N/A	N/A	N/A
Corvids	**918**	**265**	**33.27**	**43.79**	**56.21**	**0.00**
American crow	492	131	31.89	37.80	62.20	0.00
blue Jay	231	51	29.58	56.71	43.29	0.00
common raven	195	83	44.83	43.59	56.41	0.00

Table 4.
Flight height characteristics of bird species/groups observed during the fixed-point surveys.

Species/Group	Number birds flying	Number groups flying	Percent of birds flying	<25m	25-115m	> 115m
Creepers/Nuthatches	**7**	**6**	**3.66**	**57.14**	**42.86**	**0.00**
brown creeper	0	0	0.00	N/A	N/A	N/A
red-breasted nuthatch	1	1	2.13	100.00	0.00	0.00
white-breasted nuthatch	6	5	4.55	50.00	50.00	0.00
Finches	**197**	**79**	**33.97**	**62.94**	**37.06**	**0.00**
American goldfinch	191	75	34.29	61.78	38.22	0.00
pine siskin	1	1	100.00	100.00	0.00	0.00
purple finch	5	3	25.00	100.00	0.00	0.00
unidentified finch	0	0	0.00	N/A	N/A	N/A
Flycatchers	**25**	**15**	**6.00**	**76.00**	**24.00**	**0.00**
acadian flycatcher	0	0	0.00	N/A	N/A	N/A
alder flycatcher	0	0	0.00	N/A	N/A	N/A
eastern kingbird	1	1	20.00	100.00	0.00	0.00
eastern phoebe	14	9	7.87	57.14	42.86	0.00
eastern wood-pewee	0	0	0.00	N/A	N/A	N/A
great crested flycatcher	3	3	3.23	100.00	0.00	0.00
least flycatcher	6	1	31.58	100.00	0.00	0.00
olive-sided flycatcher	0	0	0.00	N/A	N/A	N/A
unidentified empidonax	1	1	6.67	100.00	0.00	0.00
yellow-bellied flycatcher	0	0	0.00	N/A	N/A	N/A
Gnatcatchers/Kinglet	**60**	**13**	**27.65**	**93.33**	**6.67**	**0.00**
blue gray gnatcatcher	0	0	0.00	N/A	N/A	N/A
golden-crowned kinglet	5	2	7.81	20.00	80.00	0.00
ruby-crowned kinglet	55	11	38.46	100.00	0.00	0.00
Grassland/Sparrows	**220**	**81**	**7.23**	**90.00**	**10.00**	**0.00**
American pipit	8	3	47.06	37.50	62.50	0.00
chipping sparrow	34	13	4.66	100.00	0.00	0.00
clay-colored sparrow	0	0	0.00	N/A	N/A	N/A
dark-eyed junco	39	7	30.47	100.00	0.00	0.00
eastern towhee	23	12	3.10	100.00	0.00	0.00
field sparrow	9	5	3.47	100.00	0.00	0.00
grasshopper sparrow	2	1	1.92	100.00	0.00	0.00
horned lark	3	3	6.82	100.00	0.00	0.00
indigo bunting	4	3	1.90	75.00	25.00	0.00
lark sparrow	0	0	0.00	N/A	N/A	N/A
Lincoln's sparrow	4	2	25.00	100.00	0.00	0.00
northern cardinal	8	5	11.43	87.50	12.50	0.00
savannah sparrow	2	1	4.88	100.00	0.00	0.00
song sparrow	16	8	4.52	100.00	0.00	0.00
swamp sparrow	0	0	0.00	N/A	N/A	N/A
unidentified sparrow	0	0	0.00	N/A	N/A	N/A
vesper sparrow	42	14	19.44	64.29	35.71	0.00
white-throated sparrow	26	4	29.21	100.00	0.00	0.00
Mimids	**8**	**7**	**5.23**	**100.00**	**0.00**	**0.00**
brown thrasher	1	1	2.63	100.00	0.00	0.00
gray catbird	7	6	6.14	100.00	0.00	0.00
northern mockingbird	0	0	0.00	N/A	N/A	N/A
Swallows	**126**	**36**	**75.45**	**91.27**	**8.73**	**0.00**
barn swallow	77	24	70.00	100.00	0.00	0.00
cliff swallow	0	0	0.00	N/A	N/A	N/A

Table 4.

Flight height characteristics of bird species/groups observed during the fixed-point surveys.

Species/Group	**Number birds flying**	**Number groups flying**	**Percent of birds flying**	**<25m**	**25-115m**	**> 115m**
northern rough-winged swallow	30	8	85.71	76.67	23.33	0.00
tree swallow	15	3	100.00	100.00	0.00	0.00
unidentified swallow	4	1	100.00	0.00	100.00	0.00
Tanagers/Groskbeaks	**59**	**21**	**20.85**	**81.36**	**18.64**	**0.00**
rose-breasted grosbeak	46	13	45.54	76.09	23.91	0.00
scarlet tanager	13	8	7.14	100.00	0.00	0.00
Thrushs	**203**	**56**	**21.80**	**77.34**	**22.66**	**0.00**
American robin	169	39	44.01	80.47	19.53	0.00
eastern bluebird	26	12	12.44	50.00	50.00	0.00
gray-cheeked thrush	0	0	0.00	N/A	N/A	N/A
hermit thrush	2	1	2.74	100.00	0.00	0.00
Swainson's thrush	0	0	0.00	N/A	N/A	N/A
unidentified thrush	0	0	0.00	N/A	N/A	N/A
Veery	0	0	0.00	N/A	N/A	N/A
wood thrush	6	4	2.87	100.00	0.00	0.00
Titmice/Chickadees	**56**	**22**	**7.40**	**94.64**	**5.36**	**0.00**
black-capped chickadee	49	17	9.94	97.96	2.04	0.00
tufted titmouse	7	5	2.65	71.43	28.57	0.00
Vireos	**30**	**15**	**4.26**	**53.33**	**46.67**	**0.00**
blue-headed vireo	10	6	5.41	100.00	0.00	0.00
Philadelphia vireo	0	0	0.00	N/A	N/A	N/A
red-eyed vireo	11	6	2.29	54.55	45.45	0.00
solitary vireo	9	3	52.94	0.00	100.00	0.00
white-eyed vireo	0	0	0.00	N/A	N/A	N/A
yellow-throated vireo	0	0	0.00	N/A	N/A	N/A
Warblers	**1031**	**201**	**31.83**	**83.90**	**16.10**	**0.00**
American redstart	3	3	6.38	33.33	66.67	0.00
bay-breasted warbler	4	3	6.78	100.00	0.00	0.00
black-and-white warbler	0	0	0.00	N/A	N/A	N/A
blackburnian warbler	2	1	7.69	100.00	0.00	0.00
blackpoll warbler	5	3	5.81	20.00	80.00	0.00
black-throated blue warbler	19	13	17.76	94.74	5.26	0.00
black-throated green warbler	31	12	7.36	64.52	35.48	0.00
blue-winged warbler	0	0	0.00	N/A	N/A	N/A
Canadian warbler	0	0	0.00	N/A	N/A	N/A
Cape May warbler	2	2	4.55	100.00	0.00	0.00
ceruleon warbler	0	0	0.00	N/A	N/A	N/A
chestnut-sided warbler	3	2	2.91	100.00	0.00	0.00
common yellowthroat	8	8	3.94	100.00	0.00	0.00
Connecticut warbler	0	0	0.00	N/A	N/A	N/A
golden-winged warbler	0	0	0.00	N/A	N/A	N/A
hooded warbler	5	2	7.81	60.00	40.00	0.00
Kentucky warbler	1	1	25.00	100.00	0.00	0.00
magnolia warbler	19	6	10.86	100.00	0.00	0.00
mourning warbler	1	1	14.29	100.00	0.00	0.00
myrtle warbler	12	1	60.00	100.00	0.00	0.00
Nashville warbler	3	2	42.86	100.00	0.00	0.00
northern parula	0	0	0.00	N/A	N/A	N/A
orange-crowned warbler	0	0	0.00	N/A	N/A	N/A
ovenbird	6	4	1.67	100.00	0.00	0.00

Table 4.

Flight height characteristics of bird species/groups observed during the fixed-point surveys.

Species/Group	**Number birds flying**	**Number groups flying**	**Percent of birds flying**	**<25m**	**25-115m**	**> 115m**
palm warbler	8	7	15.69	100.00	0.00	0.00
pine warbler	3	3	30.00	100.00	0.00	0.00
Tennessee warbler	4	2	6.90	50.00	50.00	0.00
unidentified warbler	825	101	72.05	85.09	14.91	0.00
Wilson's warbler	1	1	50.00	100.00	0.00	0.00
worm-eating warbler	0	0	0.00	N/A	N/A	N/A
yellow warbler	0	0	0.00	N/A	N/A	N/A
yellow-breasted chat	0	0	0.00	N/A	N/A	N/A
yellow-rumped warbler	63	22	57.80	66.67	33.33	0.00
yellow-throated warbler	3	1	37.50	100.00	0.00	0.00
Waxwings	**304**	**30**	**44.44**	**44.74**	**55.26**	**0.00**
bohemian waxwing	0	0	0.00	N/A	N/A	N/A
cedar waxwing	304	30	44.90	44.74	55.26	0.00
Carolina wren	0	0	0.00	N/A	N/A	N/A
Wrens	**8**	**7**	**4.60**	**100.00**	**0.00**	**0.00**
house wren	2	2	2.15	100.00	0.00	0.00
marsh wren	1	1	100.00	100.00	0.00	0.00
unidentified wren	0	0	0.00	N/A	N/A	N/A
winter wren	5	4	18.52	100.00	0.00	0.00
unidentified passerine	**2**	**2**	**100.00**	**100.00**	**0.00**	**0.00**
Other Birds	**8**	**5**	**80.00**	**25.00**	**75.00**	**0.00**
belted kingfisher	2	2	50.00	100.00	0.00	0.00
common nighthawk	6	3	100.00	0.00	100.00	0.00
unidentified bird	**4**	**2**	**66.67**	**100.00**	**0.00**	**0.00**
Overall	**4420**	**1303**	**24.95**	**60.88**	**37.76**	**1.36**

Figure 1. Proposed Mount Storm Wind Power Project location.

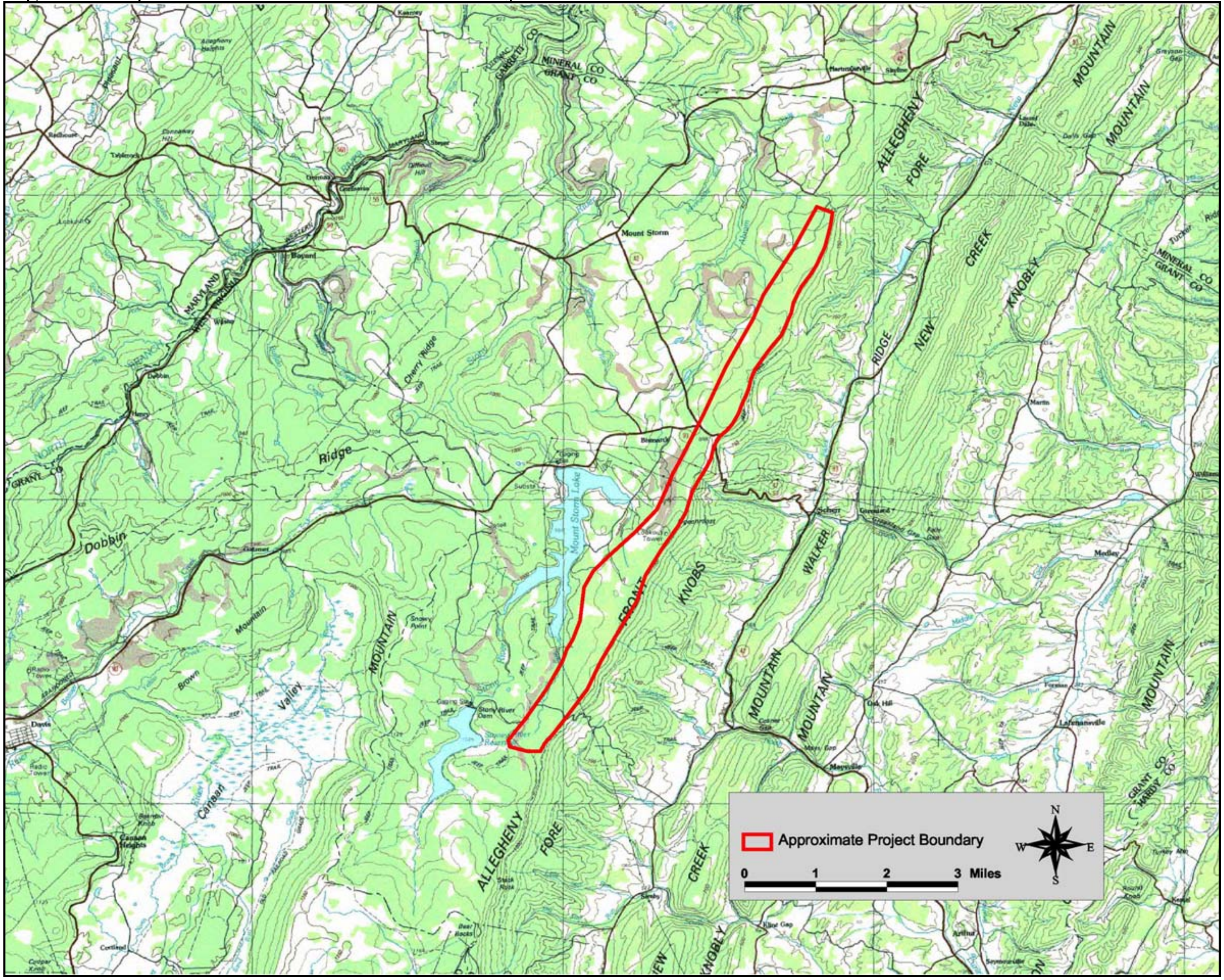


Figure 2. Fixed-point survey plots.

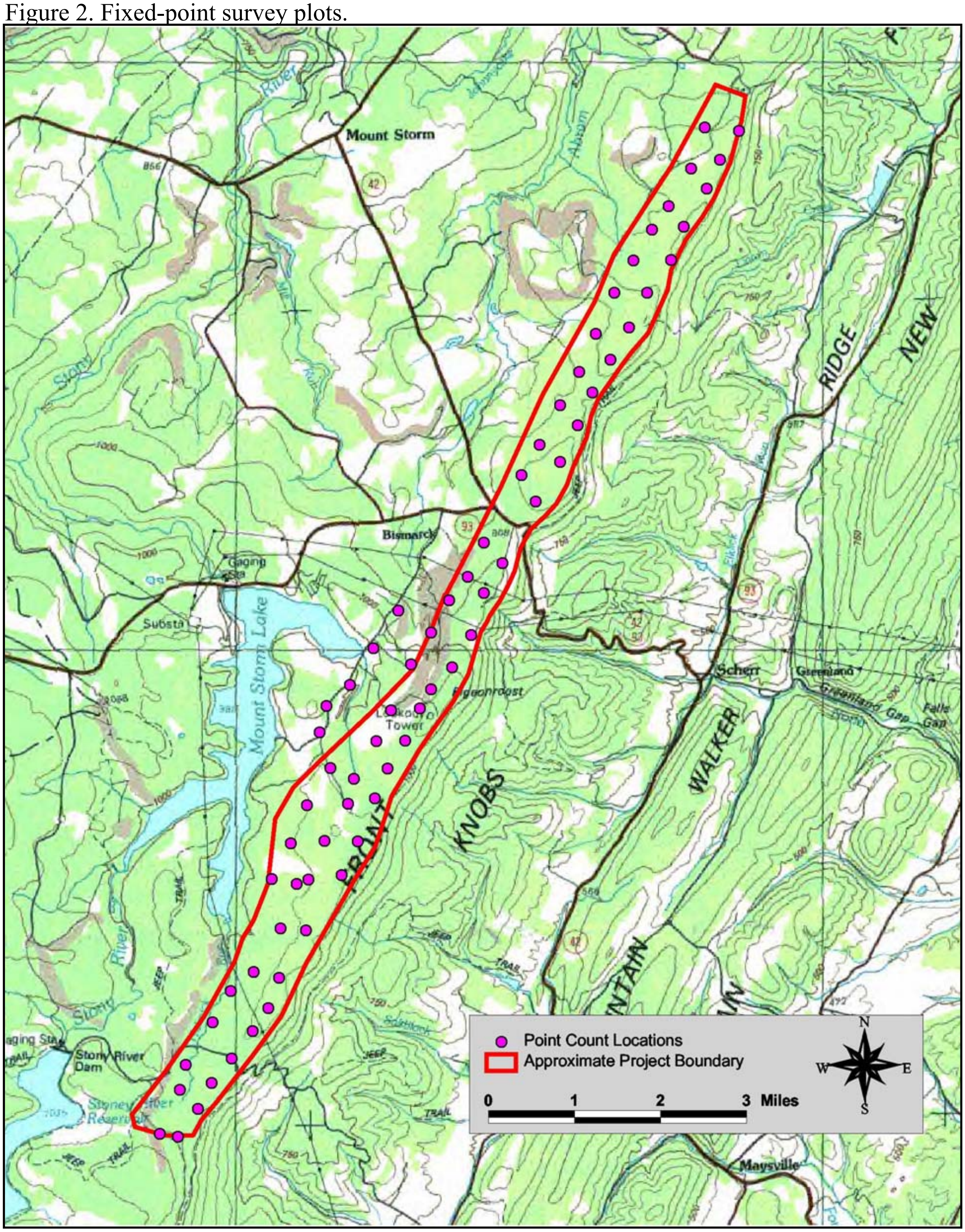


Figure 3. Radar sampling station locations.

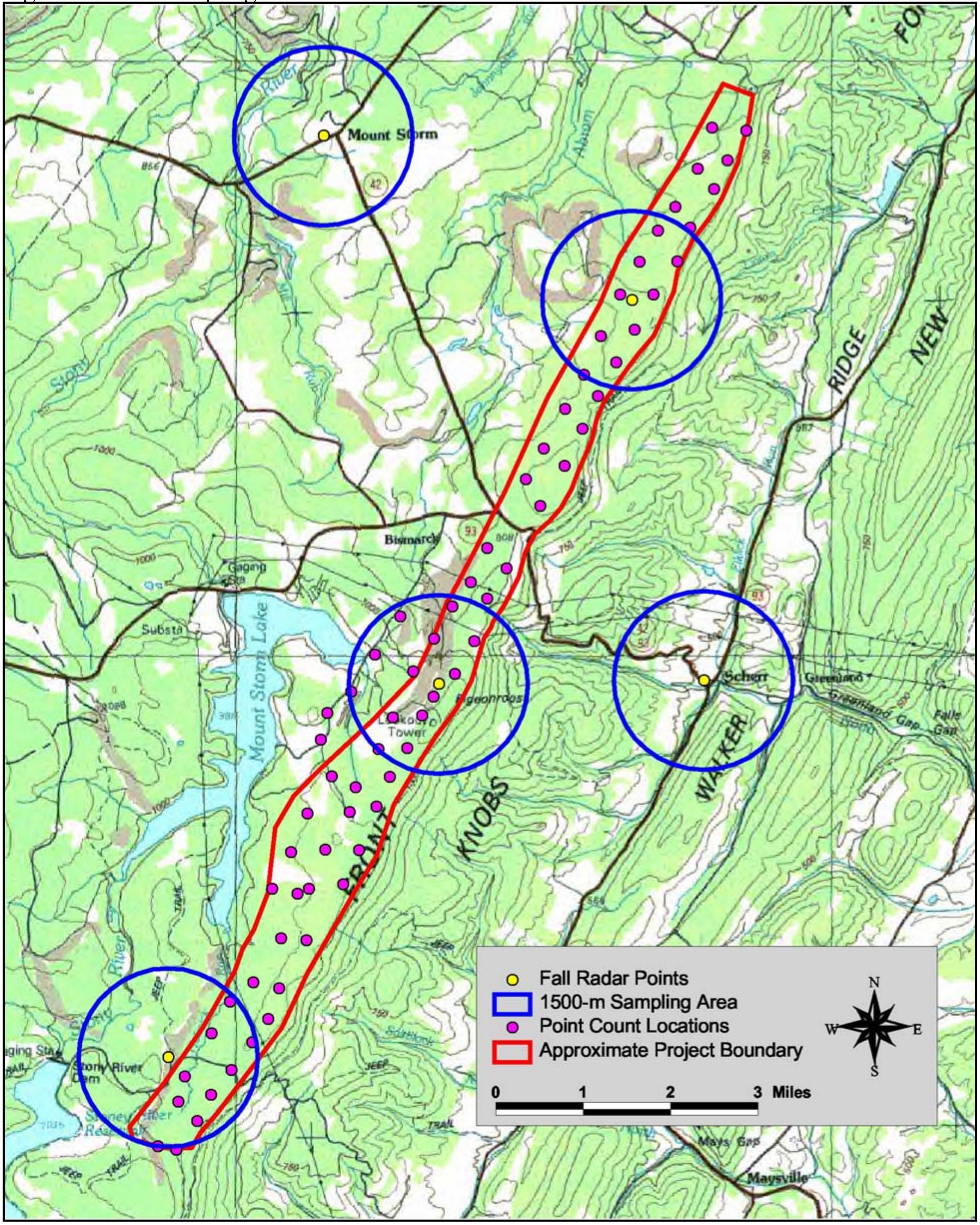


Figure 4a. Bird use by survey point – spring.

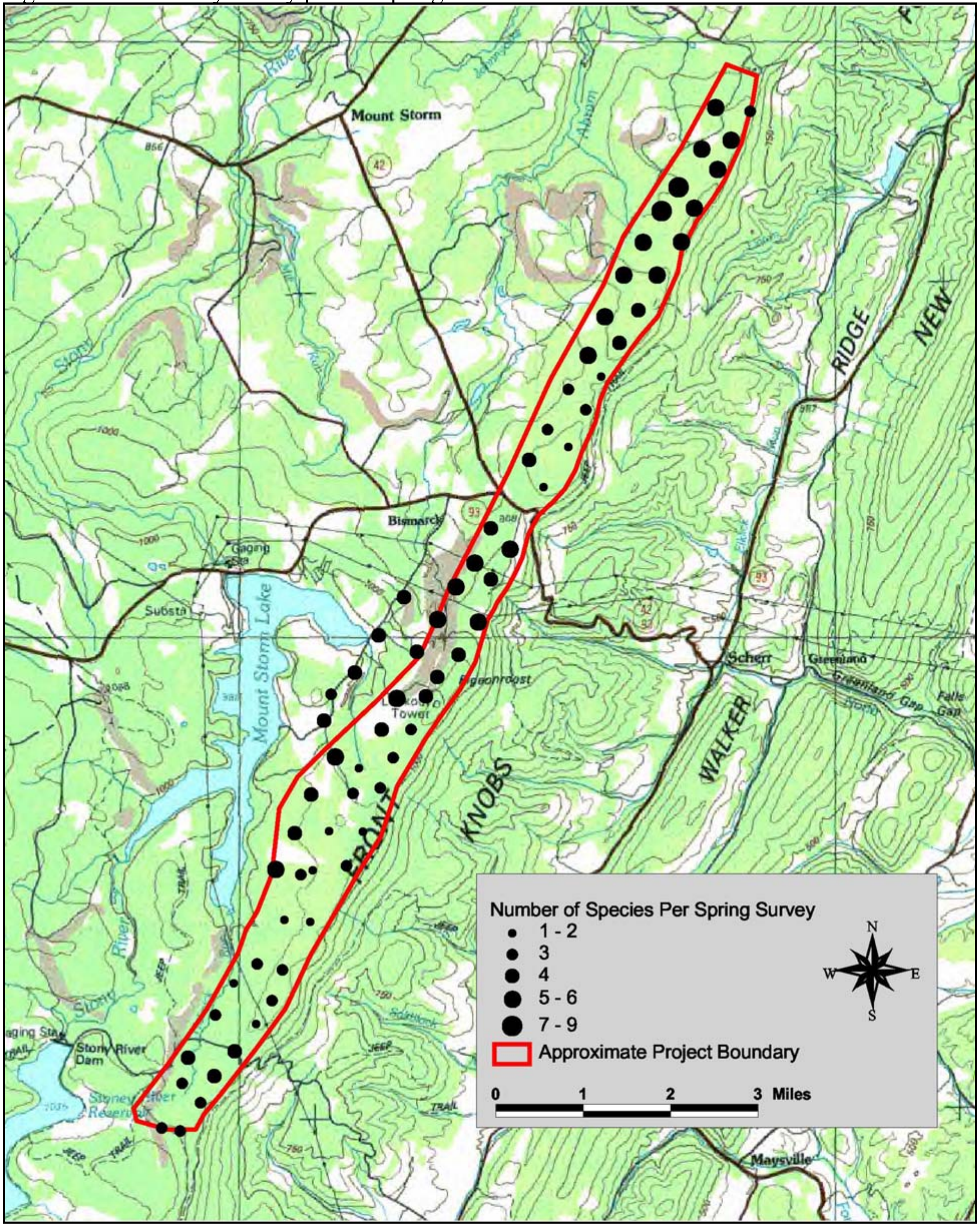


Figure 4b. Bird use by survey point - fall.

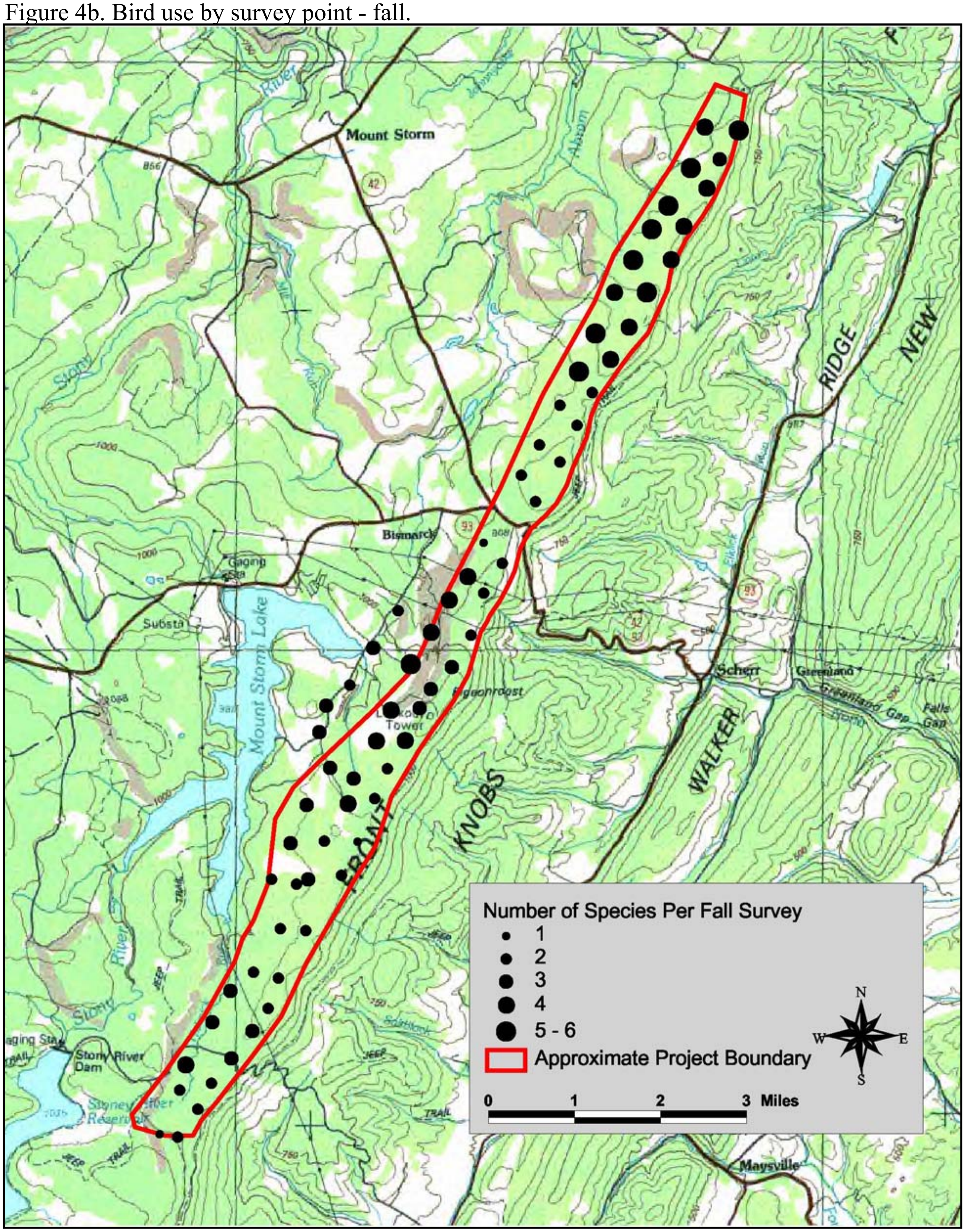


Figure 5a. Number of species per survey by survey point - spring.

