1995 Project Abstract
For the Period Ending June, 30 1997

TITLE: AVIAN POPULATION ANALYSIS FOR WIND POWER GENERATION REGIONS -- O12

PROJECT MANAGER: John R. Dunlop, P.E.
ORGANIZATION: American Wind Energy Association
ADDRESS: 448 Morgan Ave. South, Suite 300
Minneapolis, MN 55405-2030

LEGAL CITATION: ML 1995, Chapter 220, Section 19, Subd. 11(d)
APPROPRIATION AMOUNT: $75,000

Statement of Objectives: To: 1) gather background information on previous research conducted on birds in regard to wind power facilities, 2) identify sources of avian population data in the wind corridors in Minnesota 3) collect migratory bird data with field surveys in 3 wind regions (tiers) identified within the state, and 4) summarize information into one document that may be used to assist in the siting and development of wind energy facilities in Minnesota.

Overall Project Results: We compiled an annotated bibliography of national and international sources to identify factors that may affect avian activity relative to wind power development. The bibliography is included as an attachment to our final report and is available from the Natural Resources Research Institute. In addition, an avian literature database is maintained by the National Wind Technology Center at www.nrel.gov/wind/avianlit.html . We gathered information on avian population data in this region from 10 sources for 43 counties within the three wind tiers. This information is included as an attachment to our final report and is also available from the Natural Resources Research Institute. One federally threatened species, the Bald Eagle is known to nest in this region. Because breeding bird activity for most species is completed at low elevations it is not likely that they would be directly affected by wind towers. Background information gathered indicated that migratory birds were likely to be most at risk from potential wind power development in the western portion of Minnesota. Information gathered on migratory bird activity on 18 sites in three wind regions over four seasons indicated that migratory activity was quite variable, was inconsistent across sites, and only a few differences were detected in number of migrants across the three regions. We observed fewer targets in the area (near Marshall) with the highest potential for wind development in spring 1996. This pattern was not found in the other seasons of observation (fall 1995 and 1996 and spring 1997) and this inconsistency makes it difficult or impossible to rank areas for potential wind development that integrates concerns for migrating birds. Migratory bird activity in this region is quite variable and landscape features that birds respond to are not static. For example, daily movements of birds during staging are affected by local cropping patterns during both spring and fall periods and amount of winter snowfall affects distribution of water across the landscape during spring migration. We can be safe to recommend that tower construction in areas that bisect daily movement be avoided because these flights are generally done at lower altitudes than long-range migration and at an elevation that would be consistent with tower height. There is an inherent risk associated with construction of any tall structure and we can never be 100% certain that bird collisions can be avoided at any site. In general, it is impossible to calculate the simultaneous occurrence of birds migrating over a wind tower facility during bad weather. The annual incidence rate, however, would likely be lower than the number killed by vehicles or house cats.

Project results use and dissemination: Methods and techniques used to collect radar data in this study were applied to another study near Buffalo Ridge where additional wind towers are being constructed. Information gathered for this project was shared with Northern States Power. Project results were presented at the Midwest Wildlife Conference in December 1997. The avian assessment document will be distributed to interested state and national agencies and will be edited and submitted to a peer-reviewed journal for publication.

Date of report: **December 23, 1997**

LCMR Final Work Program Update

I. Project Title: AVIAN POPULATION ANALYSIS FOR WIND POWER GENERATION REGIONS — O12

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A.	**Legal Citation:**	**ML 95, Chp. 220, Sec. 19, Subd. 11(d)**
	Total biennial LCMR appropriation:	**$75,000**
	Balance:	**$0.00**

Appropriation Language: This appropriation is from the oil overcharge money to the commissioner of administration for an agreement with American Wind Energy Association to identify and assess significant avian activity areas within identified wind farm corridors in Minnesota. This appropriation must be matched by at least $75,000 of nonstate money. This project must be completed and final products delivered by December 31, 1997, and the appropriation is available until that date.