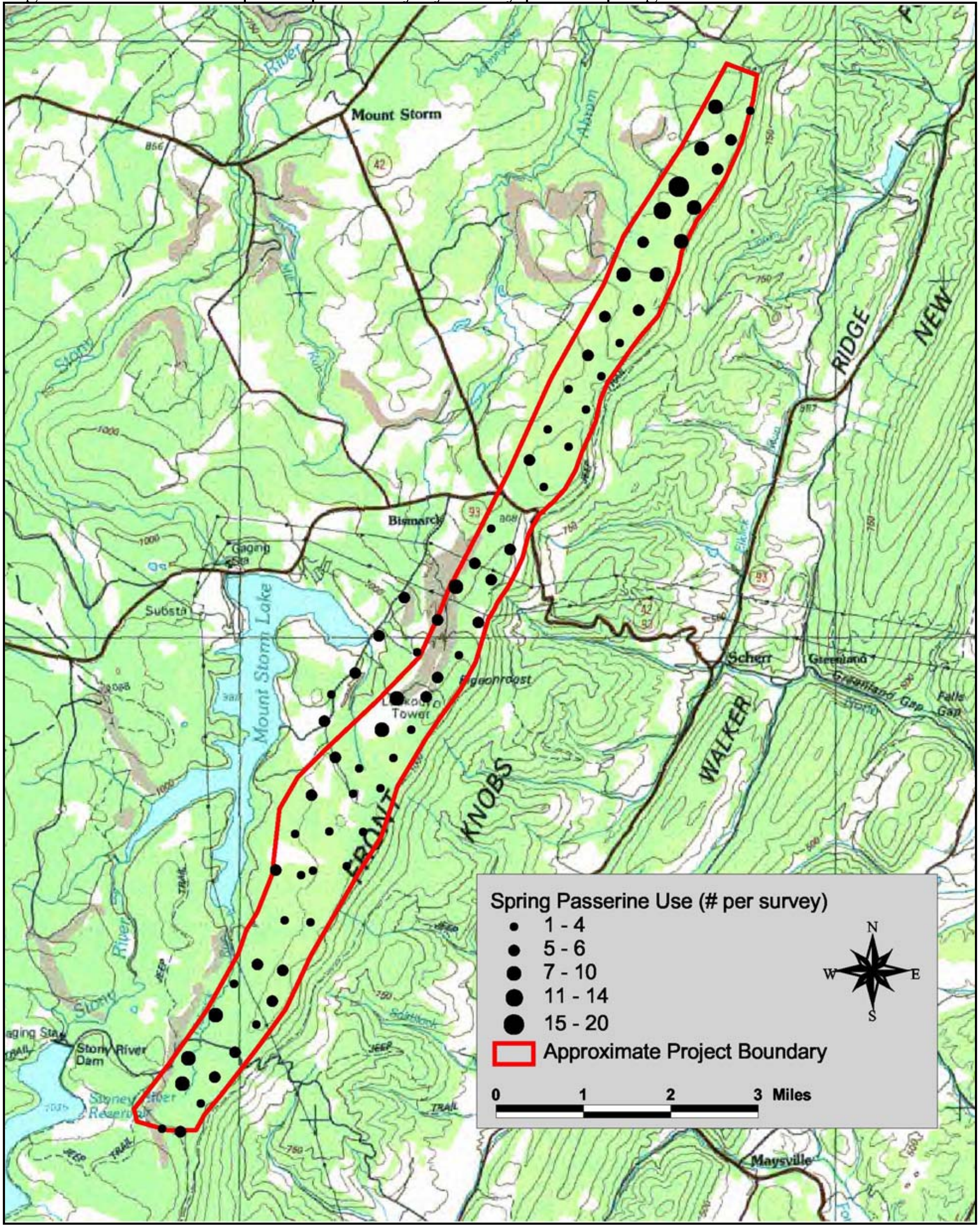


Figure 5b. Number of species per survey by survey point – fall.

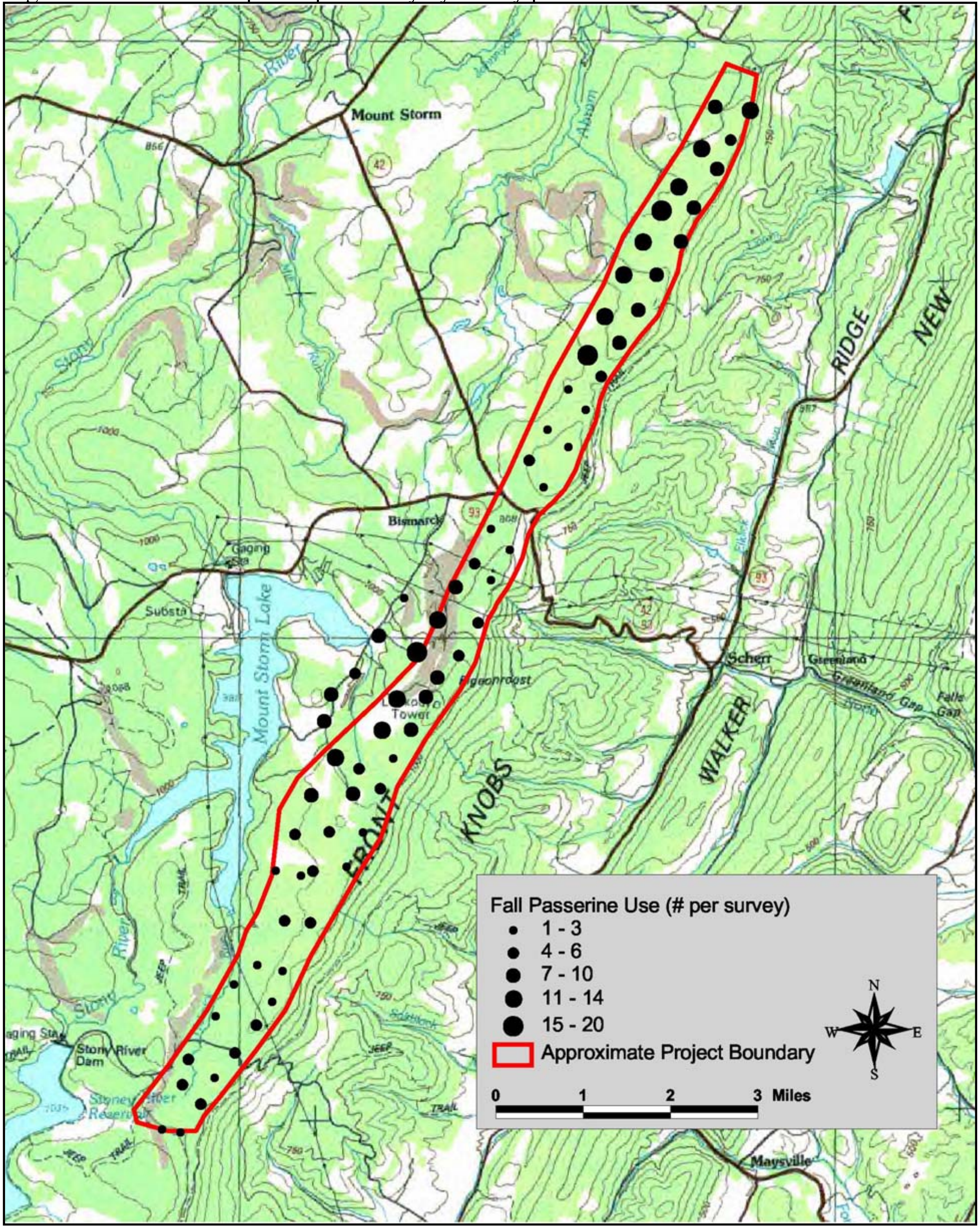


Figure 6a. Mean use and frequency of occurrence for avian groups by 5-day period from May 1 to June 15.

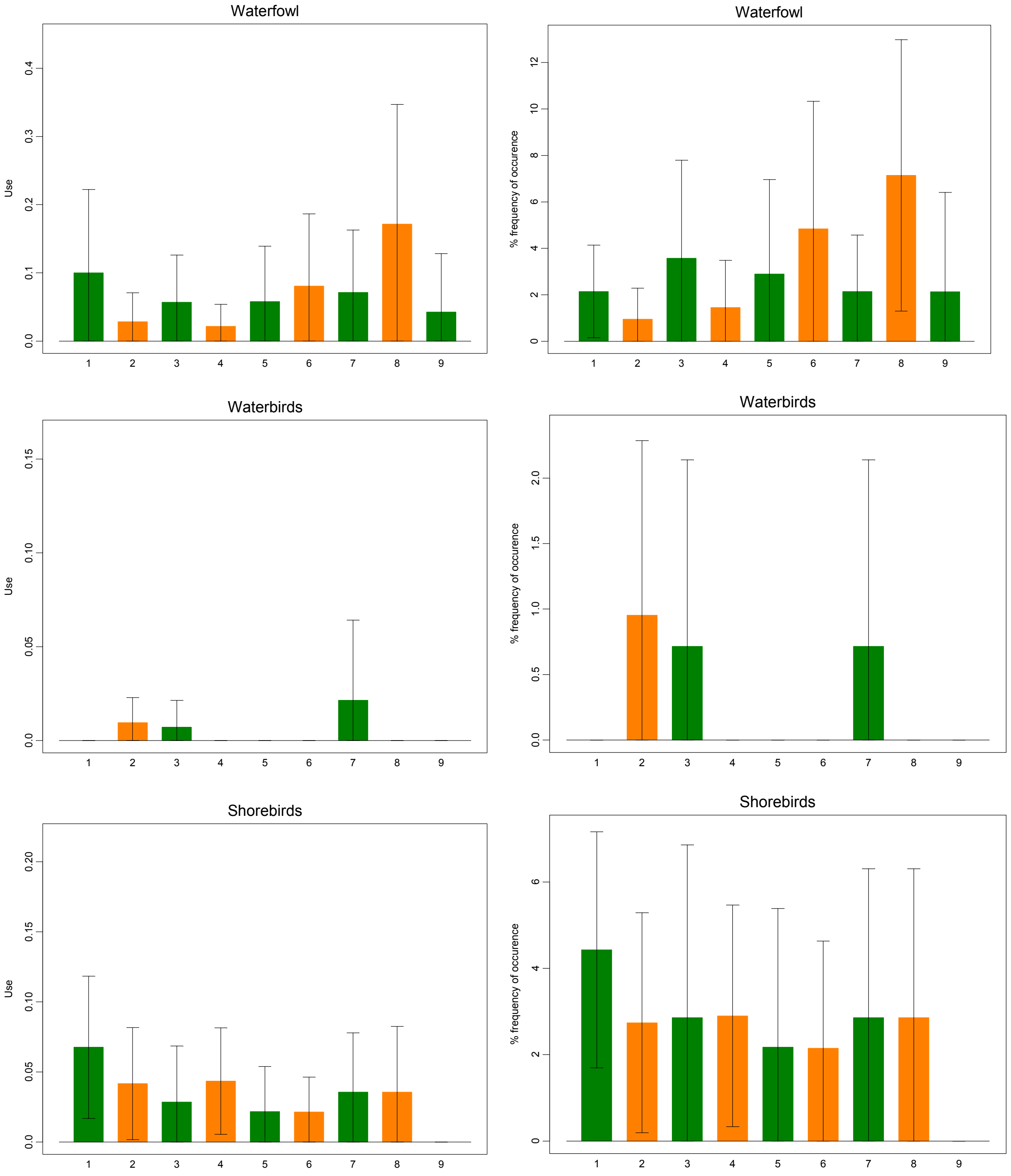


Figure 6a. (continued).

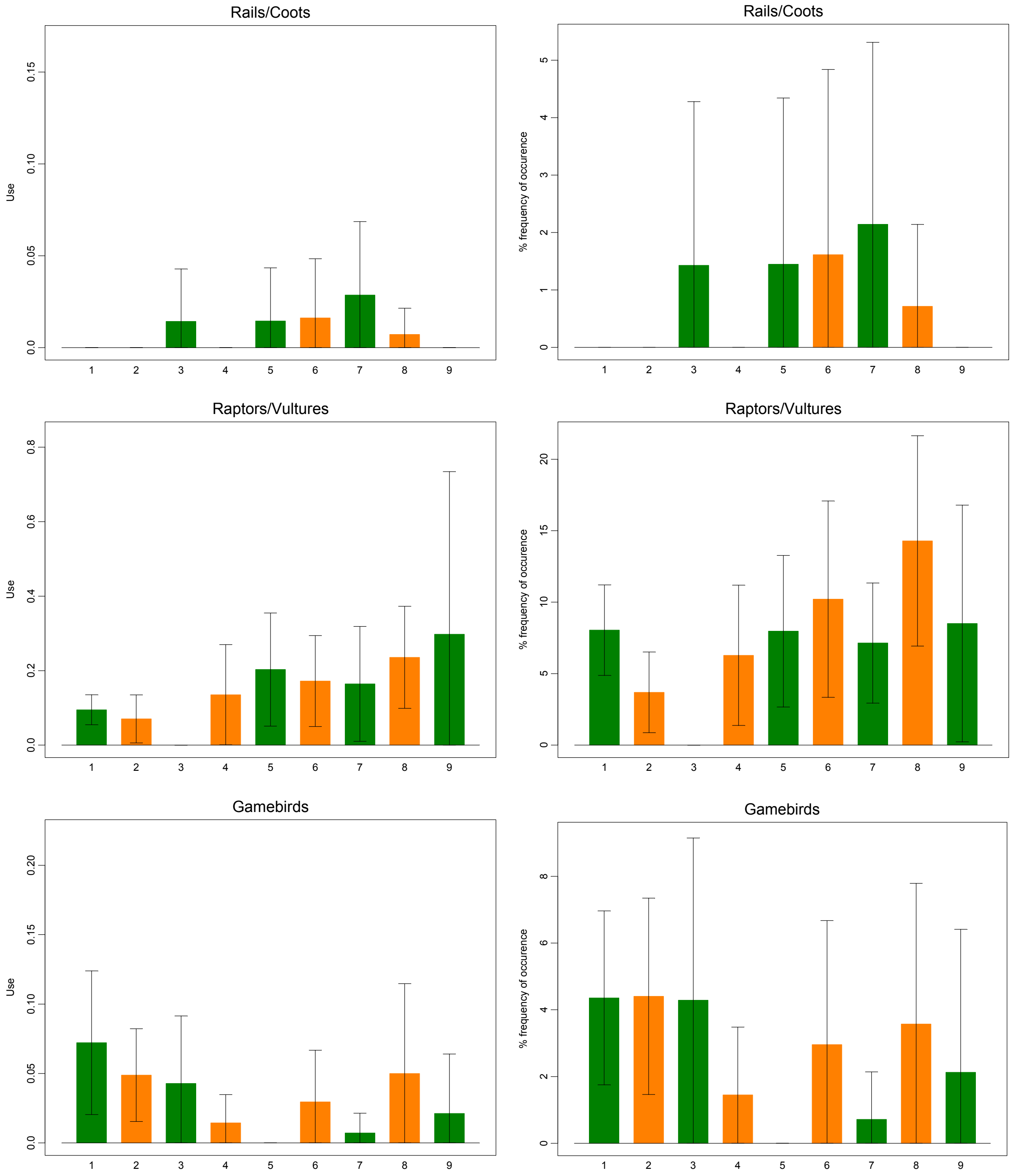


Figure 6a. (continued).

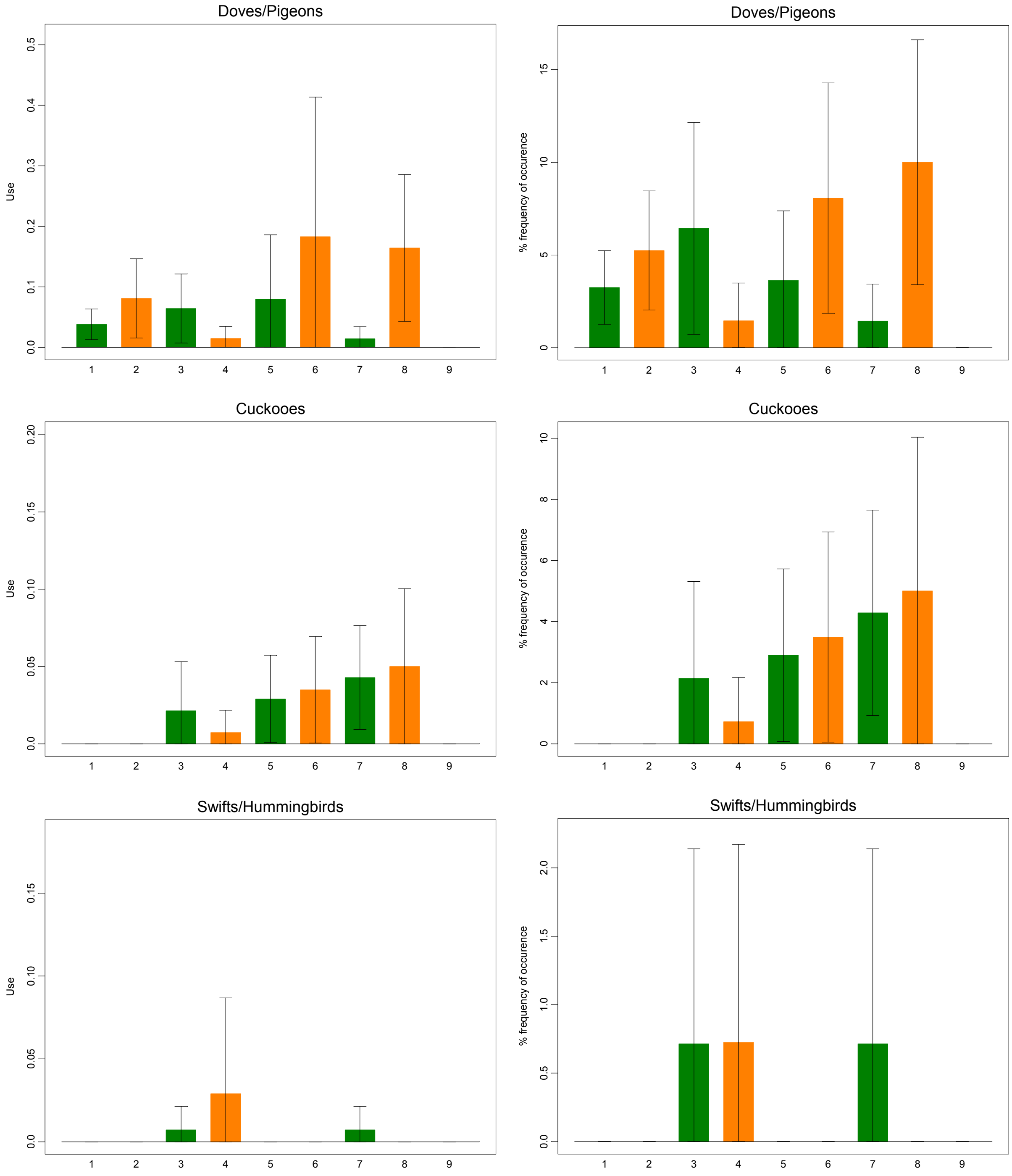


Figure 6a. (continued).

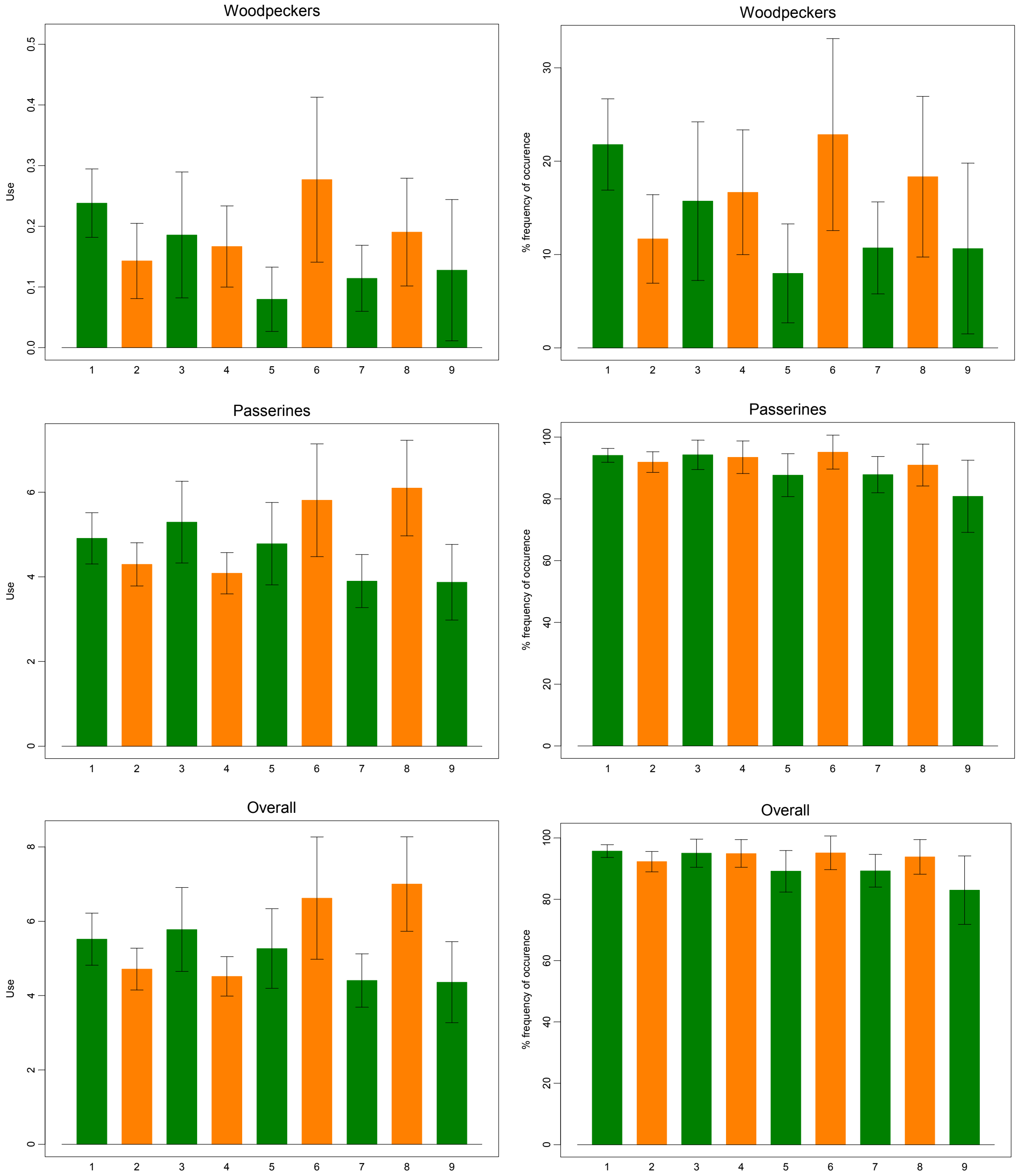


Figure 6b. Mean use and frequency of occurrence for avian groups by 1-day period from August 14 – October 15, 2003.

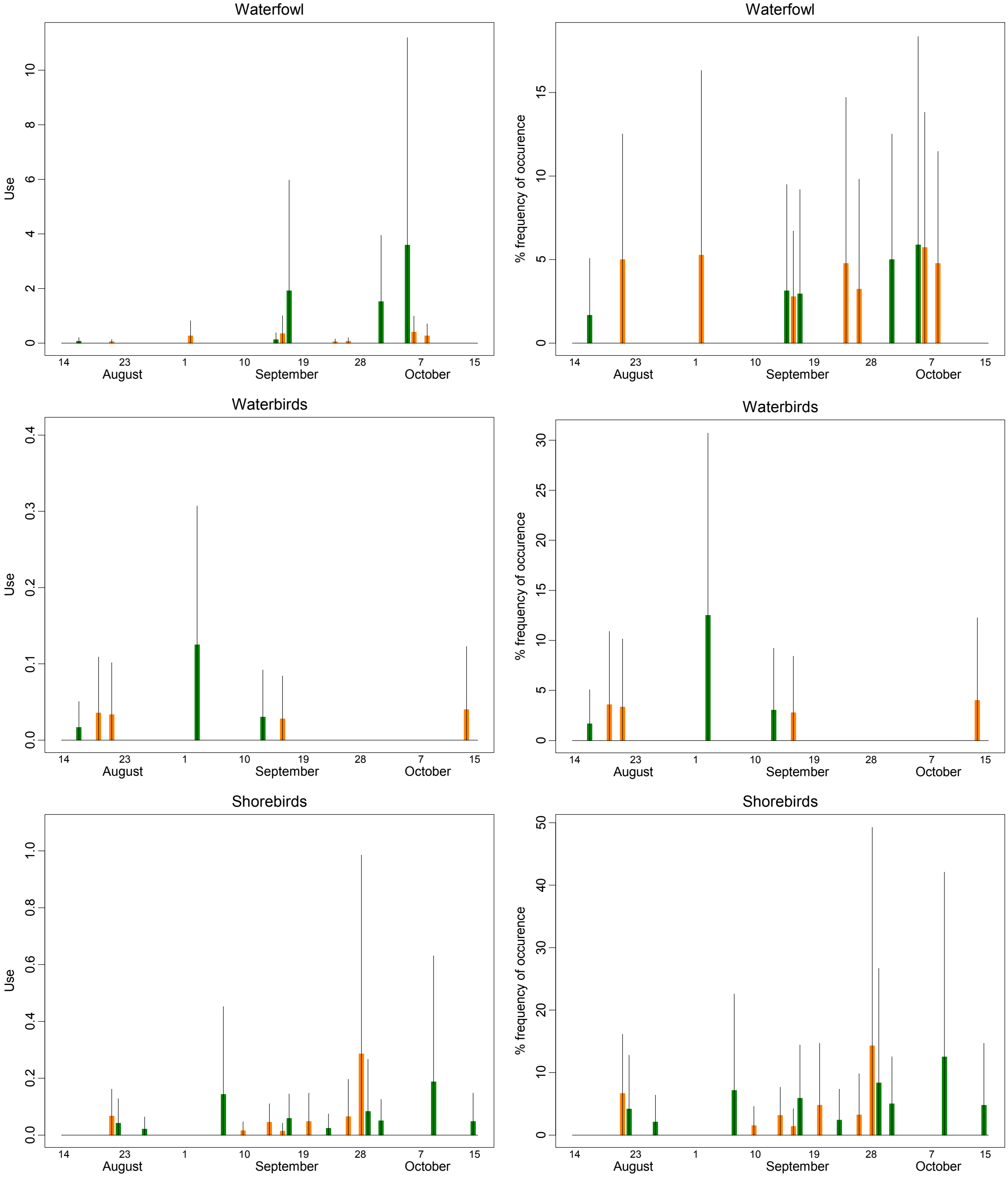


Figure 6b. (continued).

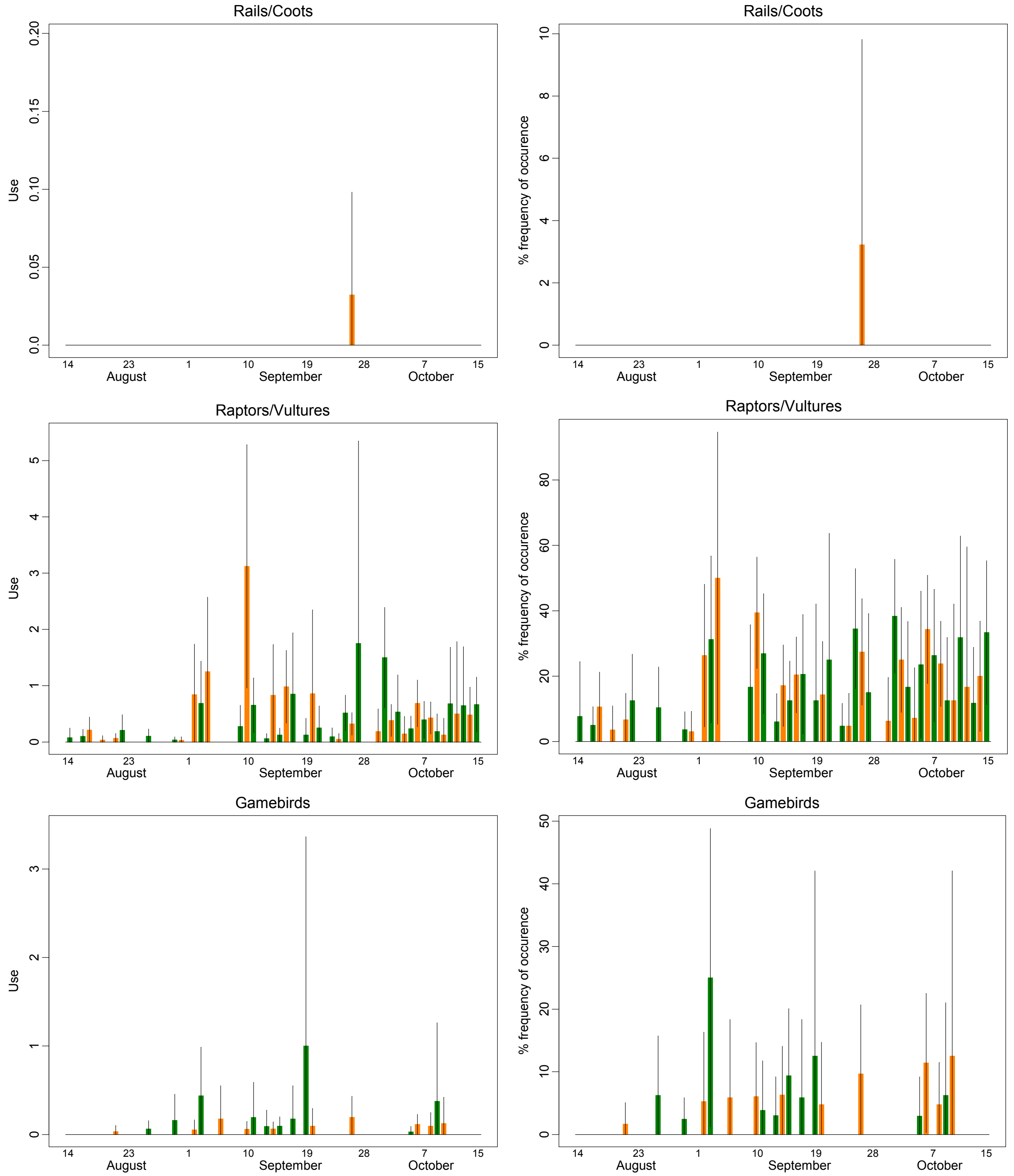


Figure 6b. (continued).

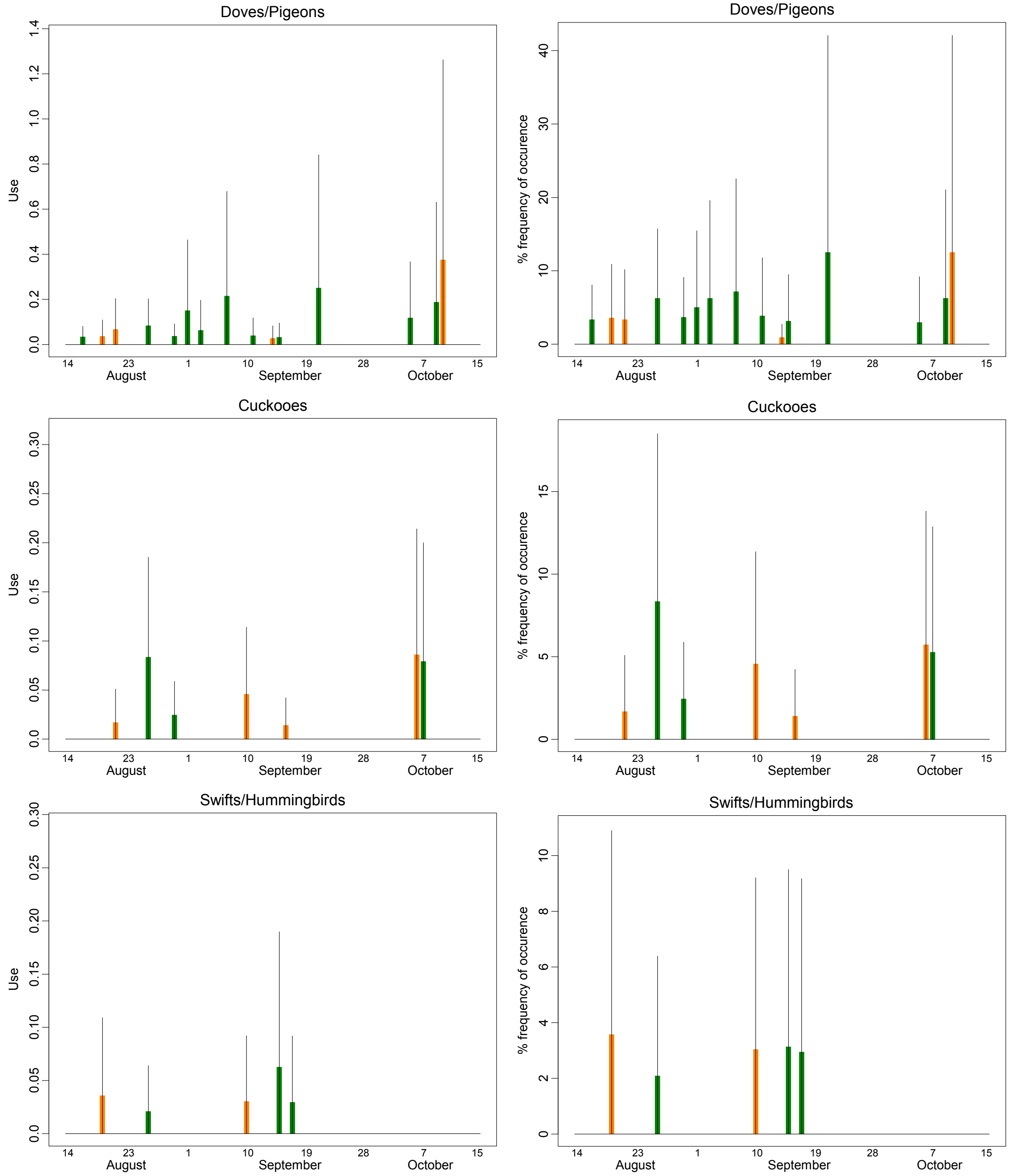


Figure 6b. (continued).

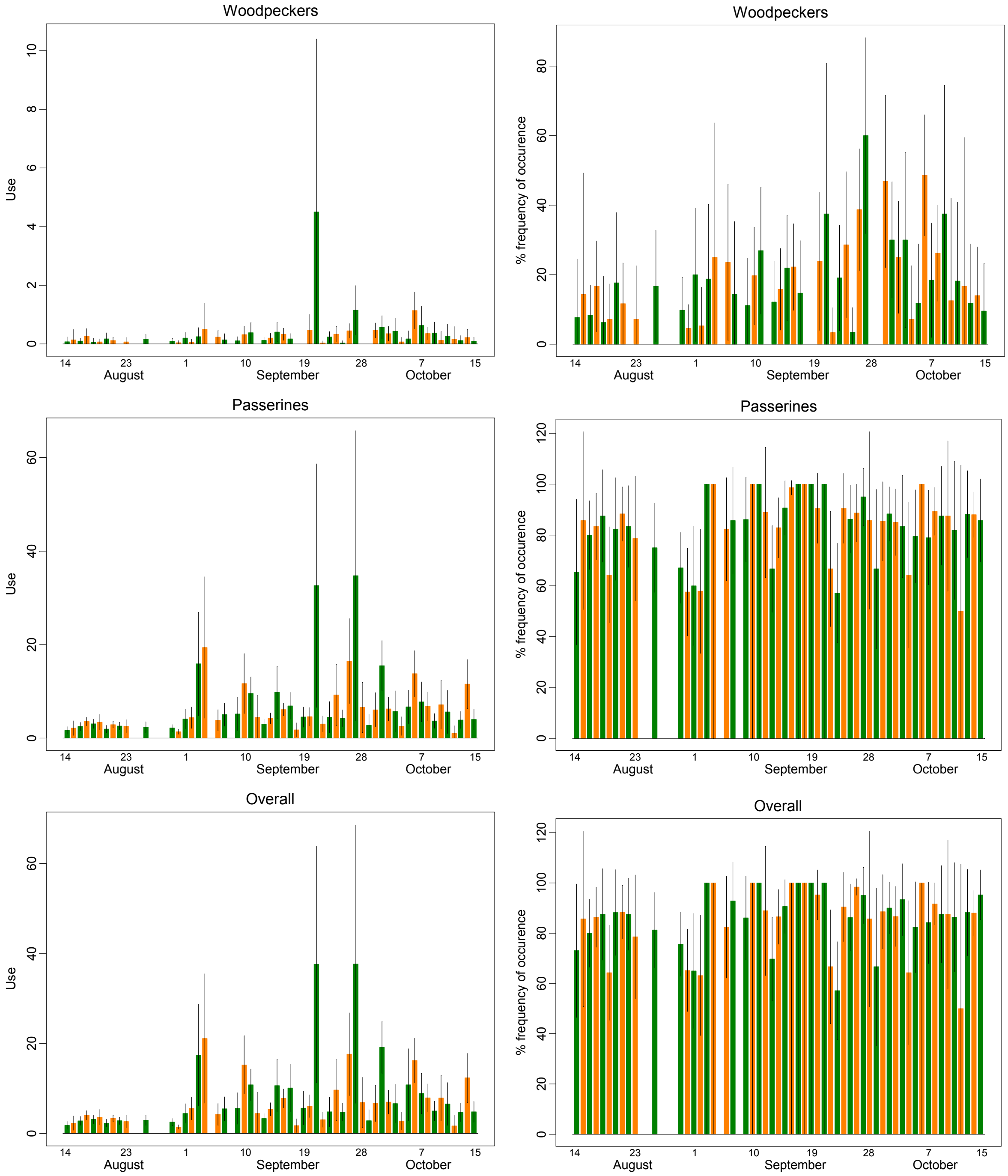


Figure 7a. Mean difference in use over two hour time periods (bar represents $\pm$1 standard error) for the spring period.

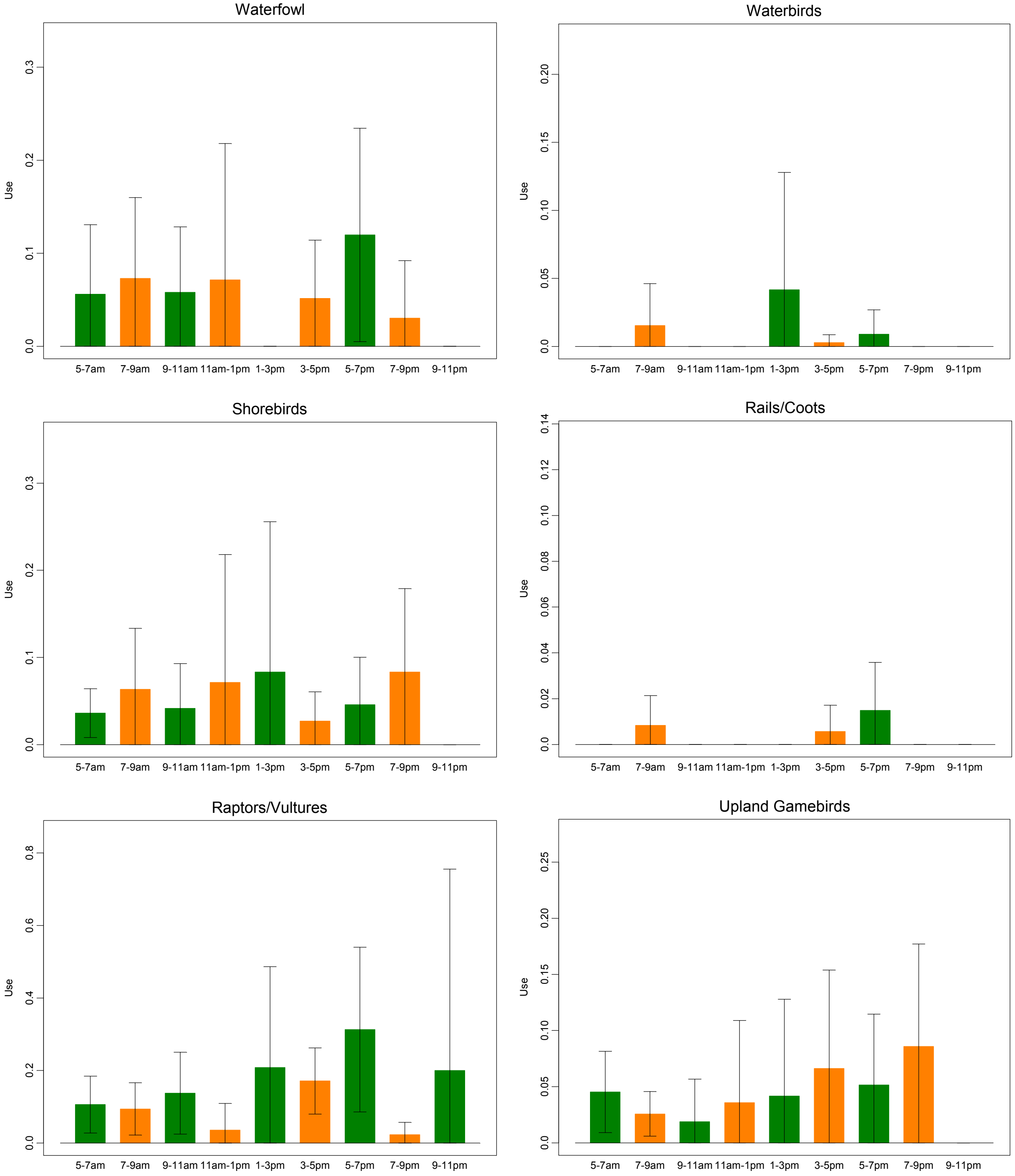


Figure 7a. (continued).

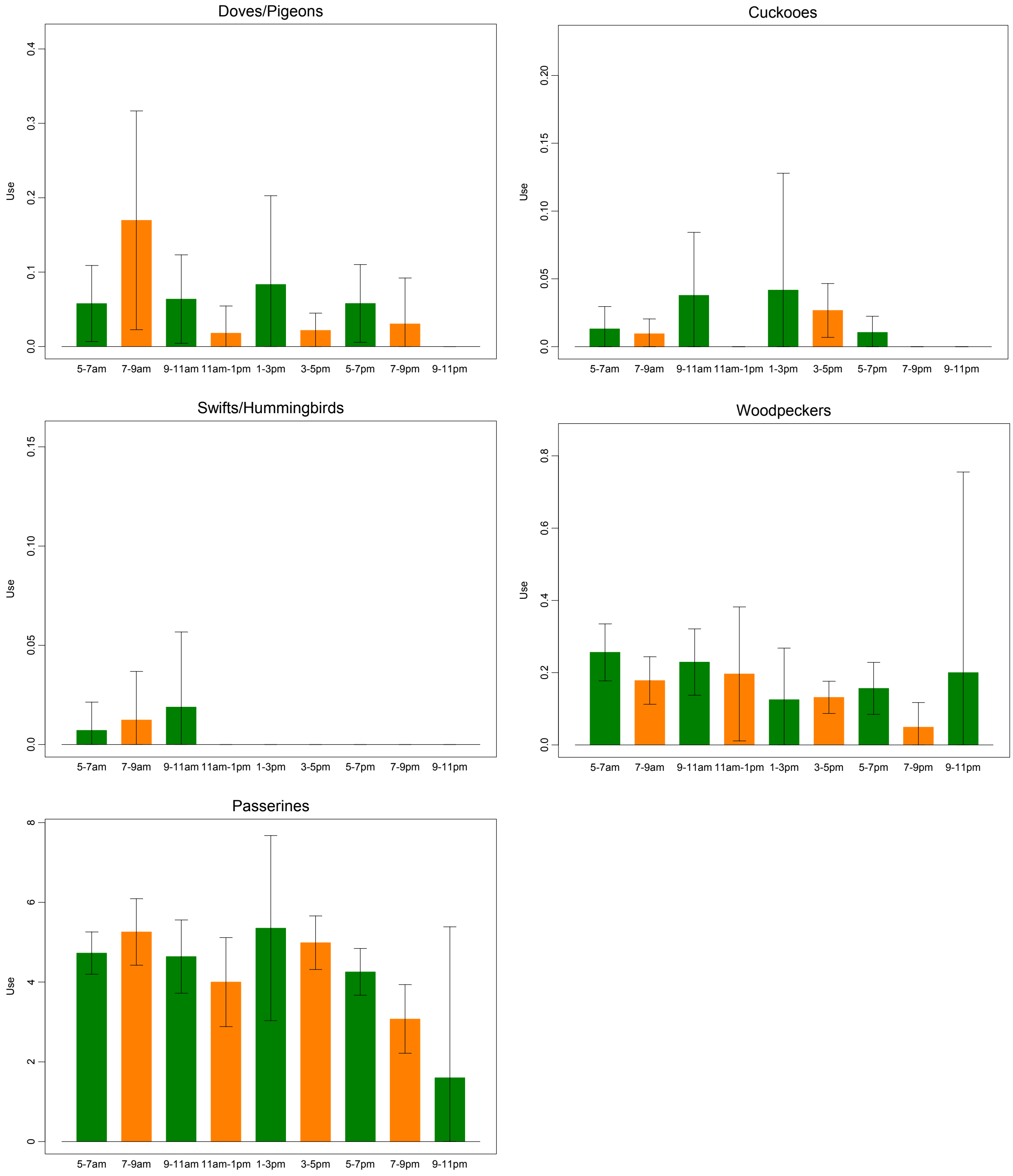


Figure 7b. Mean difference in use over two hour time periods (bar represents +1 standard error) for the fall period.

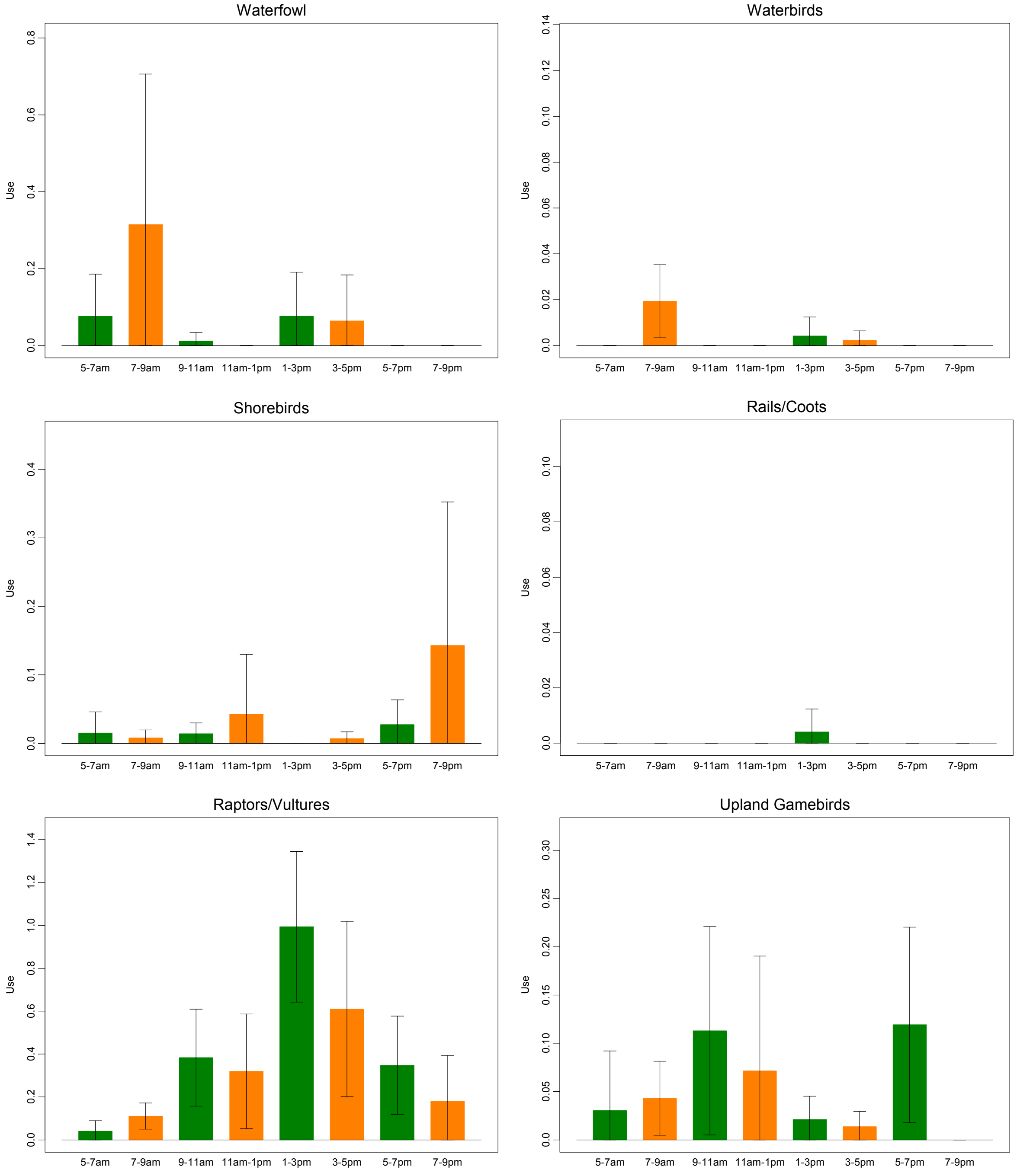


Figure 7a. (continued).

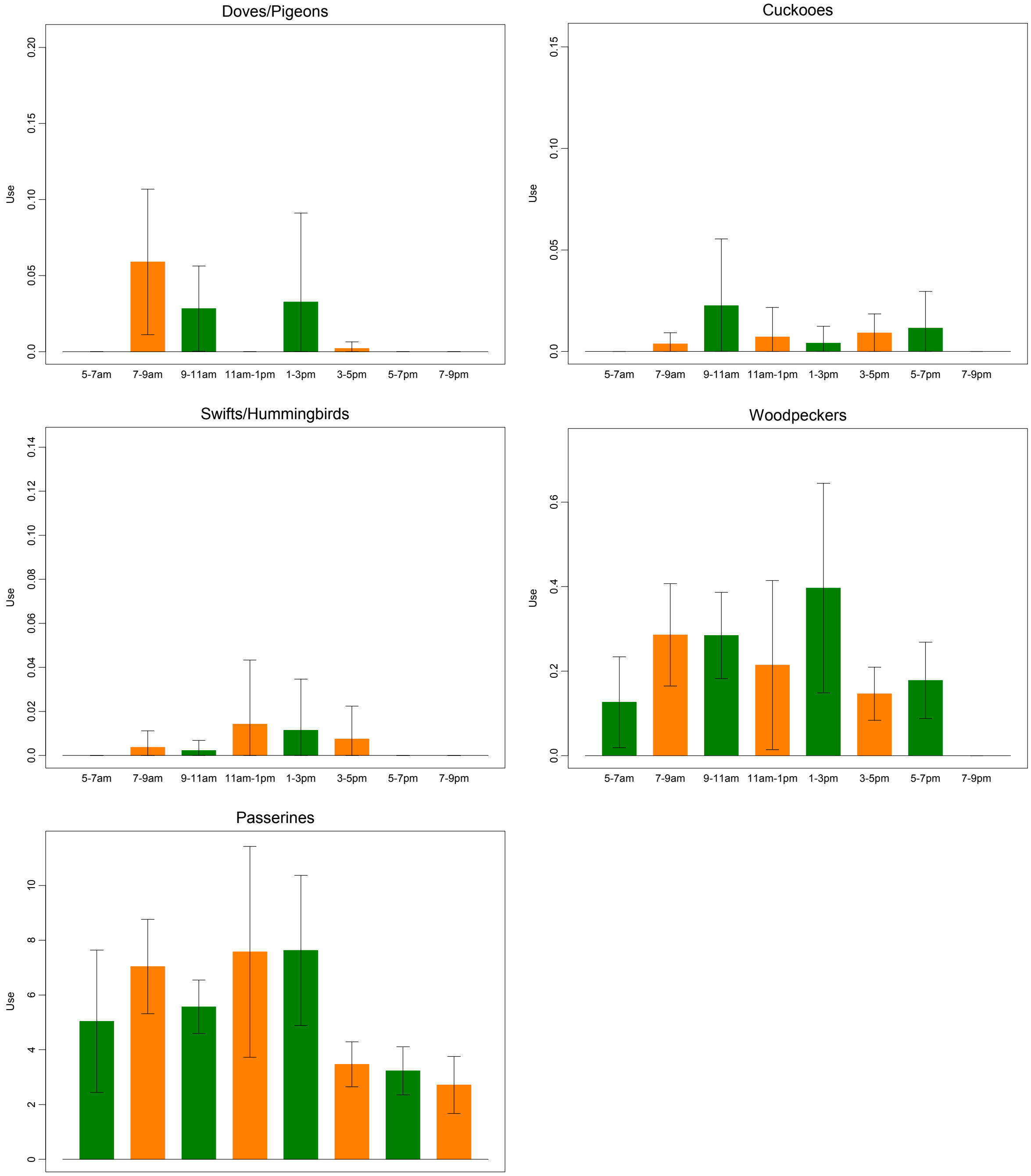


Figure 8. Mean difference in use and frequency of occurrence between surveys with low, medium, and high cloud cover (bar represents ±1 standard error).

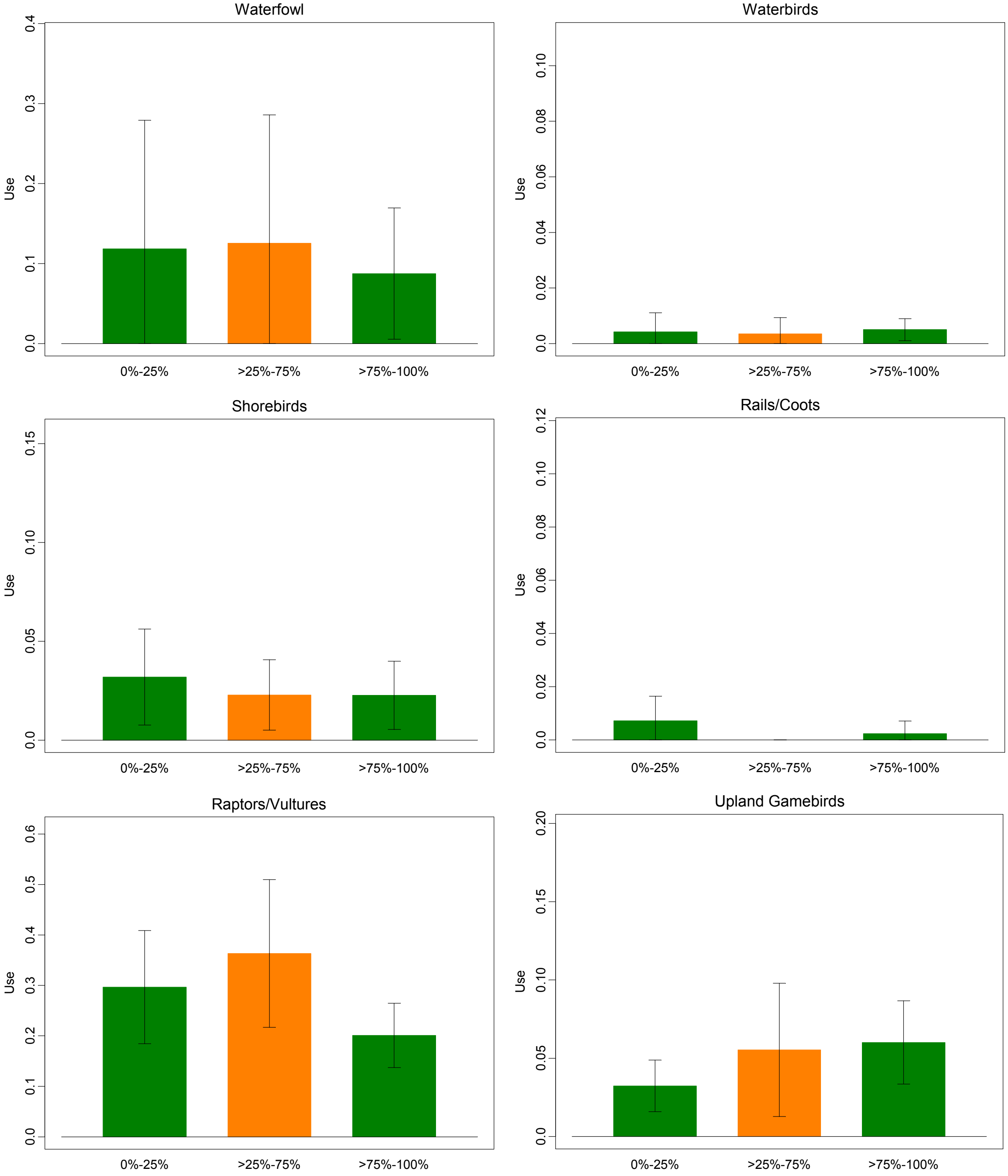


Figure 8 (continued).