B. LMIC Compatible Data Language: N/A

C. Status of Match Requirement:

Match Required	**$75,000**
Match Being Sought*	**100,000**
Match Committed to Date*	**95,000**
Match Spent to Date	**90,000**
TOTAL BUDGET	**$170,000**

* Project will require a budget of $175,000, including $75,000 from oil overcharge funds, and $100,000 from the National Renewable Energy Laboratory.

II. Project Summary: Wind power is recognized as having minimal adverse impacts on the environment compared to other electricity-generating technologies. However, collisions between birds and wind turbines have occurred at some existing wind energy installations. Research on the causes of the collisions continues, but ornithologists concur that key factors in predicting potential conflicts are the types, numbers and seasonal activities of bird species in the area.

The purpose of this investigation is to compile existing information on seasonal bird activities in areas of Minnesota that have high potential for development of wind energy and to conduct field surveys of bird species where information is lacking. Existing data on breeding bird populations were augmented with data from independently-funded surveys that cooperators at the Natural Resources Research Institute (NRRI) conducted within these areas. Information on migratory birds (numbers and types) passing through the wind corridors were collected using a portable radar and visual observations. These data were used to test whether or not variables associated with migrant densities (identified under Objective A) can be used to predict the migration patterns detected at the study sites.

A literature review of avian/turbine interactions was conducted to identify factors that may contribute to these interactions. This information was used in survey site selection so that the influence of these factors in the wind regions of Minnesota could be assessed. Field surveys were designed to document migration patterns across wind corridors in areas where wind energy development may occur; interactions at sites already operational were not examined. Sampling design was evaluated following the first survey period and appropriate modifications were implemented in subsequent samples.

The project was managed by an advisory board representing a cross-section of the organizations supporting this project. The baseline avian information gathered in this project will assist in the future siting and development of wind energy facilities. These data, however, will not preclude the necessity for detailed analyses of site-specific proposed wind project areas in the future.

III. Final Work Program Update Summary: December 23, 1997

Objective A. ***Literature review of wind generation/avian issues***
We compiled an annotated bibliography of the most current national and international sources to identify factors which may affect avian activities related to wind power development. Also, an annotated bibliography of avian collision and electrocution published by the California Energy Commission is available at www.energy.ca.gov/reports/avian_bibliography.html. Background information concentrated on three main topics: the impacts of manmade structures (e.g., television towers, wind turbines) on birds; migration and the impact of weather on migration; and radar studies of migrant birds. Radar research studies were included in the bibliography since our primary method of collecting data on migratory birds was a portable radar system.

Objective B. ***Synthesis of Minnesota data and identification of local avian issues***
We gathered information on avian population data from 10 sources for 43 counties within the three wind tiers. The most recent breeding locations of endangered, threatened or special concern species (state or federal) were provided after a review of the Minnesota Natural Heritage Information System. Supplemental sightings of rare species were provided by personal records of birders as well as seasonal summaries compiled in the Loon. Estimates of breeding waterfowl and production information from 1987 to 1994 in the Prairie Pothole Region within Minnesota were provided by the U.S. Fish and Wildlife Service. Migratory patterns and timing of waterfowl and passerines were compiled from published reports as well as personal communication with National Wildlife Refuge and Northern Prairie Science Center personnel.

Objective C. ***Conduct field surveys***
Radar field surveys were conducted during a 48 day period which encompassed peak migration dates for a variety of bird species (i.e., waterfowl, passerines, and raptors) based on spring and fall migration data collected in Minnesota and South Dakota (Janssen 1987). The sampling periods for the radar field surveys are as follows: fall 1995 ran from September 15 to October 21; spring 1996 ran from April 1 to May 8; fall 1996 ran from September 12 to October 29; and spring 1997 was from March 26 to May 12.

IV. Statement of Objectives:

A. ***Literature review of wind generation/avian issues***
A literature search of the most current national and international sources was conducted to determine the most important characteristics of interactions between birds and wind power projects. This background information was used to identify the types of data which were gathered in succeeding stages of this research project. Although problems associated with avian/turbine interactions are outside the scope of this data collecting project, references addressing these issues were included without further cost to the project.