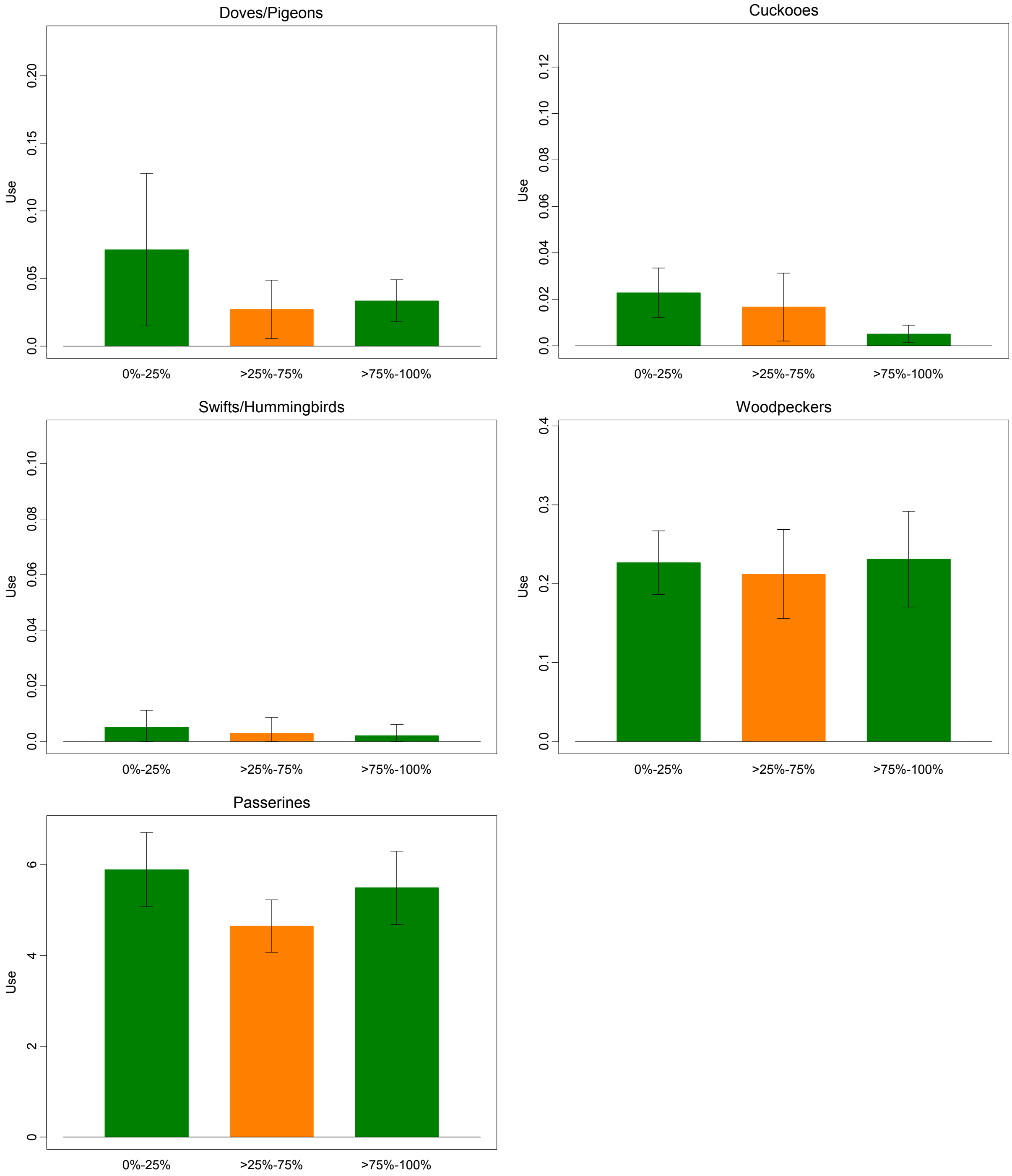
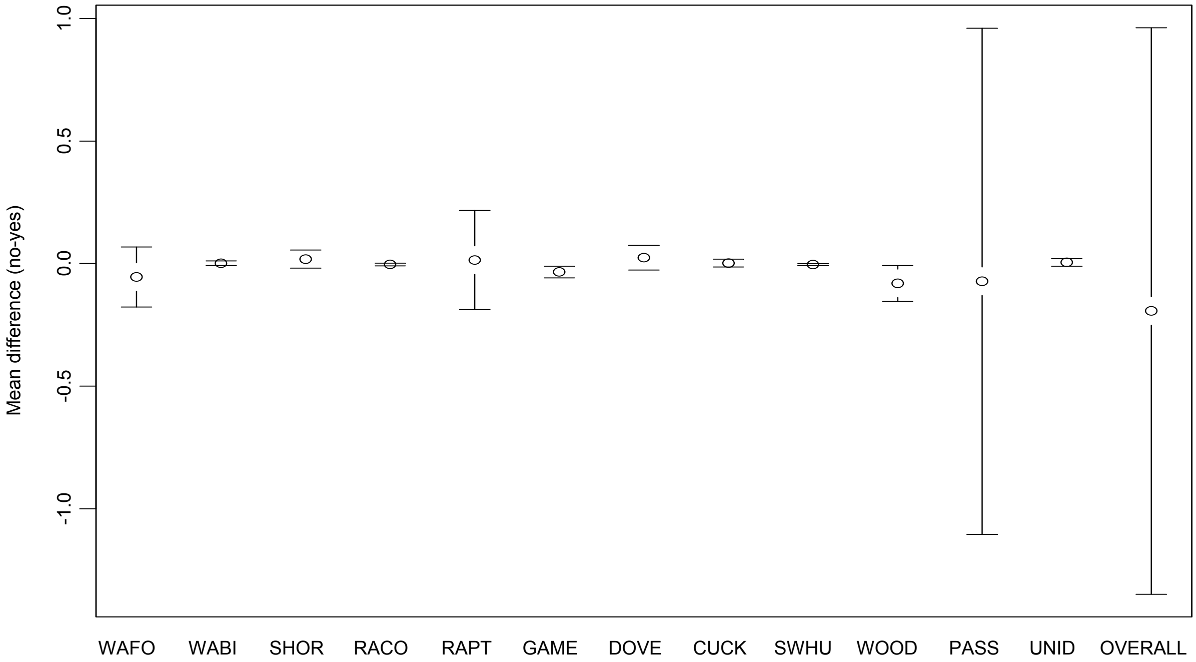


Figure 9. Mean difference in use and frequency of occurrence between surveys with and without precipitation (bar represents +1 standard error).



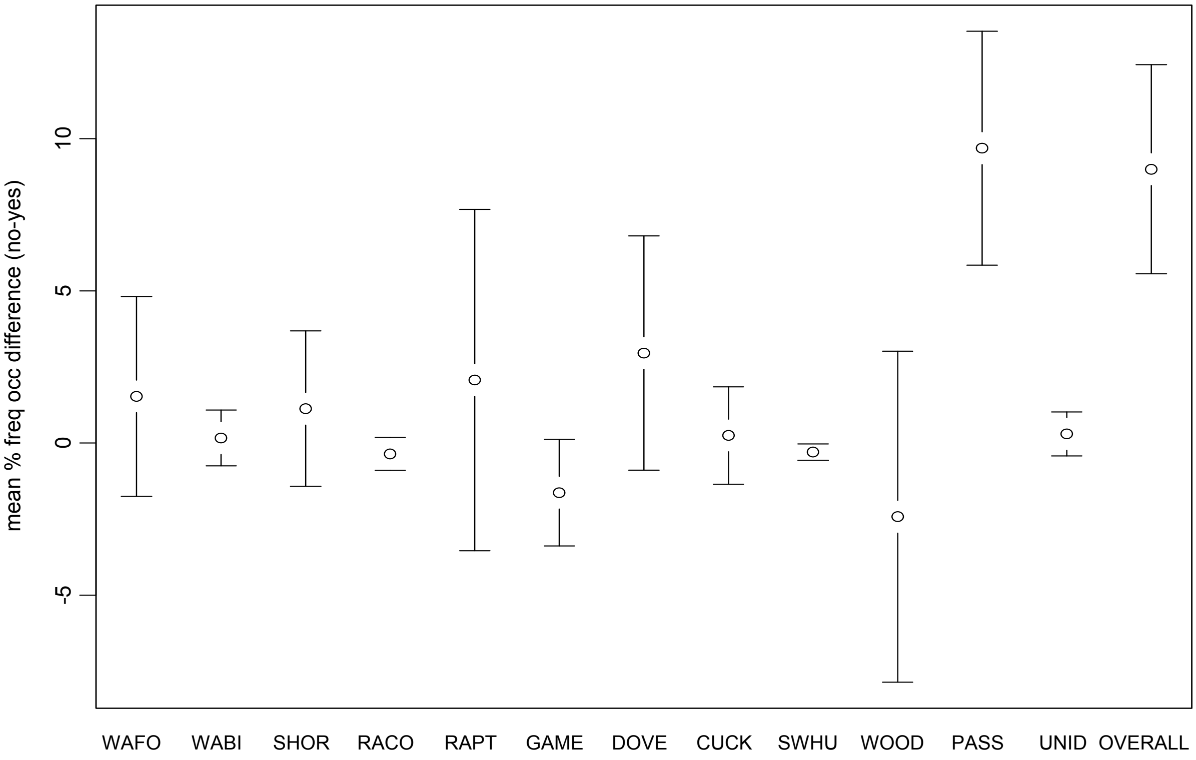


Figure 10. Vegetation type represented by percent forested for each fixed-point survey plot.

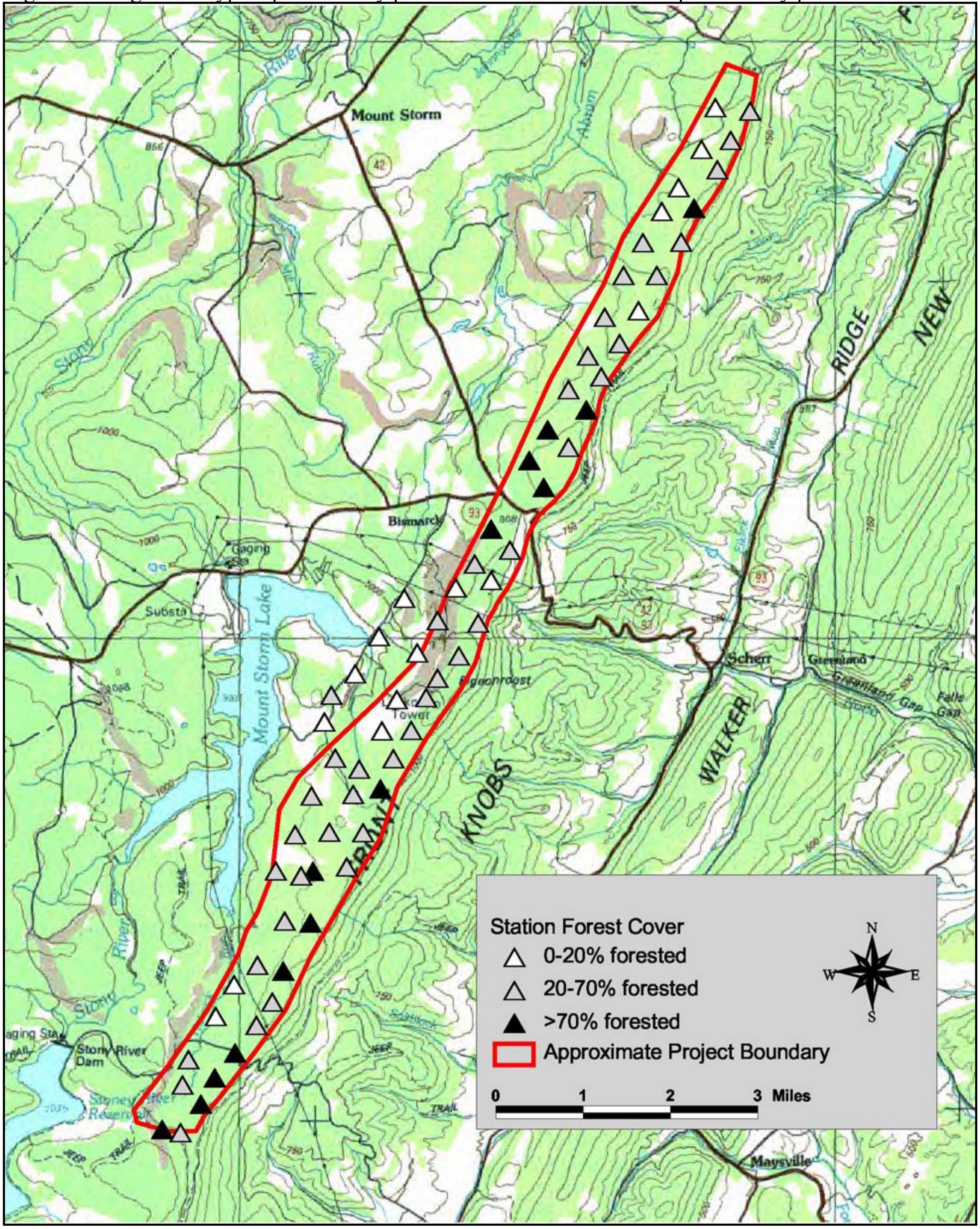


Figure 11. Passerine use by forest canopy cover.

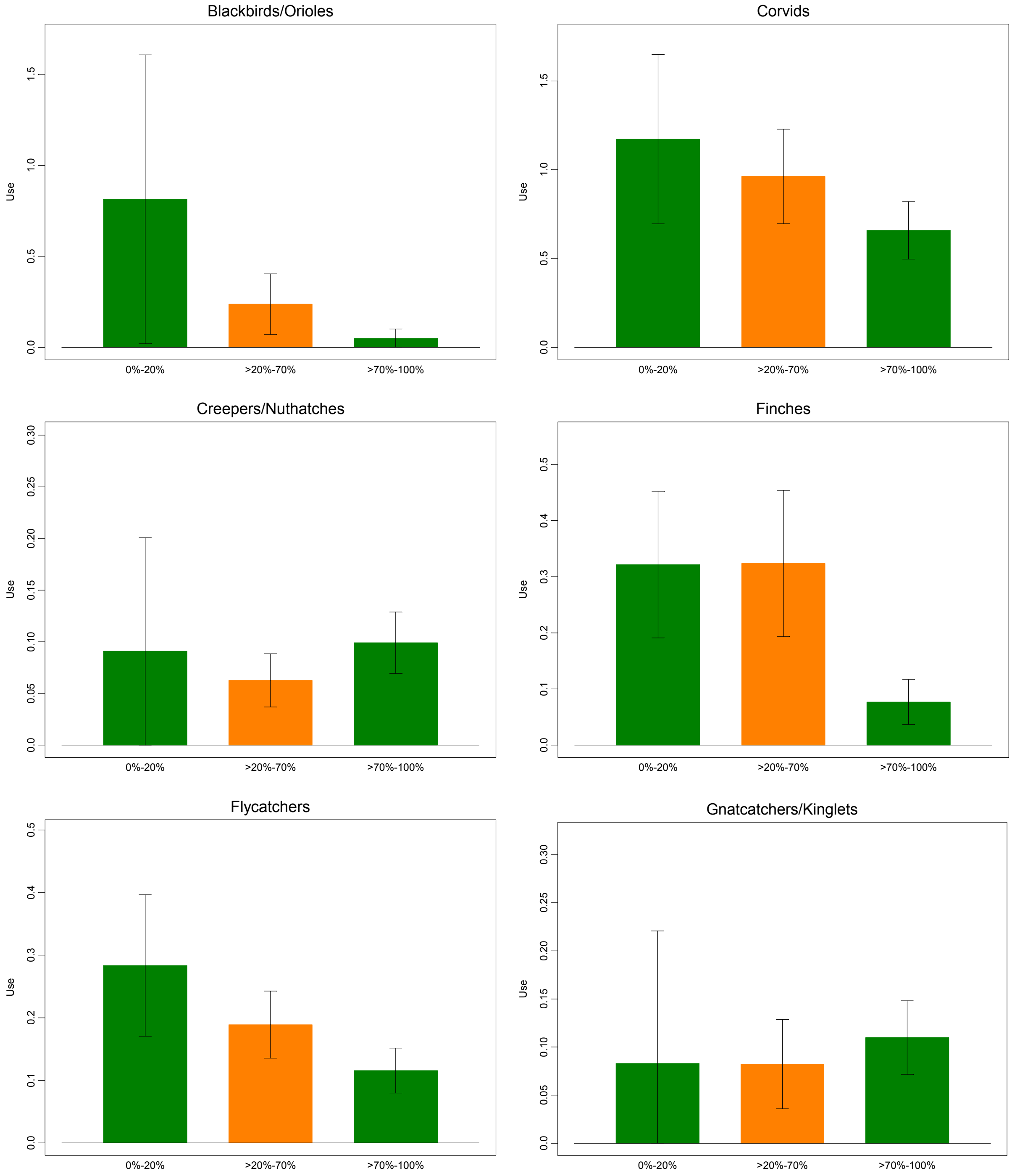


Figure 11 (continued).

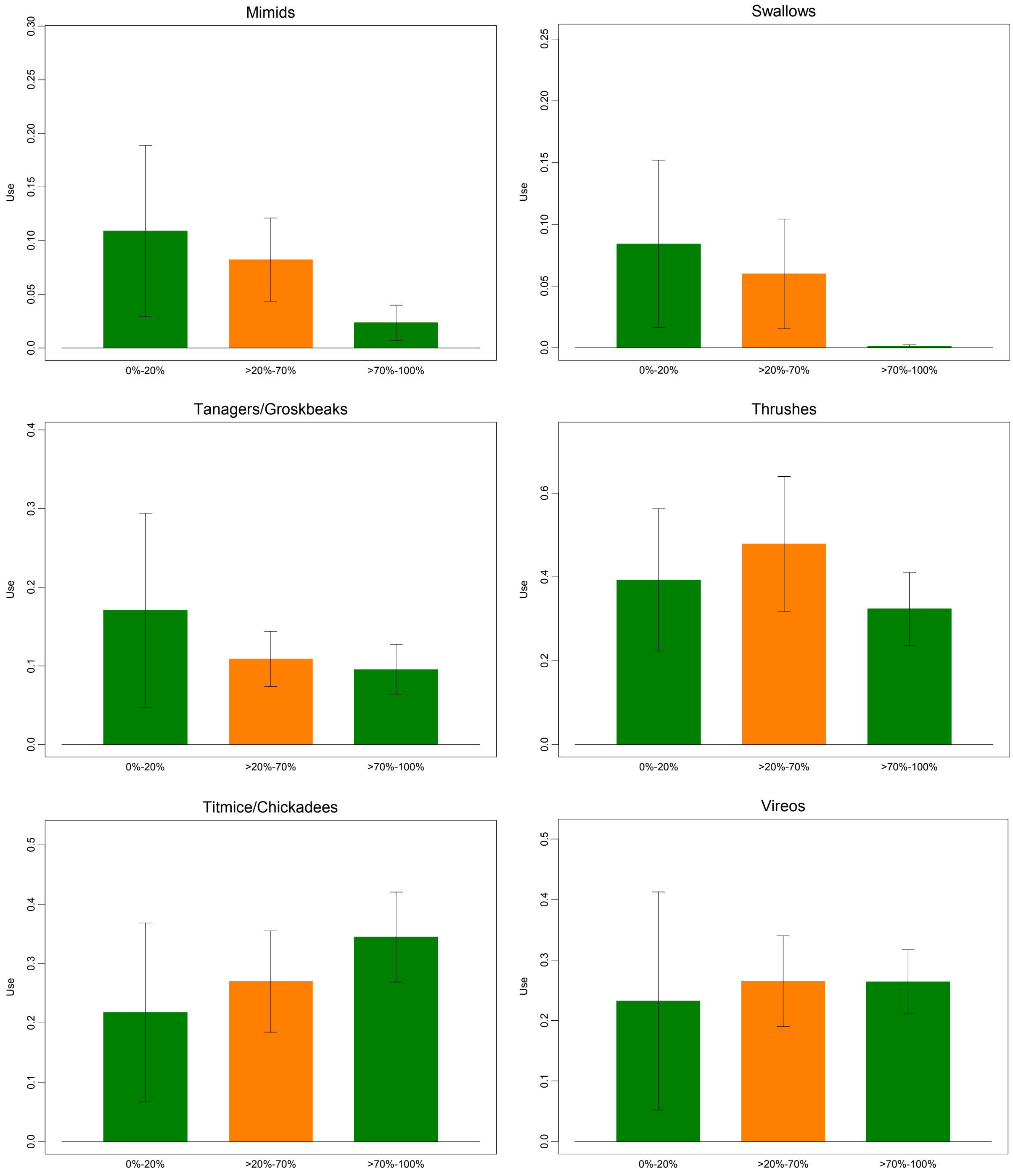


Figure 11 (continued).

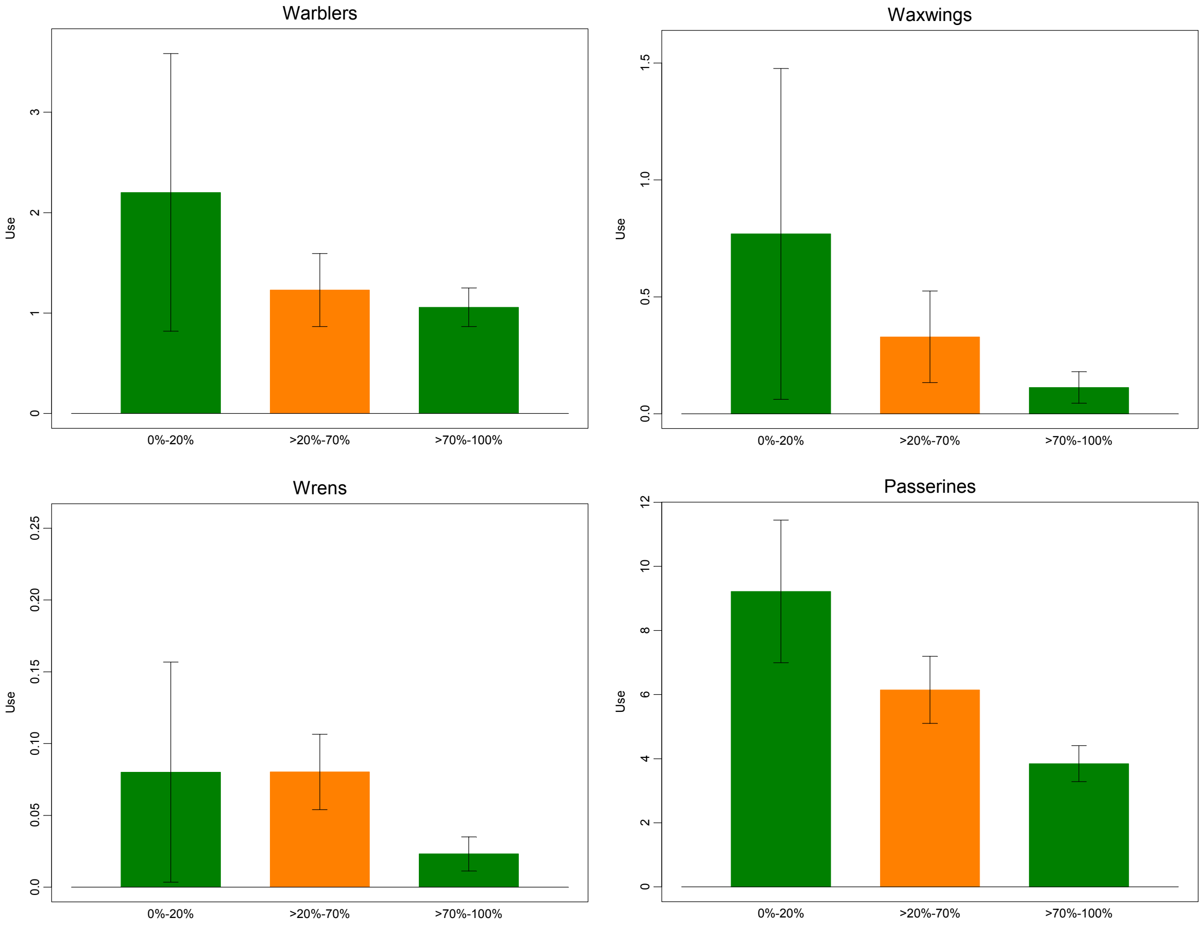


Figure 12. Golden-winged warbler survey locations and results.

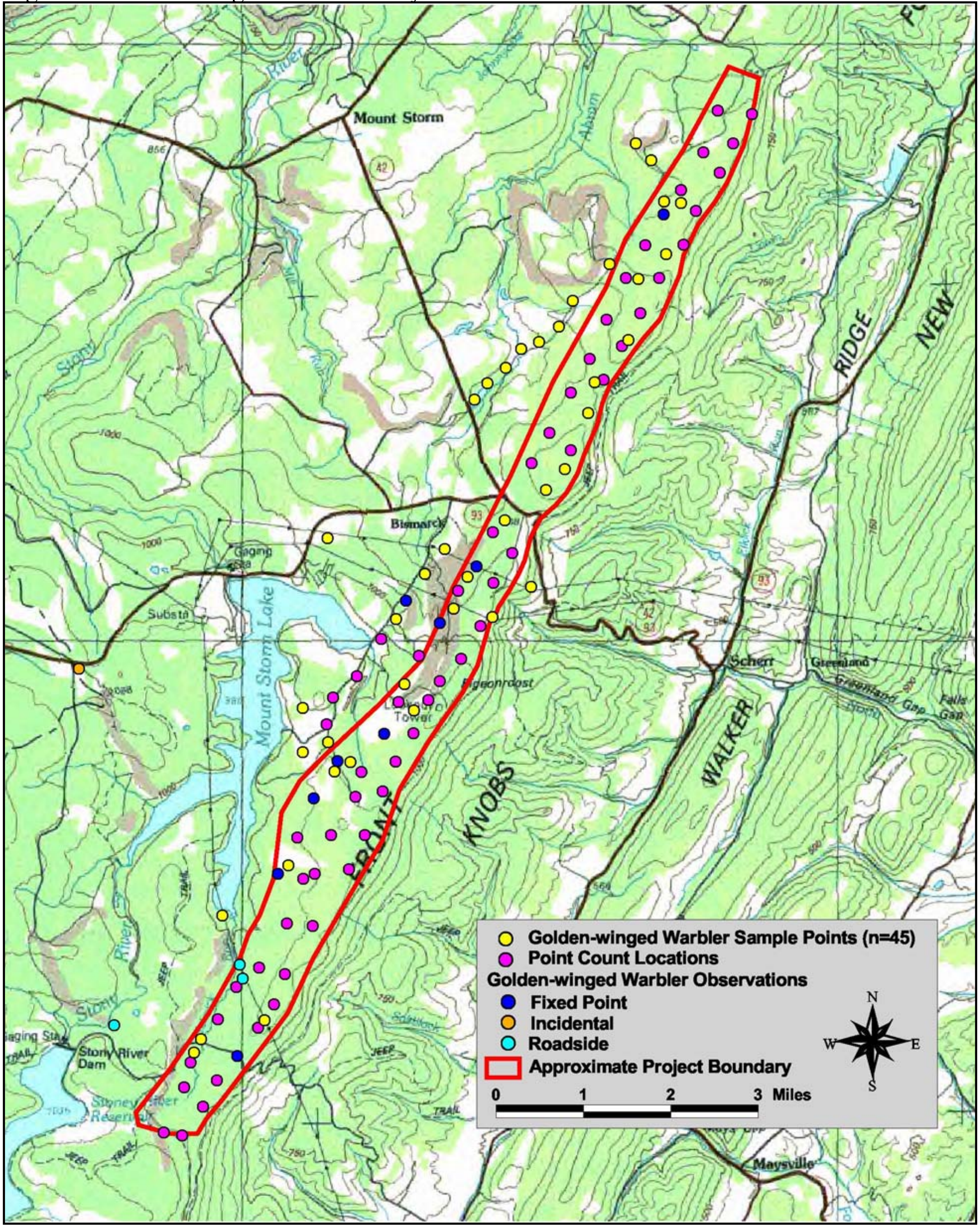


Figure 13. Winter raptor and bald eagle survey routes and observations.

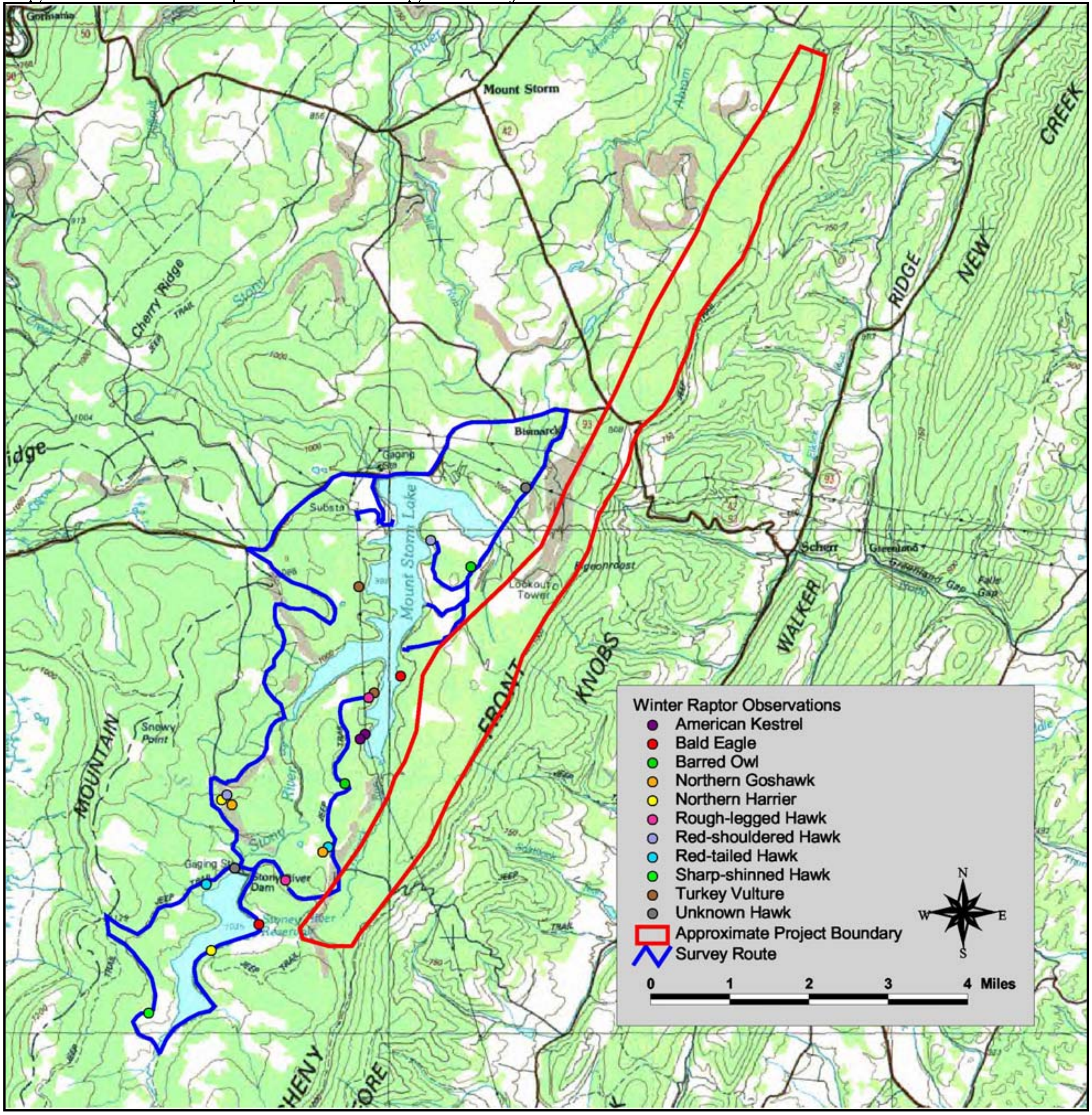
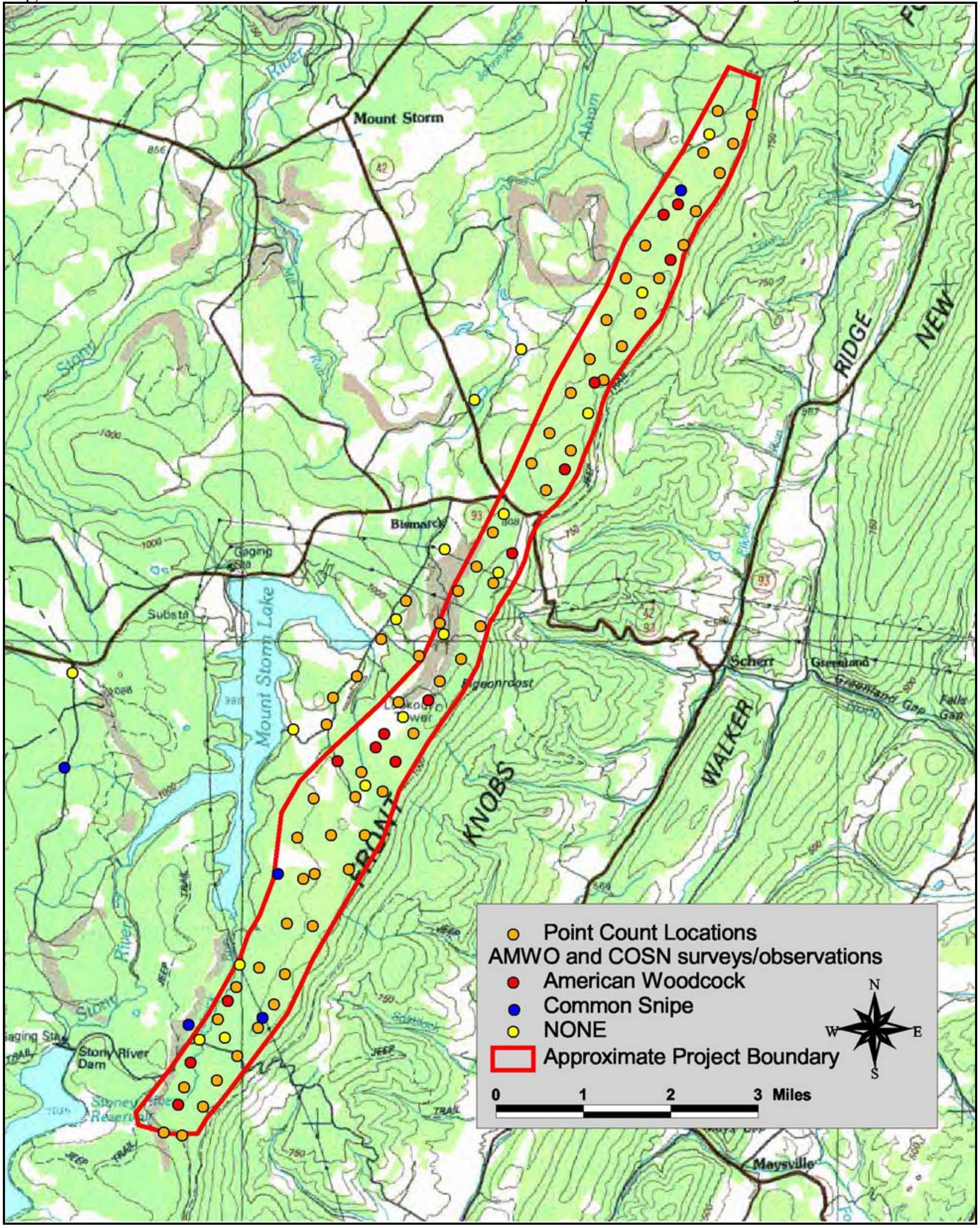


Figure 14. Locations of American woodcock and common snipe observed in the study area.



APPENDIX A

RADAR STUDY OF NOCTURNAL BIRD MIGRATION AT THE PROPOSED MOUNT STORM WIND-POWER DEVELOPMENT, WEST VIRGINIA, FALL 2003

Citation:

Mabee, T.J., B.A. Cooper, and J.H. Plissner. 2004. Radar Study Of Nocturnal Bird Migration At The Proposed Mount Storm Wind-Power Development, West Virginia, Fall 2003. Technical report prepared for: Western EcoSystems Technology, Inc. and NedPower US, LLC. ABR, Inc. Environmental Research and Services, Forest Grove, Oregon. March 2004. 40 pp.

FINAL REPORT

A RADAR STUDY OF NOCTURNAL BIRD MIGRATION AT THE PROPOSED MOUNT STORM WIND-POWER DEVELOPMENT, WEST VIRGINIA, FALL 2003

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A RADAR STUDY OF NOCTURNAL BIRD MIGRATION AT THE PROPOSED MOUNT STORM WIND POWER DEVELOPMENT, WEST VIRGINIA, FALL 2003

FINAL REPORT

Prepared for

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March 2004

Printed on recycled paper.

EXECUTIVE SUMMARY

- This report presents the results of a radar study of bird migration conducted during 3 September–17 October 2003 at the proposed Mt. Storm wind power development, located in northeastern West Virginia. Radar observations were conducted for ~6 h/night on 45 nights.
- The primary objectives of this study were to (1) collect baseline information on flight directions, migration passage rates, and flight altitudes of nocturnal passerine migrants at the proposed project area during fall 2003; (2) determine if nocturnal migrants concentrate along the proposed Allegheny Front within the project area; and (3) determine if there is variation in the amount or altitude of migrants at up to three locations along the ridge at a 1,500 m radius scale.
- At night, the mean flight direction of targets observed on radar was 184° ± 1°.
- Nocturnal passage rates were highly variable among nights during fall 2003, ranging from 8 to 852 targets/km/h. The mean nocturnal passage rate for the season was 241 ± 33 targets/km/h at the primary (central) study site and was estimated to be 199 targets/km/h for the entire proposed development area. Passage rates varied among hours of the night during fall 2003.
- Mean flight altitudes observed on radar were highly variable among nights during fall 2003. The mean nocturnal flight altitude was 410 ± 2 m agl. There were hourly differences in flight altitude among hours of the night in fall 2003, with lower altitudes occurring later in the evening. Overall, we estimated that 13% of nocturnal targets flew below 125 m agl across the length of the ridge encompassing the proposed development area.
- We calculated a mean passage rate of 36.3 targets/km/h flying below 125 m agl (or 2.91×10^{-4} targets/m^2/h) at the proposed development, for the fall passerine migration season.
- We found no strong correlations between NEXRAD reflectivity values (representing bird densities) and radar migration passage rates during 25 nights with comparable data. Mean flight directions of radar targets, however, were correlated with the direction of migration.
- The key results of our study include the following: (1) relatively high mean passage rates (i.e., 199 targets/km/h ridge-wide); (2) approximately 20% of nights with passage rates much higher than the mean rate for the fall season; (3) variation in passage rates among some ridge sites (central:southern) and between ridge and off-ridge sites (central:western); (4) the weight of evidence suggesting that migrants did not concentrate along the Allegheny Front in fall 2003; (5) similar mean flight altitudes among sites (excluding valley); and (6) 13% of targets < 125 m agl ridge-wide, which is higher than the small number of comparable studies.

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ACKNOWLEDGMENTS

We thank NedPower for funding this study and Dale Strickland, Dave Young, and Wally Erickson (WEST, Inc.) for providing input on study design, coordinating field activities, and report review. We thank Ron Canterbury and Dave Young for help with selection of study sites. At ABR, we thank Peter Sanzenbacher and Corey Grinnell for help with radar sampling and report preparation; Amy Bradford, Jen Felkay, and Pam Odom for help in report preparation; Rich Blaha for figure preparation; and Bob Day for reviewing the report.

INTRODUCTION

Records of avian collisions with communication towers in North America have been documented since 1948 (Kerlinger 2000, Manville 2000), with sporadic occurrences of large mortality events reported, especially at taller structures (e.g., guyed and lighted towers >130 m high) on foggy, overcast nights in fall (Weir 1976, Avery et al. 1980, Evans 1998, Erickson et al. 2001). Nocturnal migrants also have been recorded colliding with wind turbines (Osborn et al. 2000, Erickson et al. 2001), although large kills of migratory birds have not been documented at wind power developments. Studies examining the impacts of wind turbines on birds in the US and Europe suggest that important fatality and behavioral events (e.g., avoidance of areas with wind turbines) occur in some, but not all, locations (Winkelman 1995, Anderson et al. 1999, Erickson et al. 2001). Therefore, an understanding of the dynamics of nocturnal bird migration at specific locations is necessary to assess the potential for bird collisions with tall, human-made structures. Consideration of nocturnal migration is particularly important because considerably more birds migrate at night than during the daytime (Gauthreaux 1975, Kerlinger 1995).

In particular, neotropical migratory birds such as thrushes (Turdidae) vireos (Vireonidae), and warblers (Parulidae) seem to be the most vulnerable to collisions with communication towers during their nocturnal migrations (Manville 2000). Such passerines ("songbirds") also comprise >80% of fatalities at wind power developments (Erickson et al. 2001), with ~50% of those fatalities involving nocturnal migrants. Passerines may be more at risk of colliding with structures at night because these birds tend to migrate at lower altitudes than do other groups of migratory birds (e.g., waterfowl, shorebirds; Kerlinger 1995).

The Eastern US contains mountains, rivers, wetlands, and coastal habitats that may influence the migration patterns of birds (Zalles and Bildstein 2000, Williams et al. 2001, Diehl et al. 2003). Although West Virginia contains several known migration corridors for diurnally-migrating birds (Heintzelmann 1975, Bellrose 1976, Zalles and Bildstein 2000), few comparable data are available for nocturnal migration there. Both the lack of information on nocturnal bird migration in general and ongoing bird fatalities at most wind power facilities studied in the US (Erickson et al. 2001) have generated concern about the potential of collisions between nocturnal migrants and the proposed Mt. Storm Wind Power Development in northeastern West Virginia (Fig.1). NedPower proposes to build the Mt. Storm Wind Power Project, a ~300 MW wind power development along the Allegheny Front ridgeline (Fig. 2). The proposed development is located on the Allegheny Front, a ridgeline known for its importance for diurnally-migrating birds including raptors and passerines (Hall and Bell 1981). The proposed Mt. Storm Wind Power Development would consist of ~150–200 wind turbines, each having a total height of up to 125 m.

We used a portable X-band radar system to study the main characteristics of nocturnal bird migration during fall 2003 at the proposed Mt. Storm Wind Power Development. Portable X-band radar systems are well-suited for studying nocturnal migration patterns at wind power development sites because they are uniquely able to provide local information about bird flight heights, direction, behavior, and passages rates that are useful for avian risk assessments. Evaluating the potential for avian collisions with wind turbines is important because the appropriate siting of wind power facilities is one of the most important ways to minimize collisions with birds (Nelson and Curry 1995).

OBJECTIVES

The overall goal of this study was to collect information on the migration characteristics of nocturnal birds (particularly passerines) during the fall migration period. The specific objectives were to: (1) collect baseline information on flight directions, migration passage rates, and flight altitudes of nocturnal passerine migrants at the proposed project area during fall 2003; (2) determine if nocturnal migrants concentrate along the proposed Allegheny Front within the project area; and (3) determine if there is variation in the amount or altitude of migrants at up to three locations along the ridge at a 1,500 m radius scale.

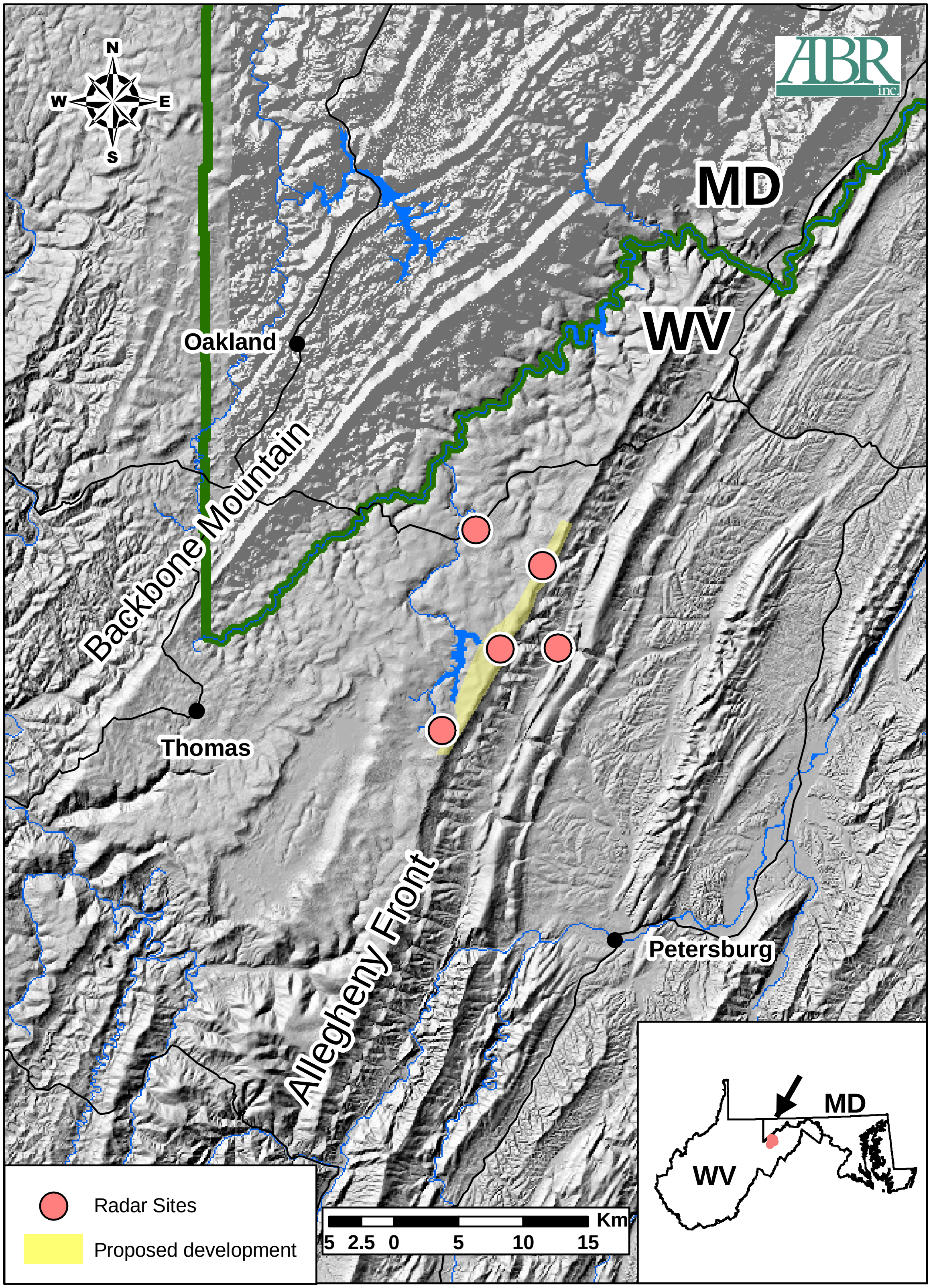

Figure 1. Map of the proposed Mt. Storm wind power development in West Virginia.

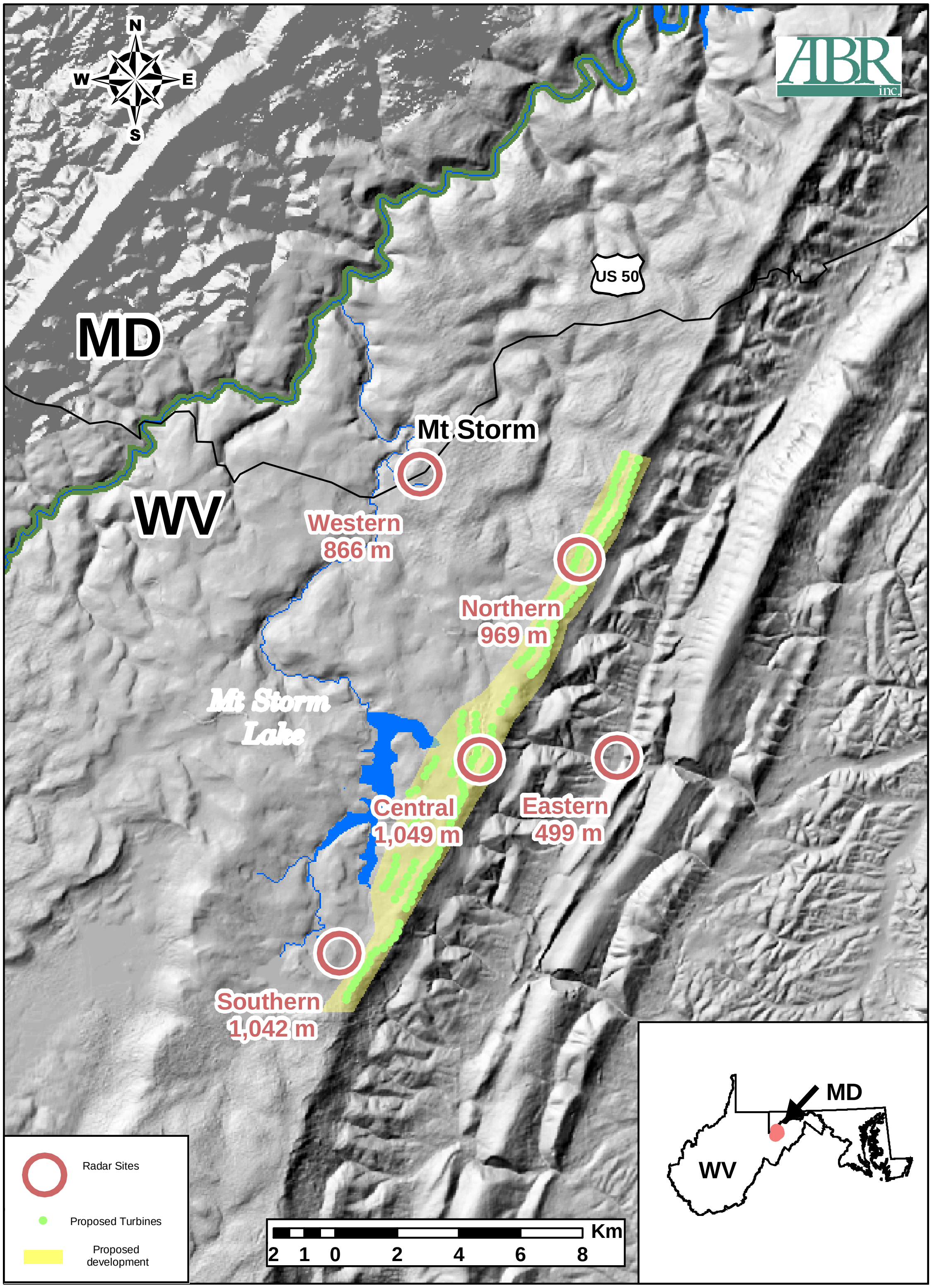

Figure 2. Map of the radar sampling sites and proposed wind turbines at the proposed Mt. Storm wind power development, West Virginia.

STUDY AREA

The proposed Mt. Storm Wind Power Development is located in Grant County, in northeast West Virginia. Grant County lies within the Allegheny Mountains physiographic region and is along the western edge of the Ridge and Valley physiographic province (Buckelew and Hall 1994). The Allegheny Mountains are characterized by steep to rolling mountains, ridges, hills and high plateaus (Fig. 1). The proposed development is located on the primary ridgeline of the Allegheny Mountains known as the Allegheny Front, located ~0.8–1.6 km east of Mt. Storm Lake, ~6 km east of Mount Storm, and ~5 km west of Scherr. West Virginia Highway 42/93, which runs between Bismarck and Scherr, bisects the site at approximately the midpoint. Elevation of the site ranges from ~800 m to ~1,150 m. The proposed project site is private land used for coal mining, commercial logging, and recreation (hunting). Three of our radar sites were located within the proposed wind power development area authorized by the West Virginia Public Service Commission permit: (1) central site (UTM 17S 653448E 4339695N; elevation 1049 m); (2) northern site (UTM 17S 656687E 4346150N; elevation 969 m); and (3) southern site (UTM 17S 648919E 4333424N; elevation 1042 m). Our western radar site (UTM 17S 651519E 4348906N; elevation 861 m) was slightly northwest of the project area, but its location was dictated by the lack of a suitable radar site along the western edge of the proposed project area. Our eastern radar site (UTM 17S 657890E 4339759N; elevation 499 m) was located in the valley adjacent to and east of the Allegheny Front escarpment (Fig. 2).

Historically, the Allegheny Mountains were a hardwood and spruce forest (Buckelew and Hall 1994). The hardwood forest type consists primarily of oaks (*Quercus* spp.), maples (*Acer* spp.), hickories (*Carya* spp.), black cherry (*Prunus serotina*), black and yellow birch (*Betula lanta* and *B. alleghaniensis*), and beech (*Fagus grandifolia*) trees (Canterbury 2002). The conifer types consist of red spruce (*Picea rubens*), hemlock (*Tsuga canadensis*), and a variety of pines (*Pinus* spp.), (including red [*P. resinosa*], pitch [*P. rigida*], and Virginia [*P. virginiana*]), that are used for reclamation of abandoned surface mines (Canterbury 2002). Much of the site has been strip mined for coal and consists of reclaimed areas. The deciduous forest vegetation type on the proposed project site has been logged both recently and historically and shows signs of severe ice and wind damage from recent winters. There are several private cabins scattered around the site, and much of the area around Mt. Storm Lake and Highway 42/93 is developed with private residences and scattered businesses. A large (1,600 MW) coal-fired power plant is located at Mt. Storm Lake.

METHODS

STUDY DESIGN

Between 3 September and 17 October 2003, we conducted 45 nights of radar observations of nocturnal bird migration to overlap with the peak diurnal migratory periods of eastern U.S. passerines along the Allegheny Front (Hall and Bell 1981). Our study design entailed using one radar laboratory at the central site and using a second radar lab to move between two secondary sites (i.e., northern, southern, eastern, or western sites) sampled each night. Each night, we conducted ~6 h or of radar observations at the central site. The central site was located centrally in the proposed project area (Fig. 2). At the secondary sites, we conducted observations for ~2.5–3 h at a site before moving to a second site for an additional 2.5–3 h of sampling. Observer assignments and starting locations of the second mobile radar lab were varied systematically to minimize bias among sites and observers. Radar surveys occurred between 2030 h and 0230 h. This sampling design provided coverage of the peak period of nocturnal migration for passerines within a night (Lowery 1951, Gauthreaux 1971, Alerstam 1990, Kerlinger 1995).

RADAR EQUIPMENT

Our mobile laboratories consisted of a marine radar mounted on the roof of a van or pickup that functioned as both a surveillance and vertical radar. In the horizontal position (i.e., in surveillance mode), the radar scanned the surrounding area around the lab, and we manually recorded information on flight direction, flight behavior, passage rates, and groundspeeds of birds into a laptop computer. When the antenna was placed in the vertical position, we measured flight altitudes of targets with an index line on the monitor and recorded this data manually into our laptop computer. A description of a similar radar laboratory can be found in Gauthreaux (1985a, 1985b) and Cooper et al. (1991), and a similar vertical radar configuration was described by Harmata et al. (1999, 2003).

The radar (Furuno Model FR-1510 MKIII; Furuno Electric Company, Nishinomiya, Japan) is a standard marine radar transmitting at 9.410 GHz (i.e., X-band) through a 2-m long slotted waveguide (antenna) with a peak power output of 12 kW. The antenna had a beam width of 1.23° (horizontal) × 25° (vertical) and a sidelobe of ±10–20°. Range accuracy is 1% of the maximal range of the scale in use or 30 m (whichever is greater), bearing accuracy is ±1°, and bearing discrimination is >2.5°.

The radar can be operated at a variety of ranges (i.e., 0.5–133 km) and pulse lengths (i.e., 0.07–1.0 μsec). We used a pulse length of 0.07 μsec while operating at the 1.5-km scale and used a pulse length of 0.50 μsec at the 3.0-km scale. At shorter pulse lengths, echo resolution is improved (giving more accurate information on target identification, location, and 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 monitor; a target is one or more birds that are flying so closely together that the radar displays them as one echo on the monitor.) This radar has a digital color display with several scientifically useful features, including True North correction for the display screen (to determine flight directions), color-coded echoes (to differentiate the strength of return signals), and on-screen plotting of a sequence of echoes (to depict flight paths). Because targets plot every sweep of the antenna (i.e., 2.5 sec) and because ground speed is directly proportional to the distance between consecutive echoes, we were able to measure ground speeds of plotted targets 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 ~15° and by parking the radar lab in locations that were surrounded fairly closely by low trees or low hills, where possible. These objects act as a radar fence that shields the radar from low-lying objects farther away from the lab and that produces 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 the bird, flock size, flight profile, proximity of birds in flocks, 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 routinely detected out to ~1.5 km (Cooper et al. 1991; Cooper and Mabee, unpubl. data).