B. ***Synthesis of Minnesota data and identification of local avian issues***
All known sources of avian population data in the wind corridors in Minnesota were gathered and correlated. Sources included County Biological Surveys, Breeding Bird Surveys, the Minnesota Ornithologists Union (MOU) and documented data collected locally. In addition to these sources, quantitative breeding bird data from independently-funded studies that NRRI cooperators are conducting was used. The resulting data set was used to determine areas which need to be augmented by field surveys. Local authorities were also consulted to help identify any issues or data that may impact where future field surveys may be conducted.

C. ***Conduct field surveys***
Based on the results of previous objectives, field survey sites were identified, survey criteria were developed, and surveys were conducted. Although much data exists regarding avian populations in the forested regions of Minnesota, information, on breeding and migratory activities of avian populations, within the study area of this project is insufficient. Therefore, data were collected during two fall and two spring migration periods to fill voids in the current information base, focusing on areas which are likely to be developed in the near future. This data will be valuable in siting future wind power plants.

Since the purpose of this project is to assimilate existing data and collect new data where lacking on avian use in regions of the state that have sufficient wind resources, a hypothesis regarding the link between birds and wind impacts or an experiment designed to examine bird populations in areas where there are currently turbine and non-turbine activities is not pertinent to the project. The null hypothesis we addressed is that there are no differences in numbers of migrant birds or types of migrant species among regions of the study area.

D. ***Minnesota Wind Corridor Baseline Avian Assessment Report***
Bird population data gathered from all sources will be summarized into a single document. This

document will be distributed to the organizations providing funding, the project coordinators, and others requesting the material. This document will then be used to assist in the siting and development of wind energy facilities in Minnesota by providing information on migratory activity within identified wind development corridors.

Timeline:

		7/95	10/95	5/96	10/96	5/97	12/97
A.	Review literature	***					
B.	Collate existing data	***					
	Field interviews	***					
	Survey needs report		***				
C.	Collect field data		***	***	***	***	
	Analysis of data			***	***	***	***
D.	Write avian assessment						*** ***

V. Objectives/Outcomes

A. Literature review of wind generation/avian issues

A.1 Activity: Review recent national and international publications to obtain background information and recommendations on the types of data required to investigate avian issues related to wind power development.

A.1.a Context: Significant commercial scale wind energy development began in the United States in the early 1980's. At most development sites, no bird strikes have been recorded. Yet at other sites, a persistent problem has been identified. The major wind energy developers, the U.S. Department of Energy (DOE) and state and local agencies have initiated a thorough investigation of the wind/avian mortality issue. They are examining such issues as the characteristics of wind turbines, the resident and migratory bird species, feeding patterns and habitat. The U.S. DOE will be spending up to $5 million on avian/wind research over the next two years.

Preliminary results indicate that bird collisions with turbines may be influenced by such factors as the species of birds residing in and passing thorough the area, terrain, ground cover, prey residing in the area, hunting patterns, natural and man-made perches, as well as the specific characteristics of the wind equipment and towers. Reports from the investigations have been published in conference proceedings, trade press, and contract progress reports.

Information gathered under this objective will guide our survey protocol and data analyses. For example, physiographic factors found to contribute to bird collisions with turbines will be incorporated into site selection so that the relevance of these effects in Minnesota's wind regions may be examined. The influence of these factors will be incorporated into the avian assessment document included under Objective D.

This project is different from the above mentioned DOE study in that we are collecting data on seasonal bird activities in areas of Minnesota that have high potential for development of wind energy. We are not addressing site-specific avian/turbine conflicts in this study, but rather are providing data to document avian use of potential wind corridor areas during the breeding and migration periods.

We have already started to gather the most current information available and have determined the type of information on avian populations which should be collected in this project to ensure that the data will be valuable and comparable with other wind/avian studies.