DATA COLLECTION

TARGET IDENTIFICATION

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 animals detected by the radar. Based on the study period and location, we assumed that the vast majority of targets we observed were passerines, which generally do not migrate as tight flocks (Lowery 1951, Kerlinger 1995); thus we assumed that targets represented single individuals. 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 bat flight speeds overlap with flight speeds of passerines (i.e., are >6 m/s; Tuttle 1988, Larkin 1991, Bruderer and Boldt 2001, Kunz and Fenton 2003; Cooper and Day, unpubl. data), it was not possible to separate bird targets from bat targets based solely on flight speeds. We were able to exclude foraging bats based on their erratic flight patterns; however, it is likely that migratory bats or any bat not exhibiting erratic flight patterns were included in our data.

Of primary importance, however, is eliminating insect targets. We used a combination of techniques to reduce insect contamination in the data and omitted either individual sampling sessions or whole nights when insects severely contaminated the data. We reduced insect contamination by (1) shifting sampling times to later evening hours, when insect activity typically decreased, (2) omitting targets with poor reflectivity (e.g., targets that plotted erratically or inconsistently in locations with good radar coverage), (3) not counting "insect-like" targets (e.g., targets the size of grain speckles or small, slow targets that only appear within 500 m of the lab), (4) editing data prior to analyses by omitting surveillance-radar targets with corrected airspeeds <6 m/s (<13.4 mi/h; following Diehl et al. 2003), and (5) excluding all vertical data collected during sessions in which corresponding surveillance data indicated that >10% of targets had airspeeds <6 m/s.

The 6 m/s airspeed cutoff speed was based on radar studies that have determined that most insects have an airspeed of <6 m/s, whereas the airspeed of birds usually is >6 m/s (Larkin 1991, Bruderer and Boldt 2001). We corrected our observed migration passage-rate estimates by the proportion of targets with airspeeds <6 m/s that were observed in each subsequent 10-min surveillance-radar session.

SAMPLING DESIGN

Each of the six, 60-min nocturnal radar sampling sessions/night consisted of: (1) one 10-min session to collect weather data and adjust the radar to surveillance mode; (2) one 5-min session with the radar in surveillance mode (1.5-km range) for collection of information on migration passage rates; (3) one 10-min session with the radar in surveillance mode (1.5-km range) for collection of information on ground speed, flight direction (°), tangential range (minimal perpendicular distance to the radar laboratory), transect crossed (the four cardinal directions—north, south, east, and west), species (if known), number of individuals (if known), flight behavior (approached and crossed ridge; approached but did not cross ridge; approached, turned but still crossed ridge; did not approach ridge; unknown), and location (west of ridge, over ridge, east of ridge); (4) one 10-min session to adjust the radar to vertical mode; (5) one 10-min session with the radar in vertical mode (1.5-km range) to collect fine-scale information on flight altitudes <1.5 km agl; and (6) one 5-min session with the radar in vertical mode (3.0-km range) to collect coarse-scale information on flight altitudes ≤3000 m agl. "Coarse-scale" refers to the fact that it is more difficult to differentiate individual targets or to determine exact flight altitudes (especially if they are flying ≤100 m agl) because of the poorer resolution on the 3-km range than at the 1.5-km range. The vertical radar was oriented so that it collected data along a southeast–northwest transect that was approximately perpendicular to the Allegheny Front ridgeline.

Other sets of data were collected opportunistically throughout the study period to supplement the principal sampling effort. For example, during 21 nights between 16 September and 17 October, we plotted target flight paths at the central site onto acetate overlays during 5-min surveillance-radar sessions (generally during the 10-min session for collecting weather data and adjusting the radar). Flight paths then were digitized and plotted as polylines (lines consisting of multiple segments) in ArcView (v. 3.2) for supplemental behavioral analysis. Following completion of radar sampling sessions on 10 nights with high passage rates, we also videotaped the monitor with the radar in 1.5-km-range vertical mode throughout the remaining hours of the night. The videotapes later were analyzed following similar protocols as real-time data collection in the field (except that altitudes were recorded categorically in 200 m layers), to assess temporal variation in flight altitudes across all hours of the night.

Visual surveys (using a 2,000,000 Cp spotlight) and auditory surveys were also conducted opportunistically to help the radar operator assess real-time insect conditions and document the presence of birds and bats. Insects were recorded on most nights, birds were observed on 20–30% of the nights sampled/site using spotlights, and were observed on 20–50% of nights sampled/site using moon watch surveys. Bats were observed infrequently on 6–10% of the nights sampled/site using spotlights and on 10–20% of nights sampled/site using moon watch surveys. This information was valuable to radar operators to identify potential targets in low altitude layers.

Weather data collected at the beginning of each hour consisted of the following: wind speed (collected with a “OMNI” anemometer in 5-mi/h [2.2-m/s] categories); wind direction (to the nearest 45°); cloud cover (to the nearest 5%); ceiling height (in m agl; 1–50, 51–100, 100–150, 151–500, 501–1,000, 1,001–2,500, 2,501–5,000, >5,000); minimal visibility in a cardinal direction (in m; 0–50, 51–100, 101–500, 501–1,000, 1,001–2,500, 2,501–5,000, >5,000); precipitation (no precipitation, fog, drizzle, light rain, heavy rain, snow flurries, light snowfall, heavy snowfall, sleet, hail); and air temperature (measured with a thermometer to the nearest 1°C). We could not collect radar data during rain because the electronic filtering required to remove the echoes of the precipitation from the display screen also removed the targets of interest. We also obtained weather data (wind speed and direction) from two 50-m-high meteorological towers located near our central and northern sites.

DATA ANALYSES

TREATMENT OF RADAR DATA

All radar data were entered into an Excel database. Data files were checked visually for errors after each night and then checked again both visually and electronically for irregularities at the end of the field season, prior to data analyses. All analyses were conducted with SPSS statistical software (SPSS 2002). For quality assurance, we cross-checked results of the SPSS analyses with hand-tabulations of small data subsets, whenever possible.

Airspeeds (i.e., groundspeed corrected for wind speed and direction) of surveillance radar targets were computed with the formula:

$$V_a = \sqrt{V_g^{\,2} + V_w^{\,2} - 2V_gV_w\cos\theta},$$

where V_a = airspeed, V_g = target groundspeed (as determined from the radar flight track), V_w = wind velocity, and θ is the difference between the observed flight direction and the direction of the wind vector.

Targets with corrected airspeeds <6 m/s (4%) were deleted from all analyses. We analyzed flight-direction data following procedures for circular statistics (Zar 1999) with Oriana software version 2.0 (Kovach 2003). Migration passage rates are reported as the mean ± 1 standard error (SE) number of targets passing along 1 km of migratory front/h (targets/km/h ± 1 SE). Passage rates were corrected at three sites for ground clutter and radar shadows. At the eastern site, targets were only counted west of the radar site, and passage rates were adjusted accordingly. Passage rates were also corrected at the northern and southern sites because of differences in detectability associated with the flight direction of targets. At the northern site, radar coverage varied from 90–100% of the screen width, with lowest detectability for targets flying along the 30°/210° axis. At the southern site, coverage decreased to a minimum of 75% of the screen for targets flying along the 45°/225° axis. To correct for this situation, we applied a flight-direction-specific weighting factor to all targets observed during each 10-minute surveillance session. An average of these weighting factors was then calculated for each session and used as a correction factor for the associated passage rate estimate. Radar data were not corrected for differences in detectability with distance from the radar unit.

All flight-altitude data are presented in m agl (above ground level) relative to a horizontal plane passing through the radar-sampling site. All statistical summaries of flight-altitude data were made with the 1.5-km-range data because this scale provided adequate target resolution; in contrast, the 3.0-km range did not provide adequate target resolution at low altitudes. Actual mean altitudes typically will be higher than reported because some targets were flying >1.5 km. Targets below 100 m were weighted for site-specific differences associated with ground clutter. For analysis of within-night temporal variation in flight altitudes, 10 nights of videotape results were combined with data obtained earlier each evening. To correspond with the structure of the video data, the real-time flight altitude data were categorized to obtain counts of targets within 200-m intervals.

For calculations of the daily patterns in migration passage rates and flight altitudes, we assumed that a day began at 0700 h and ended at 0659 h, so that a sampling night was not split between two dates. We used repeated-measures ANOVA, with the Greenhouse-Geisser epsilon adjustment for degrees of freedom, to compare passage rates and flight altitudes among hours of the night for nights with complete sampling (i.e., all six sessions). Factors that decreased our sample size of the various summaries and analyses included insect contamination and inclement weather (rain). Sample sizes therefore sometimes varied among the different summaries and analyses. The level of significance (α) for all tests was set at 0.05.

Flight behaviors were investigated by analyzing target behaviors recorded directly during surveillance radar sessions and flight paths plotted on acetate overlays. Targets were considered to have reacted to the ridge if they exhibited a change in flight direction of ≥10° while crossing the ridge. Polylines representing plotted flight paths were analyzed in ArcView 3.2 by comparing the orientation of segments over the ridge (500-m width) with that of corresponding segments east and/or west of the ridge. We also compared mean flight directions of all plotted targets east and west of the ridge using the Mardia–Watson–Wheeler (Uniform Scores) test for paired comparisons of all sessions that had a minimum of eight polylines on each side of the ridge.

SITE COMPARISONS

We provided comparisons between each of the four additional secondary sites and the central site by using paired data collected concurrently (i.e., central:northern, central:southern, central:eastern, central:western). Because of the differences in elevation, our comparisons between the central site (at the top of the ridge) and the eastern site (550 m lower than the ridgetop, at the bottom of a valley) are valid only for comparing the same relative sampling space above ground level (agl). We used nonparametric tests in all paired comparisons because our data did not meet assumptions of normality. We used the Mardia–Watson–Wheeler (Uniform Scores) test for paired comparisons with flight directions and Wilcoxon paired-sample tests for comparisons of passage rates and flight altitudes. Flight-direction analyses were conducted with Oriana software v.2.0 (Kovach 2003), and the remaining analyses were conducted with SPSS software (SPSS 2002).

RIDGE-WIDE PASSAGE RATES

We generated two ridge-wide estimates of migration passage rates across the length of the proposed development area (using the northern, central, and southern radar sites) to 1) allow comparisons with other proposed development areas, and 2) allow computation of avian risk (Appendix 1). To derive the first metric, we first applied results of our paired comparisons to our full-season passage rate estimate from the central site to calculate seasonal estimates of passage rates at the northern and southern sites. A ridge-wide estimate was then derived as the average of the seasonal estimates for all three ridge sites. To derive the second metric, we again applied results from concurrent sessions to our full-season estimate from the central site to determine seasonal passage rates in the zone within the turbine area. We multiplied the percentage of targets flying <125 m agl (from 1.5 km vertical sampling) to passage rate data (targets/km/h) on a nightly basis and derived a mean rate for each site. The passage rates of the north and south sites, relative to concurrent rates at the central site, were then applied to the full-season rate (at the central site) to calculate full-season estimates at each of the two secondary ridge sites. We then took a mean of the three sites and adjusted for the sample area (125,000 m^2) to determine a ridge-wide passage rate within the turbine area (targets/h/m^2).

RESULTS

CENTRAL SITE

FLIGHT DIRECTION

At night, most radar targets were traveling in seasonally appropriate directions for fall migration (i.e., southerly), with a mean flight direction of 184 ± 1° for the entire fall season (*n* = 4,260 targets; Fig. 3). Most (82%) of the nocturnal targets were traveling in a southerly direction, with half (51%) of the flight directions between SE (135°) and SW (225°).

FLIGHT BEHAVIOR

Of 4,252 targets observed, the behaviors of over half (59.2%) could not be determined. Unknown behaviors were primarily associated with targets whose extrapolated flight paths transected the ridge but did not plot long enough to determine if they actually crossed the ridge (Table 1). Of those targets with known behaviors (*n* = 1,733), 5.3% (91) of the targets approached the

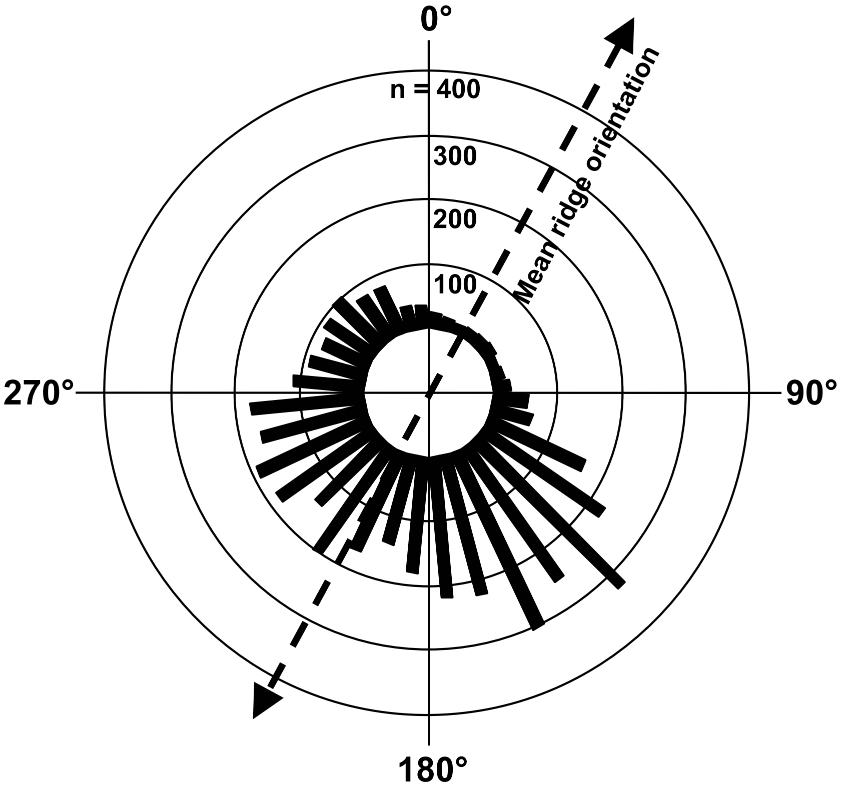

Figure 3. Flight directions of radar targets at the Mt. Storm central site, West Virginia, during fall 2003.

Table 1. Flight behavior of radar targets observed on surveillance radar at the Mt. Storm reference site, WV, during fall 2003 (*n* = number of radar targets).

Flight behavior	Percent of radar targets	*n*
Approached and crossed ridge	20.2	861
Approached, turned >10°, and crossed ridge	2.0	85
Approached and did not cross ridge (flew parallel to or away from ridge)	0.1	6
Did not approach ridge	18.4	781
Unknown	59.2	2,519

ridge and turned >10° (n = 85) or approached the ridge and did not cross the ridge (n = 6). Of those targets known to cross the ridge (n = 946), 9% (85) altered their flight direction >10° when crossing the ridge.

We also examined flight paths of targets plotted on acetate overlays. Plotted flight paths of 261 targets crossed the ridge from either the east or west, and 13.4% of these targets shifted their flight direction at least 10°. A subset of these same targets shifted their flight direction at least 15° (8%), 20° (5.4%), or 25° (3.1%). Overall, mean flight directions of targets located west of the ridge did not differ from those of targets east of the ridge (mean difference = 10°, W = 1.556, P = 0.46, n = 19 sessions).

PASSAGE RATES

The mean nocturnal passage rate for the entire fall season at the central site was 241 ± 33 targets/km/h (n = 40 nights). Mean nightly passage rates were highly variable during the study, with rates varying by two orders of magnitude (8–852 targets/km/h; Fig.4). Passage rates also varied significantly among hours of the night ($F_{3.5,\ 92}$ = 2.751; P = 0.039; n = 27 nights; Fig. 5), with lowest rates typically during the earliest session of the night.

FLIGHT ALTITUDES

The mean nocturnal flight altitude observed on vertical radar (1.5 km range) for the entire fall season at the central site was 410 ± 2 m agl (n = 17,543 targets; median = 350 m agl). Mean flight altitudes were highly variable among nights and ranged from 214 to 769 m agl (Fig. 6). Mean flight altitudes generally peaked early in the evening and then declined ($F_{3.3,\ 56.8}$= 4.01, P = 0.009, n = 18 nights; Fig. 7). Mean altitudes late in the evening (0200 h; 387 m agl), were lower than mean altitudes earlier in the evening (2200 h; 496 m agl). Further examination of the temporal patterns in passage rates (combining real-time data from 2100–0300 h and video data from 0300–0700 h) indicated that the percentage of targets flying at low altitudes (i.e., 0–200 m agl) appeared to exhibit a bimodal distribution, with one peak occurring at ~2300 h and a second peak occurring shortly before sunrise (~0500–0700; Fig. 8).

At the central site, the overall distribution of flight altitude targets in 100 m categories varied from a high of 15.6% in the 100–200-m agl

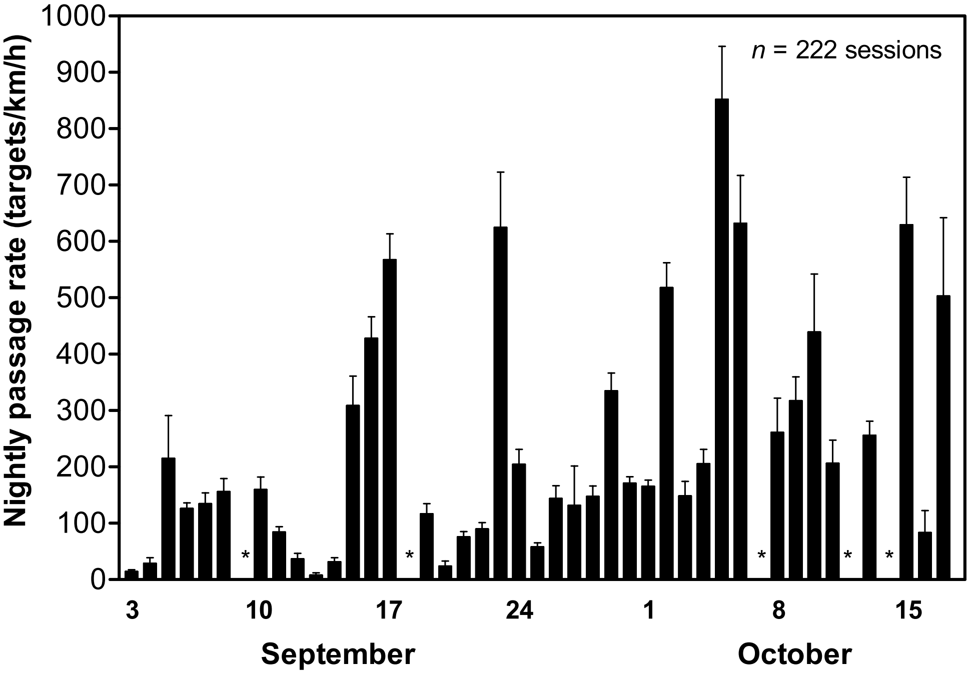

Figure 4. Mean nightly passage rates (targets/km/h ± 1SE) at the Mt. Storm central site, West Virginia, during fall 2003. Asterisks denote nights not sampled.

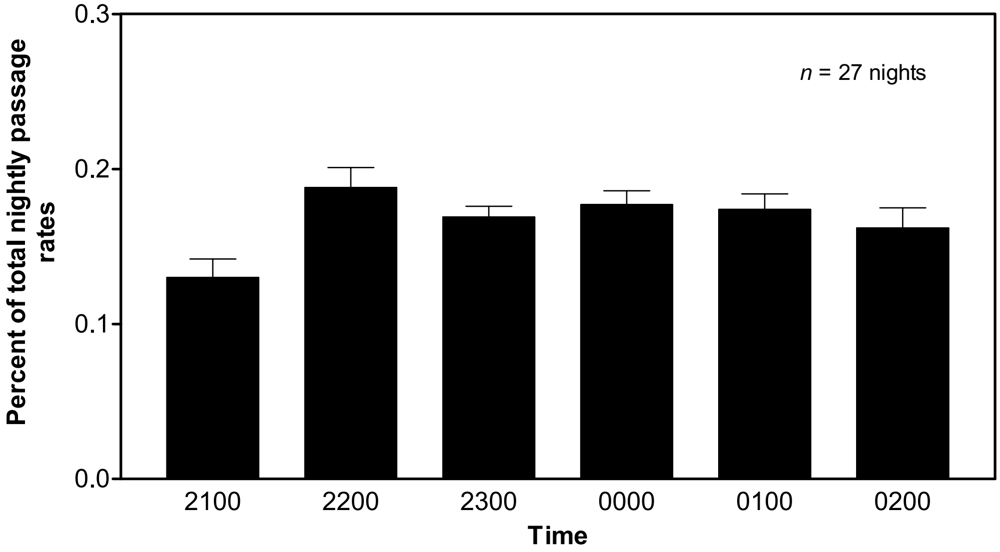

Figure 5. Percent of total nightly passage rates (± 1SE) by hour of the night at the Mt. Storm central site, West Virginia, during fall 2003.

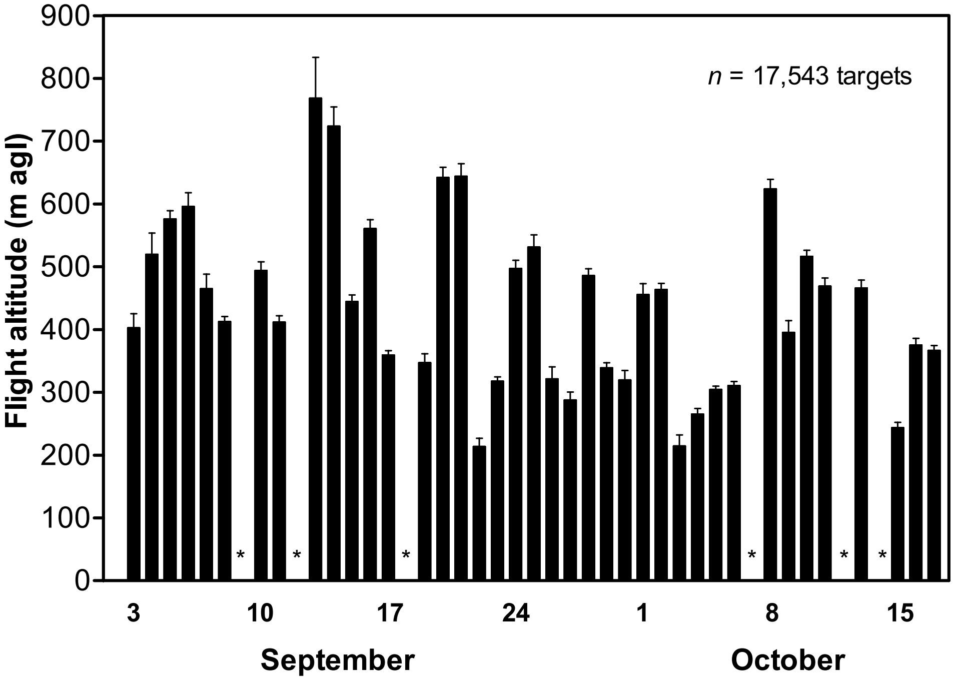

Figure 6. Mean nightly flight altitudes (m agl ± 1SE) at the Mt. Storm central site, West Virginia, during fall 2003. Asterisks denote nights not sampled.

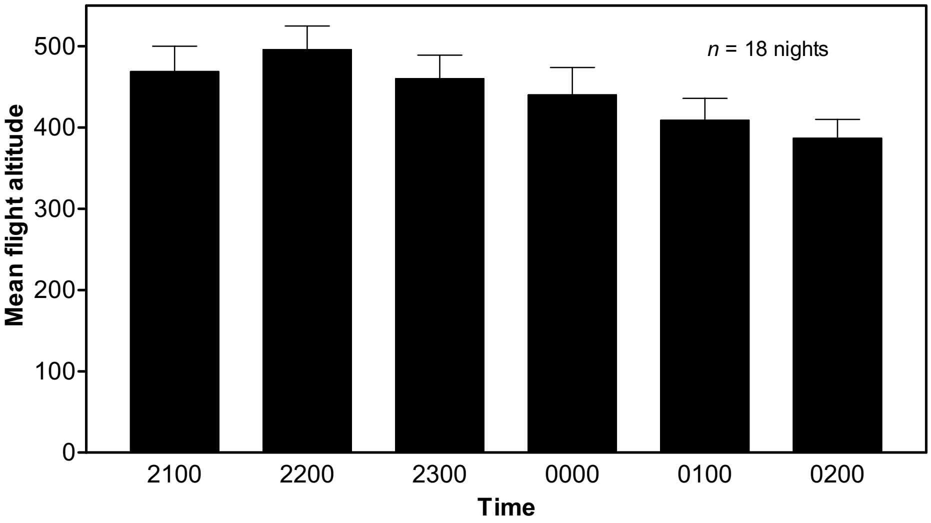

Figure 7. Mean flight altitude (m agl ± 1SE) by hour of the night at the Mt. Storm central site, West Virginia, during fall 2003.

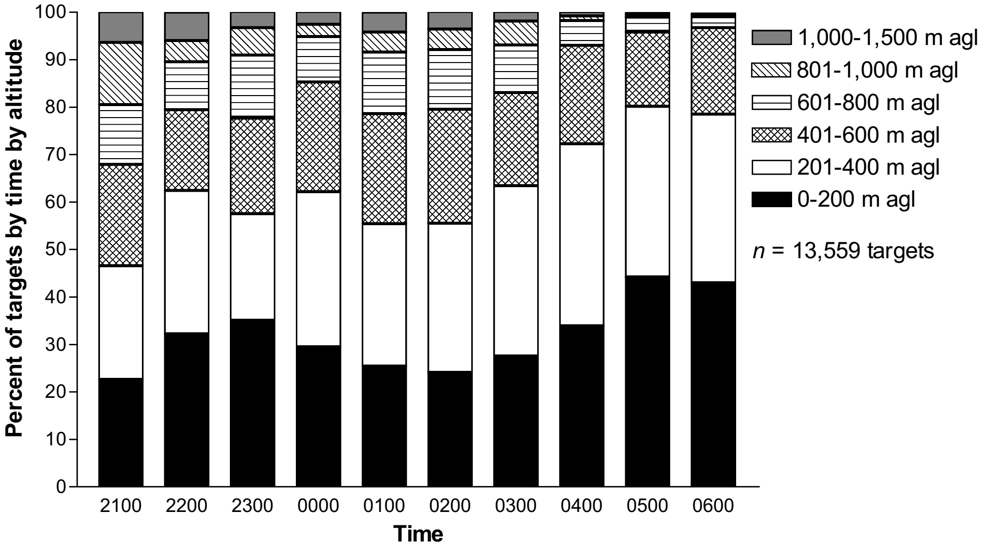

Figure 8. Percent of targets by hour of the night and altitude at the Mt. Storm central site, West Virginia, during fall 2003.

interval to a low of 0.1% in the 1,401–1,500-m agl interval (Table 2). The maximal height of the proposed wind turbines (125 m) contained 16% of all targets. Our 3.0-km vertical radar sampling indicated that 85% of the nights (*n* = 40) had at least one target flying from 1,500–3,000 m agl. For nights when targets could be effectively sampled to 3,000 m (*n* = 32), 8.2% of targets were flying >1,500 m agl, with a maximal recorded altitude of 2,880 m. The actual mean flight altitude of targets at the central site we reported for the 1.5-km range data, therefore, is higher than 410 m agl because some birds were migrating in the airspace above 1,500 m agl.

FLIGHT SPEEDS

The mean airspeed of radar targets recorded for the entire fall season was 12.5 ± 0.1 m/sec (*n* = 4,260 targets). Nightly mean air speeds varied during the fall season, ranging from 8 to 15m/sec (Fig. 9).

Table 2. Nocturnal flight altitudes of radar targets (% of targets) detected at the 1.5-km range at the Mt. Storm reference site, WV, during fall 2003 (*n* = 17,543 targets).

Flight altitude (m agl)	Percent of radar targets
0–100	12.7
101–200	15.6
201–300	14.8
301–400	13.3
401–500	11.9
501–600	9.2
601–700	6.9
701–800	5.1
801–900	3.5
901–1,000	2.9
1,001–1,100	1.7
1,101–1,200	1.2
1,201–1,300	0.7
1,301–1,400	0.3
1,401–1,500	0.1

SITE COMPARISONS

Because of our study design (see methods), analyses of site-specific variation in migration patterns are presented as paired comparisons for each of the four secondary sites, with pairs consisting of the central and one of the additional sites. We provide these paired comparisons on a daily basis for flight directions (Appendix 2), passage rates (Appendix 3), and flight altitudes (Appendix 4). These paired comparisons use concurrently collected data, which is important, given the large variation in metrics within and among nights. Note that interpretation of comparisons between the central site and eastern site requires special caution because differences in site elevations only allow comparisons to be made in the same air layer above ground level.

FLIGHT DIRECTIONS

Mean flight directions at the central site were not significantly different from those of corresponding sessions at the northern, southern, and western sites (all comparisons with $W < 4.00$, $P > 0.200$, $n = 18–22$). In contrast, mean flight directions differed significantly between the central and eastern sites ($W = 19.25$, $P < 0.001$, $n = 17$; Table 3).

MEAN PASSAGE RATES

Passage rates were not significantly different from the central and northern sites ($Z = –1.49$, $P = 0.136$, $n = 17$). In contrast, they were significantly different between the central site and the southern, eastern, and western sites (all comparisons with $Z < –1.96$, $P \leq 0.05$, $n = 18–21$; Table 3).

MEAN FLIGHT ALTITUDES

Mean flight altitudes at the central site were not significantly different from those of corresponding sessions at the northern, southern, and western sites ($Z > –0.68$, $P > 0.49$, $n = 15–21$). In contrast, they were significantly different from those at the eastern site ($Z = –2.02$, $P = 0.04$, $n = 16$; Table 3).

RIDGE-WIDE PASSAGE RATES

Based on the results of the paired comparisons, we estimated that the mean nocturnal passage rates for the entire fall season at the

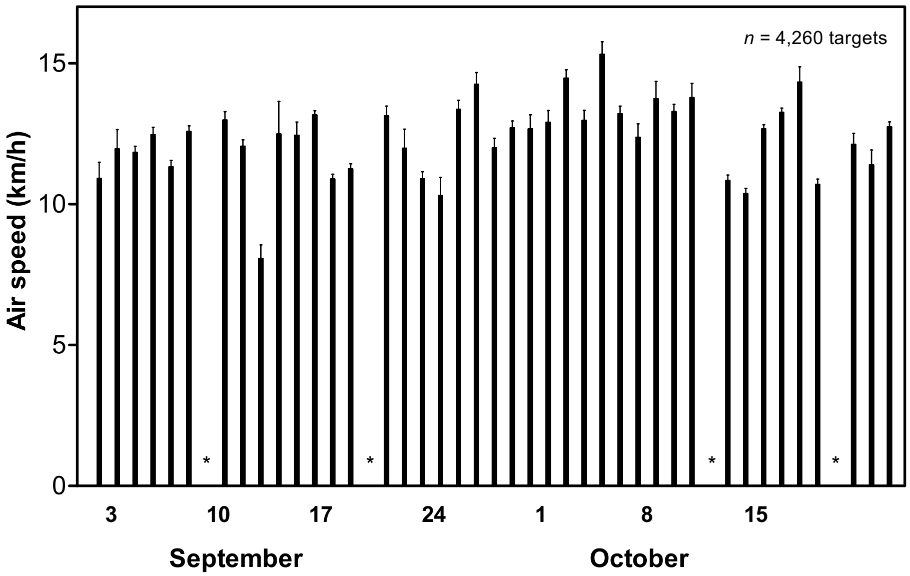

Figure 9. Mean nightly air speed (km/h ± 1SE) at the Mt. Storm central site, West Virginia, during fall 2003. Asterisks denote nights not sampled.

northern and southern ridge sites were respectively 186 and 169 targets/km/h, corresponding with the 241 targets/km/h reported from the central site. Averaging rates at these three sites, the estimated mean passage rate for the entire project development was therefore 199 targets/km/h. Estimated passage rates below 125 m were also lower at the northern and southern sites (respectively 30.8 and 35.7 targets/km/h). Combined with the calculated rate at the central site (42.5 targets/km/h below 125m), we estimated a ridge-wide mean passage rate of 36.3 targets/km/h below 125 m, or 2.91×10^{-4} targets/m^2/h within the zone of potential risk.

DISCUSSION

MIGRATION CHARACTERISTICS

Predictions of the effects of wind power development on migratory birds are hampered by a lack of knowledge of patterns of nocturnal migration. We addressed this paucity of data by documenting some of the key migration characteristics (flight directions, timing of migration, passage rates, flight altitudes, flight speeds) that can be used both to assess the risk of collision with wind turbines and to describe general properties of nocturnal bird migration at the proposed Mt. Storm Wind Power Development. These results are specific to the fall period of passerine migration, as spring migration may differ in terms of both geographical patterns of movements (e.g., Blackpoll Warblers: Hunt and Eliason 1999) and migratory flight characteristics (Blokpoel and Burton 1975, Bellrose 1976, Cooper and Ritchie 1995, Harmata et al. 2000).

FLIGHT DIRECTIONS

Mean flight directions of radar targets were typically in the expected direction during fall migration (i.e., southerly), although directions were highly variable from day to day. One paired comparison (central:eastern) suggested that targets traveling in the valley at the eastern site generally flew along the main axis of the valley (i.e., 193°), whereas targets along the ridge at the central site were generally traveling south (i.e., 178°). This comparison is confounded, however, by a 550-m difference in elevation between the sites. We can only describe flight directions of targets sampled in a comparable area above ground level. Consideration of this confounding effect at the eastern site also applies to all additional comparisons presented below.

Table 3. A comparison of flight directions, overall passage rates, and flight altitudes of radar targets at the central and other sites near Mt. Storm, WV, during fall 2003 (n = number of nights surveyed). Test statistics are for Wilcoxon paired-sample test (Z) and Mardia-Watson-Wheeler (Uniform Scores) test (W).

			Comparison site		Central site		Test results		
	Site	*n*	Mean	SE[1]	Mean	SE[1]	*Z*	*W*	*P*
Mean flight direction (degrees)	Northern	18	197°	53°	177°	54°		1.40	0.496
	Southern	22	191°	55°	207°	62°		1.06	0.588
	Eastern	19	193°	25°	178°	67°		19.25	< 0.001
	Western	17	219°	44°	191°	65°		3.23	0.199
Mean passage rate (targets/km/hr)	Northern	17	225	57	292	66	-1.49		0.136
	Southern	21	168	31	239	37	-1.96		0.050
	Eastern	21	54	10	220	52	-3.77		< 0.001
	Western	20	127	22	230	47	-2.70		0.007
Mean flight altitude (m agl)	Northern	16	448	29	439	37	-0.52		0.605
	Southern	21	447	31	467	33	-0.57		0.566
	Eastern	16	509	23	427	41	-2.02		0.044
	Western	17	436	20	472	30	-0.97		0.332

[1] Variations in mean flight directions are presented as angular deviations.

TIMING OF MIGRATION

The timing of nocturnal migration is important at several temporal scales—within nights, within seasons, and seasonally within years. Understanding the timing of migration at all scales allows determination of patterns of peak nocturnal migration that are critical to development of predictive models of avian risk and that could be used to develop mitigating measures that reduce migrant fatalities. In our study, passage rates increased ~1–2 h after sunset, leveled off, and then decreased slightly later in the evening (i.e., ~0145–0245). Several studies have found a pattern similar to this, in which the intensity of nocturnal migration begins to increase ~30–60 min after sunset, peaks around midnight, and declines steadily thereafter until dawn (Lowery 1951, Gauthreaux 1971, Kerlinger 1995).

Nocturnal migration is often a pulsed phenomenon seasonally as well (Alerstam 1990; B. A. Cooper and R. H. Day, ABR, Inc., unpubl. data). In this study, relatively large movements of birds (> 400 targets/km/h) occurred on 22.5% of the nights studied (16, 17 and 23 September, and 2, 5, 6, 10, 15, and 17 October). The high daily variation (two orders of magnitude) in migration passage rates during the fall illustrate the importance of continuous sampling throughout the entire fall migration period to identify these few and scattered, but important, peak migration nights. These peaks may correspond with factors that are predictable only within a short time span (such as passage of weather fronts); however, multi-year studies can provide resolution of general patterns of peak movements within the migratory season, narrowing the range of days in which peaks are likely to occur.

PASSAGE RATES

Passage rates are an index of the number of migrants flying past a location and can be used to assess the relative importance of sites being considered for wind power development. In this study, mean passage rates were similar in paired comparisons between the central and northern sites, but were significantly lower at the southern, western, and eastern sites relative to the central site. These differences suggest consistent spatial patterns in migration passage rates at a local scale. This contrasts with the current paradigm of broad-front passerine migration, which has generally implied a lack of distinct flight pathways, but rather uniform densities of migrants across regional migratory fronts of up to several hundred kilometers in width (Hutto 2000, Berthold 1993).

Possible explanations for this pattern include (1) variation in migration patterns across landscape features (e.g., birds responding to local topography [Williams et al. 2001] or phenomena associated with ridgelines [i.e., wind]) and (2) site-specific differences in the altitudinal zone that was sampled. Evidence for variation in migration patterns across landscape features was not found and is discussed more fully in subsequent sections. Site differences in the altitudinal zone that was sampled are plausible (the central site was 550 m higher than the eastern site, 188 m higher than the western site, 80 m higher than the northern site, and 7 m higher than the southern site); however, we believe these differences in elevation only help explain the observed differences at the eastern site. Mean flight altitudes were similar between the central and western sites (implying a similar distribution of targets in the air space over both sites), and therefore altitudinal differences do not explain the higher passage rates at the central site.

Putting our results from this study in context is difficult, as there are few published data on fall nocturnal passage rates available for other locations in the Eastern US. On a broad scale, however, our study area appeared to have relatively high rates of migration compared to other locations, where we have conducted studies using similar equipment and methods. For example, the mean fall nocturnal passage rate in this study for the central station was 241 targets/km/h, and the overall ridge-wide mean (based on results from three radar sites) was 199 targets/km/h; compared with 17–28 targets/km/h at the Stateline and Vansycle wind power facilities in eastern Oregon (Mabee and Cooper 2002), 25–100 targets/km/h at four sites in the Midwest (Day and Byrne 1990), and 122–225 targets/km/h at three sites in New York State (Cooper et al. 1995b; Cooper and Mabee 2000). Harmata et al. (1998) did not distinguish between diurnal and nocturnal migration rates in their study near Ennis Lake, Montana but reported a peak migration rate of ~62 targets/km/h within the seasonal range of dates of our study.

We also examined the influence of weather and date on migration passage rates (Appendix 5) and identified the best approximating model containing the variables date, wind direction, and ceiling height. Migration passage rates increased with date (i.e., higher passage rates were observed later in the season), and this pattern was illustrated by our figure examining passage rates by date (Fig. 4)—the highest passage rates occurred in late September and October. Passage rates also increased with tailwinds and eastern or western crosswinds, but decreased with headwinds. This pattern is generally consistent with other studies (Lowery 1951, Gauthreaux 1971; Able 1973, 1974; Blokpoel and Gauthier 1974, Richardson 1990), and wind direction was the strongest variable in our model. Passage rates also decreased with low ceiling heights (i.e., < 500 m agl). Although we are not certain why this latter pattern may have occurred, there are several possible reasons, including (1) birds migrating above the cloud layer (and potentially above the effective sampling range of our radar) and (2) a correlation between low ceiling conditions and unfavorable migratory conditions.

FLIGHT ALTITUDES

Flight altitudes are critical for understanding the vertical distribution of nocturnal migrants and are another important metric used to assess the suitability of a site for wind power development. Relative to other bird groups, passerines migrate at lower flight altitudes; whereas shorebirds and waterfowl tend to migrate at higher altitudes (Kerlinger 1995). Because we know that birds were often flying above 1.5 km in this study (based on our 3.0-km-range sampling), our mean flight altitudes (410 m agl) based on 1.5-km-range data are minima, and the percentages of targets within 100 m agl (and all other categories) are maxima.

Similar to our results, most other studies, using a variety of radar systems and analyses, have indicated that the majority of nocturnal migrants fly below 600 m agl (Bellrose 1971; Gauthreaux 1972, 1978, 1991; Bruderer and Steidinger 1972; Cooper and Ritchie 1995). Kerlinger (1995) summarized radar results from the eastern U.S. and concluded that three-quarters of passerines migrate within this lower range of altitudes (0–600 m agl). The lowest mean flight altitudes of nocturnal migrants (209 m agl) were reported during fall migration in southwestern Montana by Harmata et al. (2000), with a radar system nearly identical to that used in this study. We also examined the percentage of targets within 125 m agl and found that 16% of birds at central area (13% for all radar sites along the ridge) flew below 125 m at the proposed Mt. Storm site, compared to 3–9% (below 125 m agl) at two sites in the Pacific Northwest that were studied using similar methods (Mabee and Cooper 2002).

In contrast to these results, other researchers have found that peak nocturnal densities extend over a broad altitudinal range up to ~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 largely due to differences in location, species-composition of migrating birds, local topography, radar equipment used, and perhaps weather conditions. It 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 agl; so we believe that, given the relative paucity of migrants above 1,500 m, the data we collected for this study more accurately reflect actual flight altitudes.

In this study, mean flight altitudes were lower at the end of our nightly sampling period, although the maximal range of differences between hourly means was 70 m. An examination of our pilot data from nights with high migration passage rates ($n = 10$ nights), however, showed that the proportion of targets flying < 200 m agl was greatest at ~0500–0700 (Fig. 8). These patterns may explain why more birds are killed at tall obstacles after midnight than before midnight (Weir 1976) and suggest that, despite decreases in overall passage rates during later hours of the night, actual numbers of low altitude migrants could increase toward dawn. Total nightly passage rates at lower altitudes, therefore, could differ from those extrapolated from rates obtained for the first six hours of each night's migration.

As with our migration studies elsewhere (Cooper and Ritchie 1995; Cooper et al. 1995a, 1995b; Cooper and Mabee 2000; Mabee and Cooper 2002), we recorded large among-night variation in flight altitudes at the central site. Mean flight altitudes always were above the maximal proposed turbine heights during fall 2003, however, there were five nights when mean flight altitudes fell between 200 and 300 m agl. Weather conditions varied within and between nights, but three of the five nights had precipitation, low clouds (<500 m agl) and variable wind directions and speeds, whereas the remaining two nights had no precipitation, high clouds, and variable wind directions and speeds. Daily variation in flight altitudes probably reflected changes in both species-composition and vertical structure of the atmosphere and weather. Kerlinger and Moore (1989) and Bruderer et al. (1995) have concluded that atmospheric structure is the primary selective force determining the height at which migrants fly. Other locations also exhibit considerable variation among days in the flight altitudes of migrants that were related primarily to changes in the vertical structure of the atmosphere (Gauthreaux 1991). Birds crossing the Gulf of Mexico, for example, appear to fly at altitudes at which favorable winds minimize the energetic cost of migration.

DID MIGRANTS CONCENTRATE ALONG THE ALLEGHENY FRONT?

The Allegheny Front ridgeline is thought to be used as a leading line by some diurnal migrants (Hall and Bell 1981), but its role for nocturnal migrants is unknown. We used a weight of evidence approach to this question and evaluated data on flight directions, flight path behaviors, NEXRAD images, and passage rates. Flight directions of targets among ridge sites were similar, and targets passed over, rather than flew parallel to, the main axis of the ridge. Similarly, targets crossing the Allegheny Front showed little or no deviation in their flight paths when they passed over ridges. Strong correlations between overall flight directions of migrants from NEXRAD weather radar data and our ridge sites (see Appendix 6) further suggest that migration patterns did not vary with local topography.

In contrast, the variation in passage rates among some of the ridge sites (central:southern) and other sites (central:western), does not corroborate this pattern. These differences in passage rates, however, may not be correlated with landscape features (i.e., they may misrepresent patterns or simply reflect random variation because of our low sample size (n = 1) for off-ridge locations), and we consider this result equivocal. The main body of evidence therefore suggests that, at the scale of our observations, nocturnal migrants did not concentrate (or compress their migratory flight path) along the Allegheny Front.

CONCLUSIONS

This study focused on nocturnal migration patterns and flight behaviors during the peak period of fall passerine migration at the proposed Mt. Storm Wind Power Development in West Virginia. The key results of our study were: (1) relatively high mean passage rates (i.e., 199 targets/km/h ridge-wide); (2) approximately 20% of nights had passage rates much higher than the mean rate for the fall season; (3) variation in passage rates among some ridge sites (central:southern) and between ridge and off-ridge sites (central:western); (4) the weight of evidence suggesting that migrants did not concentrate along the Allegheny Front in fall 2003; (5) similar mean flight altitudes among sites (excluding valley); and (6) 13% of targets < 125 m agl ridge-wide, which is higher than the small number of comparable studies.

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Appendix 1. Calculation of ridge-wide passage rate estimates for proposed Mt. Storm wind development area during fall, 2003.

1) Calculations of ridge-wide migration passage rates, per km of front, for proposed Mt. Storm wind development area during fall, 2003.

The mean ridge-wide passage rate (targets/km/h) for fall season ($\overline{P}$) was derived as

$$\overline{P} = \frac{\overline{C}\left(\overline{N}/\overline{C_N} + \overline{S}/\overline{C_S} + 1\right)}{3}.$$

$\overline{C}$ = mean passage rate (targets/km/h) at central site for n nights.
$\overline{N}$ = mean passage rate (targets/km/h) at north site for n_N nights.
$\overline{S}$ = mean passage rate (targets/km/h) at south site for n_S nights.
$\overline{C_N}$ = mean passage rate (targets/km/h) at central site for n_N nights.
$\overline{C_S}$ = mean passage rate (targets/km/h) at central site for n_S nights.

n = total nights sampled.
n_N = total nights sampled at north site.
n_S = total nights sampled at south site.

2) Calculations of ridge-wide migration passage rates for turbine zone (below 125 m) at proposed Mt. Storm wind development during fall, 2003.

n = total nights sampled.
n_N = total nights sampled at north site.
n_S = total nights sampled at south site.
R_C = mean nightly passage rate (targets/km/h) at central site.
R_N = mean nightly passage rate (targets/km/h) at north site.
R_S = mean nightly passage rate (targets/km/h) at south site.
L_C = mean nightly percent of targets below 125 m agl at central site.
L_N = mean nightly percent of targets below 125 m agl at north site.
L_S = mean nightly percent of targets below 125 m agl at south site.

Appendix 1. Continued.

Season-wide passage rates of targets below 125 m agl ($\overline{B}$) were calculated as

$$\overline{B_C} = \frac{\sum_{i=1}^{n} \left(R_{Ci} * L_{Ci} \right)}{n},$$

$$\overline{B_N} = \frac{\sum_{i=1}^{n_N} \left(R_{Ni} * L_{Ni} \right)}{n_N}, \text{ and}$$

$$\overline{B_S} = \frac{\sum_{i=1}^{n_S} \left(R_{Si} * L_{Si} \right)}{n_S};$$

and comparative passage rates below 125 m at the central site were

$$\overline{B_{C_N}} = \frac{\sum_{i=1}^{n_N} \left(R_{Ci} * L_{Ci} \right)}{n_N} \text{ and}$$

$$\overline{B_{C_S}} = \frac{\sum_{i=1}^{n_S} \left(R_{Ci} * L_{Ci} \right)}{n_S}.$$

Note that mean nightly passage rates (R_C) for these last two equations were calculated only from sessions with concurrent observations at the respective secondary sites.

The fall mean of ridge-wide passage rates (targets/km/h) for targets below 125 m agl ($\overline{P}_{125}$) was then derived as

$$\overline{P_{125}} = \frac{\overline{B_C}\left(\overline{B_N} \big/ \overline{B_{C_N}} + \overline{B_S} \big/ \overline{B_{C_S}} + 1 \right)}{3}.$$

Appendix 2. Paired comparisons of nocturnal flight directions of radar targets from sites at Mt. Storm, WV, during fall 2003 (*n* = number of radar targets). Nights were divided into early (2030–2300 h) and late (2330–0200 h) periods.

	Early				Late			
Date	Site comparison	Mean direction, angular deviation (*n*)			Site comparison	Mean direction, angular deviation (*n*)		
03-Sept	Central : East	105°, 47 (22)	:	-	Central : East	91°, 57 (6)	:	-
04-Sept	Central : North	157°, 20 (19)	:	225° (1)	Central : North	156°, 31 (16)	:	219°, 25 (10)
05-Sept	Central : South	204°, 35 (43)	:	175°, 27 (12)	Central : South	226°, 50 (37)	:	171°, 36 (17)
06-Sept	Central : West	263°, 35 (49)	:	241°, 31 (37)	Central : West	230°, 33 (58)	:	251°, 34 (53)
07-Sept	Central : North	211°, 42 (58)	:	225°, 41 (24)	Central : South	220°, 36 (65)	:	210°, 41 (21)
08-Sept	Central : East	236°, 39 (61)	:	187°, 45 (15)	Central : West	251°, 22 (72)	:	237°, 23 (62)
09-Sept	Central : South	-	:	283°, 46 (18)	Central : North	-	:	266°, 33 (42)
10-Sept	Central : West	210°, 45 (38)	:	216°, 59 (16)	Central : East	219°, 32 (41)	:	128°, 72 (8)
11-Sept	Central : South	232°, 37 (44)	:	252°, 29 (24)	Central : North	238°, 27 (48)	:	245°, 15 (40)
12-Sept	Central : East	258°, 17 (12)	:	260° (1)	Central : West	256°, 11 (4)	:	-
13-Sept	Central : South	201°, 54 (4)	:	75° (1)	Central : South	275°, 60 (6)	:	150° (1)
14-Sept	Central : West	162°, 49 (21)	:	254°, 33 (35)	Central : East	61°, 47 (37)	:	173°, 45 (10)
15-Sept	Central : North	139°, 15 (221)	:	160°, 18 (57)	Central : South	162°, 17 (228)	:	143°, 26 (44)
16-Sept	Central : East	161°, 24 (73)	:	184°, 51 (21)	Central : West	182°, 33 (86)	:	186°, 13 (144)
17-Sept	Central : South	236°, 30 (91)	:	227°, 33 (36)	Central : North	240°, 24 (99)	:	232°, 19 (55)
19-Sept	Central : West	109°, 34 (61)	:	128°, 50 (27)	Central : East	96°, 40 (47)	:	207°, 55 (20)
20-Sept	Central : North	194°, 67 (9)	:	211°, 36 (63)	Central : South	329°, 34 (21)	:	288°, 50 (20)
21-Sept	Central : East	336°, 35 (40)	:	179°, 35 (20)	Central : West	330°, 16 (51)	:	276°, 40 (35)
22-Sept	-	-	:	-	Central : North	119°, 22 (24)	:	100°, 42 (22)
23-Sept	Central : West	150°, 24 (56)	:	156°, 30 (59)	Central : East	142°, 20 (56)	:	203°, 55 (29)
24-Sept	Central : North	10°, 61 (36)	:	355°, 56 (41)	Central : South	21°, 47 (40)	:	49°, 53 (31)
25-Sept	Central : East	110°, 43 (27)	:	211°, 70 (8)	Central : West	28°, 69 (39)	:	254°, 34 (25)
26-Sept	Central : South	318°, 35 (62)	:	262°, 67 (18)	Central : South	324°, 30 (53)	:	287°, 51 (22)
27-Sept	Central : West	57°, 56 (7)	:	221°, 42 (7)	Central : East	130°, 23 (52)	:	157°, 12 (2)
28-Sept	Central : South	149°, 25 (38)	:	163°, 30 (70)	Central : South	131°, 19 (41)	:	153°, 31 (54)
29-Sept	Central : South	139°, 19 (50)	:	166°, 22 (32)	Central : West	151°, 15 (78)	:	180°, 42 (36)
30-Sept	Central : North	113°, 29 (43)	:	115°, 42 (50)	Central : East	90°, 41 (25)	:	201°, 41 (30)

Appendix 2. Continued.

	Early				Late			
Date	Site comparison	Mean direction, angular deviation (*n*)			Site comparison	Mean direction, angular deviation (*n*)		
1-Oct	Central : West	133 27 (65)	:	124º, 20 (14)	Central : East	123º, 24 (54)	:	188º, 51 (5)
2-Oct	Central : North	163 20 (56)	:	168º, 17 (34)	Central : South	177º, 28 (82)	:	161º, 20 (29)
3-Oct	Central : East	10º, 57 (37)	:	217º, 50 (10)	Central : West	32º, 50 (17)	:	-
4-Oct	Central : South	132º, 33 (27)	:	162º, 31 (52)	Central : North	136º, 29 (39)	:	144º, 38 (44)
5-Oct	Central : West	157º, 29 (38)	:	181º, 33 (73)	Central : East	184º, 36 (39)	:	203º, 18 (37)
6-Oct	Central : North	200º, 54 (23)	:	207º, 29 (65)	Central : South	240º, 56 (30)	:	249º, 34 (68)
7-Oct	Central : East	-	:	182º, 42 (13)	Central : West	-	:	222º, 48 (30)
8-Oct	Central : South	271º, 33 (78)	:	252º, 49 (27)	Central : North	314º, 53 (52)	:	315º, 50 (30)
9-Oct	Central : West	240º, 33 (63)	:	239º, 23 (67)	Central : East	265º, 25 (78)	:	205º, 13 (20)
10-Oct	Central : West	212º, 28 (143)	:	235º, 22 (78)	Central : South	234º, 23 (72)	:	252º, 31 (19)
11-Oct	Central : North	260º, 37 (59)	:	243º, 24 (82)	Central : East	252º, 39 (71)	:	193º, 16 (41)
12-Oct	Central : South	119º, 12 (23)	:	162º, 32 (47)	Central : North	169º, 17 (36)	:	178º, 19 (88)
13-Oct	Central : West	258º, 42 (82)	:	193º, 37 (19)	Central : East	313º, 23 (61)	:	287º, 33 (76)
15-Oct	Central : North	140º, 12 (51)	:	150º, 12 (141)	Central : South	136º, 14 (78)	:	138º, 16 (85)
16-Oct	Central : West	49º, 72 (18)	:	-	Central : East	172º, 41 (60)	:	201º, 61 (11)
17-Oct	Central : East	220º, 43 (43)	:	175º, 60 (6)	Central : North	196º, 23 (170)	:	191º, 23 (77)

Appendix 3. Paired comparisons of mean nightly passage rates of radar targets between sites at Mt. Storm, WV, during fall 2003 (*n* = number of sessions). Each night was divided into an early (2030–2300 h) and late (2330–0200 h) period.