A.1.b Methods: Avian issues have been reported in current trade and association publications, as well as in preliminary reports on other wind/avian research. The National Wind Coordinating Committee (NWCC), established in 1994, has appointed an avian subcommittee which is developing guidelines for investigating wind/avian issues. We will review published reports and confer with other investigators involved in avian studies and members of the NWCC avian subcommittee to determine the types of data that should be collected in the LCMR research project.

This process has been initiated as shown by the details of the sampling design included under Objective C.

Other sources of information regarding avian/turbine interactions, such as technical reports and scientific journals, will be searched using bibliographic services and software programs. Recent journal articles addressing patterns of bird migrations will also be included in the literature review. Printed copies of all references identified under this objective will be obtained and housed at NRRI. A bibliography of these references will be included in the avian assessment document (Objective D). Citations for these references will also be documented on magnetic media using a bibliographic software program. Copies of the files will be provided to other agencies upon request.

A.1.c Materials: Computer searches utilizing bibliographic software or services will eliminate search time and allow us to review only the most pertinent studies. Reports on avian studies will be obtained from the U.S. Department of Energy and other organizations sponsoring research. Much of the information on wind/avian issues is in the public domain or in published trade magazines. The amount budgeted for this objective has been reduced due to these computer-assisted searches and low- or no-cost materials; the background work completed with other funding sources that we have already initiated in order to plan Objective C; and our expertise in the field of avian ecological studies. NRRI cooperators will be directly responsible for conducting literature searches and compiling information on bird data that has been collected in the State. The program manager will assist in the search process and provide information from sources that he is familiar with, but that may not be readily available in the public domain (e.g., reports).

A.1.d Budget:

LCMR Budget:	$1,000	
LCMR Balance:	0	
Match Budget:	1,000	
Match Balance:	0	
ACTIVITY BUDGET:		$2,000

A.1.e Timeline:

	7/95	10/95	5/96	10/96	5/97	12/97
Review literature	***					
Produce bibliography		***				

A.1.f. Final Workprogram Update: December 23, 1997

We compiled an annotated bibliography (see attachment B) of the most current national and international sources to identify factors which may affect avian activities related to wind power development. Also, an annotated bibliography of avian collision and electrocution published by the California Energy Commission is available at www.energy.ca.gov/reports/avian_bibliography.html. Background information concentrated on three main topics: the impacts of manmade structures (e.g., television towers, wind turbines) on birds; migration and the impact of weather on migration; and

radar studies of migrant birds. Radar research studies were included in the bibliography since our primary method of collecting data on migratory birds was a portable radar system.

Studies conducted in Florida, North Dakota, Minnesota, and Wisconsin looked at the impacts of manmade structures on birds, in particular, television towers. Wind turbine/avian interaction studies were conducted in California and concentrated on raptors. A study completed in southwestern Minnesota indicated that avian vulnerability to wind turbine collisions was directly related to population density and flight patterns at or below the elevation of the structures.

Most migrational studies were conducted in Texas and California and addressed flight behavior and seasonal migration of passerines and raptors. A study completed in North-central Minnesota indicated that premigrational movements and behavior of young Mallards and Wood Ducks differed between the sexes of young birds and between young and adult birds. Research conducted in Iowa, Illinois, Indiana, and Canada. indicated that passage of a cold front, change in wind direction, sky condition, and barometric pressure the day before were important weather variables during seasonal migration.

A study using a portable marine radar system was conducted in Alaska, Minnesota, and South Dakota. Results from this study included information on optimal detection of birds by radar and flight patterns of migrating birds. A study conducted in Red Wing, Minnesota applied radar techniques to evaluate the impacts of transmission lines on local and migrating birds. Both of these radar research studies were similar to ours in methods used.

B. Synthesis of Minnesota avian and wind data and identification of local avian issues

B.1 Activity: Review avian studies that have been conducted in Minnesota to establish a database of avian information and to determine where additional field surveys should be conducted.

B.1.a Context: Public and private organizations have collected data on avian activities in Minnesota for many years. Formal studies have systematically recorded data on avian populations and migratory activities. In addition to these data, hundreds of birders in Minnesota have kept meticulous personal records on bird sightings. Data collected from these sources will form the baseline data set on avian population and activities in the windy areas of Minnesota.

The U.S. Department of Energy has provided a rough estimate that winds in Minnesota have the potential to produce over 10 times the amount of electricity that is currently used in the state. DOE, the Minnesota Department of Public Service (DPS) and the Union of Concerned Scientists (UCS) have all published maps identifying the areas of the state with the greatest wind resource. The most sophisticated study has been conducted by UCS, in which they used extensive historical wind data from the U.S. Department of Energy in combination with detailed geographic, elevation, terrain and land use data to project the areas of the state with winds which could support significant development. UCS published the results of their study in 1993, and a copy of their Minnesota wind resource map is attached (Minnesota Wind Resource Assessment Map, Union of Concerned Scientists, *Powering the Midwest,* Boston, 1993).

Wind energy is expected to be developed initially in areas of the state with Class 4 or higher winds. Based on the UCS study, those areas comprise approximately one third of the land area of the state (excluding urban areas, transportation systems, parks, etc.), or about 74,000 km² (18.3 million acres). The wind corridors are located along the west, and southwest and southern borders of the state. These are the areas of the state where information on avian populations and migratory activities is most crucial to subsequent analysis of potential avian/wind power concerns, and are herein subsequently referred to as "study target areas."

Preliminary investigation indicates that existing avian data is more extensive in the calm forested areas of the state and less complete in the areas of the state with higher winds. Quantitative breeding bird data from studies we have previously conducted in the wind power production region of the state as part of an unrelated project will be used to supplement existing avian data for this region. Data collection within these areas is expected to continue at no cost to this project, contingent upon funding for this independent project. Other sources of avian data recorded to date in this region must be reviewed for completeness and areas where additional information needs to be gathered need to be identified.

B.1.b Methods: Many organizations have collected avian population data in Minnesota. The state and local offices of the Department of Natural Resources, county level biological surveys and breeding bird surveys are sources of avian population studies. The Minnesota Ornithologists Union has collected county-by-county data throughout much of the state on bird populations. Furthermore, members of environmental and nature societies, such as the Audubon Society, maintain thorough records of avian activities in specific locations. Data from these and other sources will be synthesized into a single resource.

The data required for this task is in the public domain, or the organizations with the data have agreed to provide copies for this study. We will collect reports on avian populations from public agencies and private, published studies. The Minnesota Audubon Council has agreed to solicit from its members personal historical records of bird sightings in the study target area. The most important data for this study, in decreasing order of priority, will be records of rare or endangered species, birds protected by the migratory bird treaty act or the eagle protection act, waterfowl and other water birds, passerines and resident birds. The data will be examined on a county by county basis in the wind corridors (on a more detailed grid if feasible), and areas with inadequate data will be identified.

As this study is designed to establish a baseline avian population summary where potential wind development will occur, areas with inadequate avian data will be prioritized by the estimated wind resource in the area -- the higher the wind speeds, the greater the need to augment avian data with field surveys. In addition, high wind sites will be further prioritized by the probability of the existence of high risk avian species, specified above, in the physiographic region. The highest priority areas lacking data will become the areas in which field surveys will be conducted.

Once the existing data has been compiled, it will be examined for completeness of coverage and will be used as a guideline in determining areas in which field surveys will be conducted. These data will also be analyzed to determine approximate timing and patterns of migration, distribution of listed

species (i.e., endangered), and areas of relatively high densities of breeding birds. These data will be summarized in Objective D and included within the avian assessment document.

B.1.c Materials: Published reports and copies of unpublished surveys were acquired. Upon completion of this research project, the reports and other materials acquired through this project will be reposited with the County Biological Survey of the Department of Natural Resources, with a copy of all avian materials donated to the Minnesota Ornithologists Union.

The amount for this objective was reduced primarily because much of the data that exists is in digital form and no effort was required for data entry (e.g., Breeding Bird Surveys, County Biological Surveys, Natural Heritage, colonial breeding birds). NRRI cooperators were responsible for synthesizing data collected in objective A to determine locations of study areas for objective C. The program manager will assist in this process by providing the critical link between agencies (DOE) that have additional information (e.g., wind data) to guide the selection process.