	Early				Late			
Date	Site comparison	Mean ± SE (*n*)			Site comparison	Mean ± SE (*n*)		
03-Sept	Central : East	16 ± 2 (3)	:	0 ± - (1)	Central : East	12 ± 8 (2)	:	-
04-Sept	Central : North	39 ± 29 (2)	:	2 ± 2 (2)	Central : North	22 ± 1 (3)	:	13 ± 8 (3)
05-Sept	Central : South	304 ± 139 (3)	:	17 ± 7 (3)	Central : South	127 ± 42 (3)	:	44 ±10 (3)
06-Sept	Central : West	125 ± 17 (3)	:	87 ± 30 (3)	Central : West	127 ± 15 (3)	:	127 ± 10 (3)
07-Sept	Central : North	128 ± 36 (3)	:	57 ± 18 (3)	Central : South	141 ± 22 (3)	:	54 ± 1 (2)
08-Sept	Central : East	128 ± 28 (3)	:	28 ± 6 (3)	Central : West	198 ± 14 (2)	:	177 ± 11 (3)
09-Sept	Central : South	-	:	29 ± 16 (3)	Central : North	-	:	76 ± 7 (3)
10-Sept	Central : West	119 ± 5 (3)	:	31 ± 1 (3)	Central : East	200 ± 29 (3)	:	11 ± 1 (3)
11-Sept	Central : South	80 ± 20 (3)	:	145 ± 7 (2)	Central : North	88 ± 5 (3)	:	157 ± 28 (3)
12-Sept	Central : East	27 ± 5 (2)	:	0 ± - (1)	Central : West	56 ± - (1)	:	0 ± 0 (2)
13-Sept	Central : South	1 ± 1 (3)	:	5 ± 5 (2)	Central : South	18 ± 2 (2)	:	8 ± - (1)
14-Sept	Central : West	22 ± 3 (3)	:	81 ± 17 (3)	Central : East	41 ± 14 (3)	:	15 ± 5 (3)
15-Sept	Central : North	308 ± 100 (3)	:	246 ± 21 (3)	Central : South	309 ± 61 (3)	:	228 ± 29 (3)
16-Sept	Central : East	402 ± 70 (3)	:	23 ± 3 (3)	Central : West	455 ± 40 (3)	:	253 ± 20 (3)
17-Sept	Central : South	478 ± 36 (3)	:	205 ± 18 (3)	Central : North	657 ± 55 (3)	:	256 ± 34 (3)
19-Sept	Central : West	133 ± 31 (3)	:	55 ± 21 (3)	Central : East	99 ± 20 (3)	:	17 ± 8 (3)
20-Sept	Central : North	46 ± 6 (2)	:	367 ± 64 (3)	Central : South	9 ± 7 (3)	:	143 ± 73 (3)
21-Sept	Central : East	69 ± 13 (3)	:	57 ± 15 (3)	Central : West	82 ± 16 (3)	:	104 ± 8 (3)
22-Sept	-	-	:	-	Central : North	90 ± 11 (3)		21 ± 8 (3)
23-Sept	Central : West	527 ± 177 (3)	:	156 ± 52 (3)	Central : East	722 ± 86 (3)	:	40 ± 27 (3)
24-Sept	Central : North	159 ± 14 (3)	:	106 ± 34 (3)	Central : South	251 ± 34 (3)	:	87 ± 21 (2)
25-Sept	Central : East	47 ± 7 (3)	:	16 ± 5 (3)	Central : West	69 ± 10 (3)	:	38 ± 18 (2)
26-Sept	Central : South	135 ± 40 (3)	:	80 ± 6 (3)	Central : South	153 ± 30 (3)	:	101 ± 42 (2)
27-Sept	Central : West	18 ± 4 (2)	:	40 ± - (1)	Central : East	207 ± 96 (3)	:	16 ± - (1)
28-Sept	Central : South	177 ± 12 (3)	:	418 ± 121 (3)	Central : South	117 ± 28 (3)	:	197 ± 97 (3)
29-Sept	Central : South	267 ± 22 (3)	:	346 ± 110 (3)	Central : West	403 ± 7 (3)	:	99 ± 14 (3)
30-Sept	Central : North	177 ± 14 (3)	:	132 ± 32 (3)	Central : East	152 ± - (1)	:	56 ± 6 (3)

Appendix 3. Continued.

	Early				Late			
Date	Site comparison	Mean ± SE (*n*)			Site comparison	Mean ± SE (*n*)		
1-Oct	Central : West	162 ± 24 (3)	:	31 ± 11 (3)	Central : East	169 ± 5 (3)	:	20 ± 12 (2)
2-Oct	Central : North	472 ± 57 (3)	:	231 ± 68 (3)	Central : South	564 ± 67 (3)	:	226 ± 7 (2)
3-Oct	Central : East	158 ± 51 (3)	:	35 ± 8 (3)	Central : West	135 ± 12 (2)	:	-
4-Oct	Central : South	287 ± 55 (3)	:	251 ± 28 (3)	Central : North	204 ± 17 (3)	:	88 ± 11 (3)
5-Oct	Central : West	745 ± 162 (3)	:	264 ± 58 (3)	Central : East	959 ± 81 (3)	:	72 ± 5 (3)
6-Oct	Central : North	744 ± 70 (3)	:	535 ± 76 (3)	Central : South	520 ± 138 (3)	:	493 ± 55 (3)
7-Oct	Central : East	-	:	59 ± 9 (3)	Central : West	-	:	57 ± 9 (3)
8-Oct	Central : South	369 ± 74 (3)	:	64 ± 23 (3)	Central : North	153 ± 38 (3)	:	76 ± 32 (3)
9-Oct	Central : West	251 ± 42 (3)	:	156 ± 52 (3)	Central : East	384 ± 53 (3)	:	24 ± 9 (3)
10-Oct	Central : West	604 ± 76 (3)	:	374 ± 44 (3)	Central : South	275 ± 159 (3)	:	63 ± 18 (3)
11-Oct	Central : North	159 ± 53 (3)	:	317 ± 18 (3)	Central : East	255 ± 58 (3)	:	80 ± 13 (3)
12-Oct	Central : South	-	:	221 ± 8 (2)	Central : North	-	:	519 ± 37 (2)
13-Oct	Central : West	266 ± 16 (3)	:	41 ± 11 (3)	Central : East	247 ± 52 (3)	:	251 ± 47 (3)
15-Oct	Central : North	812 ± 8 (2)	:	958 ± 131 (3)	Central : South	507 ± 73 (3)	:	354 ± 77 (3)
16-Oct	Central : West	50 ± 6 (2)	:	-	Central : East	106 ± 66 (3)	:	6 ± 2 (2)
17-Oct	Central : East	206 ± 186 (2)	:	9 ± 1 (3)	Central : North	701 ± 63 (3)	:	255 ± 29 (3)

Appendix 4. Paired comparisons of mean nightly flight altitudes of radar targets from sites at Mt. Storm, West Virginia, during fall 2003. Nights were divided into early (2030-2300 hrs) and late (2330-0200 hrs) periods. *n* = number of radar targets.

	Early				Late			
Date	Site comparison	Mean ± SE (*n*)			Site comparison	Mean ± SE (*n*)		
03-Sept	Central : East	403 ± 22 (79)	:	-	-	-	:	-
04-Sept	Central : North	505 ± 42 (26)	:	570 ± 23 (33)	Central : North	575 ± 18 (7)	:	517 ± 48 (19)
05-Sept	Central : South	580 ± 14 (214)	:	620 ± 45 (24)	Central : South	551 ± 40 (35)	:	747 ± 97 (14)
06-Sept	Central : West	618 ± 34 (58)	:	464 ± 29 (82)	Central : West	571 ± 29 (52)	:	509 ± 23 (57)
07-Sept	Central : North	514 ± 44 (28)	:	421 ± 40 (17)	Central : South	438 ± 27 (52)	:	450 ± 19 (22)
08-Sept	Central : East	439 ± 12 (168)	:	624 ± 45 (32)	Central : West	387 ± 11 (181)	:	412 ± 13 (140)
10-Sept	Central : West	533 ± 27 (50)	:	517 ± 42 (19)	Central : East	475 ± 16 (103)	:	402 ± 48 (11)
11-Sept	Central : South	435 ± 15 (150)	:	406 ± 27 (42)	Central : North	389 ± 14 (157)	:	391 ± 16 (114)
13-Sept	Central : South	716 ± 115 (16)	:	496 ± 79 (4)	Central : South	827 ± 52 (14)	:	320 ± 55 (2)
14-Sept	Central : West	701 ± 47 (74)	:	544 ± 65 (31)	Central : East	746 ± 41 (75)	:	620 ± 87 (10)
15-Sept	Central : North	428 ± 17 (314)	:	494 ± 20 (151)	Central : South	458 ± 13 (383)	:	534 ± 17 (129)
16-Sept	Central : East	697 ± 36 (88)	:	613 ± 20 (218)	Central : West	534 ± 15 (445)	:	549 ± 13 (498)
17-Sept	Central : South	422± 11 (498)	:	451 ± 15 (214)	Central : North	292 ± 7 (460)	:	344 ± 9 (388)
19-Sept	Central : West	361 ± 18 (219)	:	390 ± 26 (93)	Central : East	305 ± 23 (72)	:	425 ± 18 (120)
20-Sept	Central : North	729 ± 36 (48)	:	579 ± 35 (124)	Central : South	606 ± 16 (113)	:	610 ± 36 (82)
21-Sept	Central : East	680 ± 24 (183)	:	441 ± 15 (168)	Central : West	583 ± 33 (106)	:	361 ± 14 (208)
22-Sept	-	-	:	-	Central : North	214 ± 13 (41)	:	343 ± 24 (47)
23-Sept	Central : West	347 ± 9 (604)	:	518 ± 12 (220)	Central : East	270 ± 11 (371)	:	557 ± 14 (155)
24-Sept	Central : North	555 ± 18 (320)	:	660 ± 30 (128)	Central : South	416 ± 19 (230)	:	585 ± 23 (198)
25-Sept	Central : East	452 ± 27 (111)	:	462 ± 15 (137)	Central : West	589 ± 26 (153)	:	354 ± 21 (118)
26-Sept	Central : South	353 ± 24 (182)	:	420 ± 29 (112)	Central : South	257 ± 31 (89)	:	357 ± 24 (170)
28-Sept	Central : South	510 ± 14 (460)	:	405 ± 12 (639)	Central : South	460 ± 18 (424)	:	240 ± 20 (231)
29-Sept	Central : South	349 ± 15 (346)	:	373 ± 13 (327)	Central : West	331 ± 9 (441)	:	441 ± 11 (547)
30-Sept	Central : North	333 ± 17 (273)	:	494 ± 22 (247)	Central : East	246 ± 20 (49)	:	424 ± 26 (58)

Appendix 4. Continued.

	Early				Late			
Date	Site comparison	Mean ± SE (*n*)			Site comparison	Mean ± SE (*n*)		
1-Oct	Central : West	556 ± 20 (291)	:	549 ± 31 (132)	-		:	-
2-Oct	Central : North	441 ± 14 (490)	:	359 ± 13 (292)	Central : South	486 ± 14 (507)	:	411 ± 20 (99)
3-Oct	Central : East	214 ± 18 (104)	:	324 ± 11 (211)	-	-	:	-
4-Oct	Central : South	231 ± 13 (128)	:	302 ± 14 (163)	-	-	:	-
5-Oct	Central :West	316 ± 8 (727)	:	372 ± 12 (471)	Central : East	293 ± 7 (752)	:	525 ± 10 (525)
6-Oct	Central : North	283 ± 8 (575)	:	343 ± 23 (85)	Central : South	339 ± 10 (555)	:	392 ± 12 (471)
8-Oct	Central : South	609 ± 20 (317)	:	637 ± 25 (151)	Central : North	653 ± 23 (164)	:	632 ± 17 (278)
9-Oct	-	-	:	-	Central : East	395 ± 19 (222)	:	560 ± 15 (274)
10-Oct	Central : West	501 ± 16 (301)	:	468 ± 16 (226)	Central : South	528 ± 13 (430)	:	581 ± 19 (121)
11-Oct	Central : North	478 ± 21 (242)	:	333 ± 21 (181)	Central : East	462 ± 16 (309)	:	518 ± 15 (270)
13-Oct	Central : West	487 ± 15 (362)	:	642 ± 18 (278)	Central : East	417 ± 22 (149)	:	473 ± 16 (319)
15-Oct	Central : North	250 ± 12 (317)	:	291 ± 16 (259)	Central : South	235 ± 12 (235)	:	249 ± 11 (288)
16-Oct	-	-	:	-	Central : East	363 ± 13 (184)	:	516 ± 15 (249)
17-Oct	Central : East	302 ± 22 (91)	:	492 ± 27 (50)	Central : North	378 ± 8 (499)	:	405 ± 12 (264)

Appendix 5. AIC modeling of the effects of weather on migration passage rates and flight altitudes at Mt. Storm, West Virginia, during fall 2003.

METHODS

We modeled the influence of weather and date separately on the dependent variables passage rates and flight altitudes. We obtained our weather data (i.e., wind speed and direction) from 50-m meteorological towers located near the central and northern sites. All wind categories except the calm category had a mean wind speed of ≥2.2 m/s (i.e., ≥5 mph) and were categorized as the following: tailwinds, WNW to ENE (i.e., 293º–068º), headwinds ESE to SSW (i.e., 113º–248º), eastern crosswinds (069º–112º), western crosswinds (249º–292º), and calm (<2.2 m/s).

Prior to model specification, we examined the data for redundant variables (Spearman's $r_S > 0.70$) and retained all 5 parameters for inclusion in the model. We examined scatterplots and residual plots to ensure that variables met assumptions of analyses (i.e., linearity, normality, collinearity) and did not contain presumed outliers (>4 SE). We used a square-root transformation on both dependent variables to approximate normality. We specified 12 models: a global model containing all 5 parameters and subset models representing potential influences of weather variables and date on migration passage rates and flight altitudes. We analyzed both model sets with linear regression. Prior to model selection, we examined fit of global models following recommendations of Burnham and Anderson (1998) that included examining residuals and measures of fit ($R^2 = 0.38$ and 0.30, respectively, for passage-rate and flight-altitude models).

Because the number of sessions sampled for passage rates ($n = 217$) and flight altitudes ($n = 185$) was small relative to the number of parameters (K) in many models (i.e., $n/K < 40$), we used Akaike's Information Criterion corrected for small sample size (AICc) for model selection (Burnham and Anderson 1998). We used the formulas presented in Burnham and Anderson (1998) to calculate AICc for our least-squares (linear regression) methods. We ranked all candidate models according to their AICc values, and the best model (i.e., most parsimonious) was the model with the smallest AICc value (Burnham and Anderson 1998). We drew primary inference from models within 2 units of the minimal AICc value, although models within 4–7 units may have some empirical support (Burnham and Anderson 1998). We calculated Akaike weights (w_i) to determine the weight of evidence in favor of each model and to estimate the relative importance of individual parameters (Burnham and Anderson 1998). All analyses were conducted with SPSS software (SPSS 2002).

RESULTS

PASSAGE RATES

The best approximating model explaining migration passage rates of nocturnal migrants during fall migration was the model containing the variables date, wind direction, and ceiling height (Table A5.1). The second-best model, the global model containing date, wind direction, ceiling height, wind speed, and fog, also received strong empirical support (ΔAICc = 1.55; Table A5.1). Both models contained the same strong positive associations with date, tailwinds, and eastern and western crosswinds and strong negative associations with low ceiling heights (i.e., <500 m agl; Table A5.2). Calm wind directions, wind speed, and fog were not related to passage rates. The weight of evidence in favor of the "best" model ($w_{best}/w_{second\ best}$; Burnham and Anderson 1998), was only ~2.1 times greater than that of the global model, indicating some

Table A5.1. Linear regression models explaining their influence on migration passage rates of radar targets at the Mt. Storm central site, WV, during fall 2003 (*n* = 217 sessions). Model weights (w_i) were based on Akaike's Information Criterion (AIC).

Model	RSS[a]	K[b]	AIC_c[c]	Δ AIC_c[d]	w_i[e]
Date + wind direction + ceiling height	6,989.7	8	770.18	0.00	0.68
Global model: date + wind direction + wind speed + ceiling height + fog	6,899.3	10	771.73	1.55	0.32
Date + ceiling height	7,881.1	4	787.72	17.54	0.00
Date + wind direction	7,994.3	7	797.17	26.98	0.00
Date + wind direction + fog	7,994.3	8	799.32	29.14	0.00
Date	9,118.1	3	817.28	47.10	0.00
Fog + date	9,114.9	4	819.28	49.10	0.00
Ceiling height	9,864.4	3	834.36	64.18	0.00
Wind direction	10,208.4	6	848.08	77.90	0.00
Wind direction + wind speed	10,170.5	7	849.41	79.23	0.00
Wind speed	10,978.5	3	857.58	87.40	0.00
Fog	11,164.1	3	1,359.95	589.77	0.00

[a] Residual sum of squares.
[b] Number of estimable parameters in approximating model.
[c] Akaike's Information Criterion corrected for small sample size.
[d] Difference in value between AIC_c of the current model versus the best approximating model with the minimal AIC_c value.
[e] Akaike weight—probability that the current model (*i*) is the best approximating model among those being considered.

Table A5.2. Parameter estimates from the two best models explaining their influence on passage rates of radar targets at the Mt. Storm central site, WV, during fall 2003 (*n* = 217 sessions). Coefficients (B) of the categorical variables (wind direction, ceiling height, fog) were calculated relative to headwinds, high ceiling height (>500 m agl), and fog conditions.

Model	B	SE	R^2
Date + wind direction + ceiling height			0.374
Intercept	–53.600	8.596	
Date	0.251	0.032	
Wind direction = tailwind	4.058	1.156	
Wind direction = calm	-0.356	1.935	
Wind direction = E crosswind	5.454	1.358	
Wind direction = W crosswind	3.039	0.977	
Ceiling height <500 m agl	-4.828	0.879	
Global model: Date + wind direction + wind speed + ceiling height + fog			0.382
Intercept	–52.060	8.640	
Date	0.254	0.032	
Wind direction = tailwind	3.876	1.162	
Wind direction = calm	-0.897	2.050	
Wind direction = easterly crosswind	5.057	1.379	
Wind direction = westerly crosswind	3.568	1.091	
Wind speed	-0.109	0.172	
Ceiling height <500 m agl	-5.269	0.917	
Fog = absent	-1.876	1.222	

uncertainty in selection of the best candidate model (Burnham and Anderson 1998). Summing Akaike weights (Σw_i) of parameters across all models provided evidence for the relative importance of variables from these models, with wind direction (1.00) being more important than date, wind speed, ceiling height, and fog (all 0.68). The remaining 10 model sets received no empirical support (ΔAICc > 17, $w_i = 0.00$; Table A5.1).

FLIGHT ALTITUDES

The best approximating model explaining flight altitudes of nocturnal migrants during fall migration was the global model containing the variables date, wind direction, wind speed, ceiling height, and fog (Table A5.3). The second-best model contained date, wind direction, and ceiling height but received limited empirical support (ΔAICc = 3.37; Table A5.3). Both models

Table A5.3. Linear regression models explaining the influence of environmental factors on mean flight altitudes of radar targets at the Mt. Storm central site, WV, during fall 2003 (n = 185 sessions). Model weights (w_i) were based on Akaike's Information Criterion (AIC).

Model	RSS[a]	K[b]	AIC_c[c]	$\Delta\ AIC_c$[d]	w_i[e]
Global model: date + wind direction + wind speed + ceiling height + fog	1,858.8	10	448.12	0.00	0.77
Date + wind direction + ceiling height	1,939.0	8	451.49	3.37	0.14
Date + wind direction + fog	1,949.9	8	452.53	4.41	0.08
Date + wind direction	2,030.0	7	457.79	9.67	0.01
Wind direction + wind speed	2,102.0	7	464.24	16.12	0.00
Wind direction	2,225.1	6	472.60	24.48	0.00
Fog + date	2,278.1	4	472.71	24.59	0.00
Wind speed	2,309.2	3	473.13	25.01	0.00
Date + ceiling height	2,283.5	4	473.15	25.03	0.00
Date	2,416.0	3	481.49	33.37	0.00
Fog	2,564.6	3	492.53	44.41	0.00
Ceiling height	2,635.9	3	497.61	49.49	0.00

[a] Residual sum of squares.
[b] Number of estimable parameters in approximating model.
[c] Akaike's Information Criterion corrected for small sample size.
[d] Difference in value between AIC_c of the current model versus the best approximating model with the minimum AIC_c value.
[e] Akaike weight—probability that the current model (*i*) is the best approximating model among those being considered.

contained strong negative associations with date and western crosswinds, and the second-best model also contained a strong negative association with low ceiling heights (i.e., <500 m agl; Table A5.4). Wind speed and fog were not related to flight altitudes. The weight of evidence in favor of the "best" model ($w_{best}/w_{second\ best}$) was 5.5 times greater than that of the second best model. The Σw_i suggested that both wind direction (0.92) and wind speed (0.86) were more important than date, ceiling height, and fog (all 0.68). The third-best model containing the variables date, wind direction, and fog also received marginal support (ΔAICc = 4.41) whereas the remaining 9 model sets received no empirical support (ΔAICc > 9; $w_i \leq 0.08$; Table A5.3).

DISCUSSION

MIGRATION PASSAGE RATES

It is a well-known fact that general weather patterns and their associated temperatures and winds affect migration (Richardson 1978, 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 an area is affected by a low to the west or a high to the east

Table A5.4. Parameter estimates from the two best models explaining the influence of environmental factors on mean flight altitudes of radar targets at the Mt. Storm central site, WV, during fall 2003 (*n* = 185 sessions). Coefficients (B) of the categorical variables (wind direction, ceiling height, fog) were calculated relative to headwinds, high ceiling height (>500 m agl), and fog conditions.

Model	B	SE	R²
Global model: Date + wind direction + wind speed + ceiling height + fog			0.303
Intercept	44.797	5.242	
Date	–0.080	0.020	
Wind direction = tailwind	0.126	0.719	
Wind direction = calm	–0.454	1.315	
Wind direction = easterly crosswind	–1.459	0.907	
Wind direction = westerly crosswind	–2.310	0.686	
Wind speed	–0.222	0.112	
Ceiling height <500 m agl	1.070	0.585	
Fog = absent	–1.189	0.796	
Date + wind direction + ceiling height			0.295
Intercept	44.109	5.214	
Date	–0.087	0.020	
Wind direction = tailwind	0.572	0.699	
Wind direction = calm	0.669	1.232	
Wind direction = easterly crosswind	–0.904	0.859	
Wind direction = westerly crosswind	–2.983	0.611	
Ceiling height <500 m agl	1.599	0.551	

and are cool and northerly in the reverse situation. Clouds, precipitation, and strong, variable winds are typical in the centers of lows and near fronts between weather systems, whereas weather usually is fair with weak or moderate winds in high-pressure areas. Numerous studies in the Northern Hemisphere have shown that, in fall, most bird migration tends to occur in the western parts of lows, the eastern or central parts of highs, or in intervening transitional areas. In contrast, warm fronts, which are accompanied by southerly (unfavorable) winds and warmer temperatures, tend to slow migration in the fall (Lowery 1951, Gauthreaux 1971; Able 1973, 1974; Blokpoel and Gauthier 1974, Richardson 1990). Conversely, spring migration tends to occur in the eastern parts of lows, the western or central parts of highs, or in intervening transitional areas.

We examined the influence of weather and date on migration passage rates and identified the best approximating model containing the variables date, wind direction, and ceiling height. Migration passage rates increased with date (i.e., higher passage rates were observed later in the season) and this pattern was displayed by our figure examining passage rates by date—the highest passage rates occurred in late September and October. Passage rates also increased with tailwinds and eastern or western crosswinds, but decreased with headwinds. This pattern is generally consistent with other studies (Lowery 1951, Gauthreaux 1971; Able 1973, 1974; Blokpoel and Gauthier 1974, Richardson 1990), and wind direction was the strongest variable in our model. Passage rates also decreased with low ceiling heights (i.e., < 500 m agl). Although we are not certain why this latter pattern may have occurred, there are several possible reasons, including (1) birds migrating above the cloud layer (and potentially above the effective sampling range of our radar) and (2) fewer bird migrating because of low ceiling conditions associated with unfavorable migratory conditions.

FLIGHT ALTITUDES

Radar studies have shown that wind is a key factor in migratory flight altitudes (Alerstam 1990). Birds fly mainly at heights at which headwinds are minimized and tailwinds are maximized (Bruderer et al. 1995). Because wind strength generally increases with altitude, bird migration generally takes place at lower altitudes in headwinds and at higher altitudes in tailwinds (Alerstam 1990). Most studies (all except 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.

The best approximating model explaining flight altitudes was the global model containing the variables date, wind direction, wind speed, ceiling height, and fog. Flight altitudes decreased with date (i.e., lower flight altitudes were observed later in the season), with the lowest flight altitudes occurring in late September and October. Flight altitudes also decreased with western crosswinds, a pattern not consistent with other studies (see above). The remaining variables (wind speed, ceiling height, fog) did not have a strong influence on flight altitudes.

In this study, we examined the hourly relationships between passage rates, flight altitudes, and weather conditions because of the dynamic weather conditions within a night. This treatment of the data, however, may violate the assumption of statistical independence (between hourly passage rates or flight altitudes) and our results, therefore, may overemphasize the strength of the relationships presented. The ability of weather (and other variables) to influence migration passage rates and flight altitudes of nocturnal birds has been established in many studies, but it will require additional field data under a greater variety of weather conditions to predict those conditions that would put nocturnal migrants at risk of collision with wind turbines. Studies at existing wind power facilities that concurrently examine passage rates and flight altitudes of nocturnal migrants throughout the full migratory seasons are needed to encompass the wide variation in weather conditions that are essential for predictive modeling of these relationships. Large kills of migratory birds have not been documented at wind farms, 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, approximately 25 nocturnal spring migrants (passerines) were reported killed on one foggy night near three turbines and a floodlit substation at the Mountaineer wind power development in West Virginia.

Appendix 6. NEXRAD weather comparisons at Mt. Storm, West Virginia, during fall 2003.

METHODS

We compared base reflectivity (representing bird densities) and base velocity (representing bird speeds and flight directions) results from NEXRAD (WSR-88D radar) images to the migration passage rates and flight direction results of our marine radar studies at the proposed Mt. Storm site during September and early October, 2003. We used NEXRAD images from the KPBZ radar station, located near Pittsburgh, PA (UTM 17T 566226E 4487063N; 172 km from the proposed development). For each night analyzed, we used NEXRAD base velocity and base reflectivity images taken at ~2330 h local time.

Because the proposed wind power project is located beyond radar coverage of any NEXRAD station, we calculated reflectivity values for a 20-km-wide band of area, 30-50 km from the KPBZ radar station. At this distance, the NEXRAD beam encompasses the range of flight altitudes of the majority of nocturnal passerine migrants (this study; Bellrose 1971; Gauthreaux 1972, 1978, 1991; Bruderer and Steidinger 1972; Cooper and Ritchie 1995; Kerlinger 1995). Images with precipitation patterns within the sample band were omitted from the analyses. From the base velocity images, we determined the direction of migration as the azimuth perpendicular to a line through the region representing zero radial velocity. Average target velocity was estimated as the median velocity value along the migration axis (in both directions from the station) between 30 km and 50 km from KPBZ.

To eliminate nights with suspected heavy insect contamination, we adjusted our velocity results for wind speeds to determine true airspeed of NEXRAD targets. We used wind velocities from radiosondes launched from the Pittsburgh weather station. Radiosondes are released only twice daily (at 0800 and 2000 EDT); so we used wind data only from the 2000 h launch times, which most-closely represent the time periods of our nightly observations. We calculated and applied wind velocities and directions measured at 500 m agl, approximately the midpoint of the altitudes within the NEXRAD beam in the sample area. Wind-velocity vectors then were subtracted from the base velocity vectors to determine true mean airspeeds of NEXRAD targets. For subsequent analyses, we reduced insect contamination by including data only for nights where NEXRAD airspeeds were ≥6 m/s (Larkin 1991, Bruderer and Boldt 2001, Diehl et al. 2003.

DATA ANALYSES

To compare the Mt. Storm radar results with the NEXRAD data, we computed correlation coefficients between mean hourly rates of radar targets at the Mt. Storm central site and mean, median, and maximal reflectivity values in the NEXRAD sample area for non-insect nights between 3 September and 10 October. Because reflectivity values represent logarithmic densities, we log-transformed passage rates prior to analysis. By using an insect airspeed threshold of 6 m/s, we still were able to include 22 nights in the analyses. We also compared nightly mean flight directions of targets at the Mt. Storm central site with the mean direction of broad-scale migration from the KPBZ base velocity images using the Mardia–Watson–Wheeler (Uniform Scores) test for paired comparisons (Oriana software version 2.0).

RESULTS

For 23 nights with comparable data, nightly flight directions of radar targets at the Mt. Storm central site (mean = 160° ± 16°) did not differ from concurrent directions of broad-front migration (mean = 166° ± 14°), as determined from base velocity images of the WSR-88 ($W = 0.68$, $n = 23$, $P = 0.71$). We found only weak correlations, however, between NEXRAD reflectivity values (representing bird densities) and radar migration passage rates for those nights (mean reflectivity: $r^2 = 0.13$; median reflectivity: $r^2 = 0.06$; maximal reflectivity: $r^2 = 0.09$).

DISCUSSION

Doppler weather radar systems have recently been used to describe large-scale patterns of bird migration, both quantitatively and qualitatively (Larkin et al. 2002, Diehl et al. 2003, Gauthreaux and Belser 2003, Gauthreaux et al. 2003). Although there currently are 151 WSR-88D (NEXRAD) radar stations operating throughout the US, effective coverage of the country's landmass is incomplete. The NEXRAD station closest to Mt. Storm is located near Pittsburgh, PA, at a distance of ~170 km from the proposed wind power development project, and outside of

Appendix 6. Continued.

the effective coverage area of the base-level radar; so direct comparison of the radar systems is not possible for migration activity at the study site. Nevertheless, some characteristics of nocturnal migration at Mt. Storm hypothetically may be correlated with large-scale migration patterns in the region, as characterized by NEXRAD-generated data. If there was a strong correlation, the weather radar data therefore might be useful as predictors of general passage rates of nocturnal migrants at the project site.