B.1.d Budget:

LCMR Budget:	$2,500	
LCMR Balance:	0	
Match Budget:	2,500	
Match Balance:	0	
ACTIVITY BUDGET:		$5,000

B.1.e Timeline:

	7/95	10/95	5/96	10/96	5/97	12/97
Collate existing data	***					
Field interviews	***					
Survey needs report		***				

B.1.f. Final Workprogram Update: December 23, 1997

We gathered information on avian population data from 10 sources for 43 counties (see Attachment C) within the three wind tiers. Distributions and densities of breeding passerines were obtained from Breeding Bird Survey (BBS) routes and censuses of Conservation Reserve Program (CRP) lands. Distributions and relative abundances of breeding passerines within hybrid poplar plantations in this region, compiled from an independently-funded census conducted by NRRI, were included with these data. These records were augmented with manuscripts and seasonal bird summaries published in the Loon (Minnesota Ornithologist's Union) as well as personal records of accomplished birders.

The most recent breeding locations of endangered, threatened or special concern species (state or federal) were provided after a review of the Minnesota Natural Heritage Information System. Supplemental sightings of rare species were provided by personal records of birders as well as seasonal summaries compiled in the Loon.

Estimates of breeding waterfowl and production information from 1987 to 1994 in the Prairie Pothole Region within Minnesota were provided by the U.S. Fish and Wildlife Service. These data were summarized by Wetland Management District. The locations of colonial waterbirds (e.g., herons, egrets) were acquired from the colonial waterbird database which is part of the Minnesota Natural Heritage Information System. These records were also augmented with records from published reports from the Loon and personal records of birders.

Migratory patterns and timing of waterfowl and passerines were compiled from published reports as well as personal communication with National Wildlife Refuge and Northern Prairie Science Center personnel. Seasonal counts of migratory waterfowl from 1990-1994 within National Wildlife Refuges, Wildlife Management Areas, and other wetland areas in Minnesota were obtained from Minnesota DNR personnel. Estimates of migratory birds within Wetland Management Districts and other National Wildlife Refuges were provided by the U.S. Fish and Wildlife Service. Summaries of fall and spring raptor and passerines migration were compiled from the Loon. Distributions of wintering raptors and passerines were compiled for the counties within the wind regions of Minnesota from Christmas Bird Counts.

C. Conduct field surveys

C.1 Activity: Field surveys were conducted in each of the three wind regions (tiers) identified within the state under Objective B. Surveys were designed to identify areas which experience high concentrations of migratory birds. Densities of breeding populations of bird species will also be addressed using data from point counts conducted in western Minnesota. Our focus for this project is to document migratory bird use of identified areas. Avian breeding populations within these areas are primarily comprised of migrant species.

Variables associated with migrant densities (e.g., elevation, distance to a National Wildlife Refuge) were identified under Objectives A and B. We will test the ability of these variables to predict the migration patterns documented at our study sites using multivariate statistics (e.g., discriminant function analysis). If successful, areas within the wind corridor will be categorized by expected migration densities using these variables.

C.1.a Context: Preliminary investigations indicate that some areas of the state with adequate winds for wind power production have only sketchy avian data, at best. Field surveys were conducted over a two-year period to document migratory bird patterns in areas where information is lacking as determined by objective B. Areas within wind power production tiers were classified into categories reflecting potential wind turbine/bird interactions based on survey results and previously collected avian population data. Relative abundance of breeding bird populations will also be used in the classification process.

C.1.b Methods: Independent study sites for field surveys were selected from wind regions identified under Objective B. Selected study sites were evenly distributed within each tier and were stratified by variables deemed influential in migration (e.g., elevation, distance to a National Wildlife Refuge).

Eighteen (year 1) or 20 sites (year 2) were surveyed for a minimum of eight days within each migratory period (e.g., spring and fall) using a two-person team. Surveys were four hours in length and will take place (4 total) during a 16-hour period reflecting optimal migrations times (e.g., crepuscular, nocturnal, and early diurnal hours). Surveillance radar imaging was used to detect targets (individuals and flocks of birds). Radar images were augmented by visual observations. Information on numbers of targets, direction of movement, and species were collected at each site. Weather data, topography, and other potential covariates identified under Objective A were also collected.

Based on migration data collected in South Dakota and Minnesota, there appears to be a "main pulse" of migration for approximately one month in both the spring and the fall. We concentrated our monitoring effort during this 30 to 32 day period when migration rates were at their highest, as well as the two weeks preceding and following this peak. Selected sites were sampled both years to determine the variability of migration between years at a given site. Sampling designs were evaluated following the 1995 fall migration period using power analysis based on the means and variances of survey results. Modifications to sampling design were made if deemed necessary.

Quality of data were assured by training all field assistants in survey protocol prior to data collection. Data collected during this project were compiled in databases which were checked against data forms to identify errors in data entry. Data integrity was confirmed through computer programs designed to identify recording or entry errors in the database.

Because standardized methods were used in this project to collect data to answer a specific question, results from this project are adequate and could be used in the future to assist in the construction of an Environmental Impact Statement addressing wind/avian conflicts. Information from this project could be incorporated into Geographic Information System (GIS) applications. GIS technology could aid in the selection of survey sites, spatial analyses of migration variables, and presentation of results.

Site selection was coordinated with the County Biological Survey to assure that monitoring efforts were not duplicated. Information gathered from this work will be freely shared with the County Biological Survey and other agencies. Survey results will be made available in generic format on magnetic media and will be archived at the Natural Resources Research Institute, University of Minnesota, Duluth.

C.1.c Materials: Census materials, such as a portable radar unit, was purchased and tested prior to field surveys. The radar unit was purchased for approximately $10,000. It will either be bought by NRRI or sold to another party at the end of the project period for the purchase price less depreciation. Funds liquidated from this sale will be made available to complete reports. The vehicle for transporting materials and personnel was rented. Cooperators at NRRI will collect all field data. The program manager will assist in determining the most relevant data to collect to meet the needs of DOE and other agencies involved with wind development.

C.1.d Budget:

LCMR Budget:	$66,500	
LCMR Balance:	$0.00	
Match Budget:	$91,500	
Match Balance:	$0.00	
ACTIVITY BUDGET:		$158,000

C.1.e Timeline:

	7/95	10/95	5/96	10/96	5/97	12/97
Collect field data		***	***	***	***	
Analysis of data		***	***	***	***	
Complete report						***

C.1.f. Final Workprogram Update: December 23, 1997

Methods, sample dates, and results are summarized in Attachment D: Avian Assessment Report.

D. Minnesota Wind Corridor Baseline Avian Assessment Report

D.1 Activity: The final product for this research project will be a concise assessment of avian populations in the wind corridors of Minnesota. This assessment will be used to rank regions within the wind corridors at the county level or finer, in terms of migration activities. This ranking will take into account such factors as number of migrants passing through the area, relative density of breeding birds, and the distribution of listed species.

D.1.a Context: The main value of this project to future wind energy development is a compilation of the most complete data gathered to date on avian populations in windy areas of Minnesota. The data will be used by town and county officials, community leaders, state planners and wind energy developers to ensure responsible wind energy development in the future.

D.1.b Methods: The avian assessment document completed for this project will rank areas within the wind corridors based on number of migrant birds, distribution of listed species, and density of breeding birds. Survey results will be extrapolated to other areas based upon variables found to be correlated with avian densities.

The rankings that will be included in the avian assessment document are intended to be used as a means to assess the probability of avian/turbine interactions. By no means will these rankings ensure that such interactions will not take place. Migration events are controlled in part by stochastic events, such as weather patterns, and these rankings can not account for such events.

The final report for this project will include a bibliography of references identified under Objective A, a summary of the existing avian data for the study area compiled under Objective B, the results of field surveys documenting migratory activities within the study area (Objective C), and the assigned rankings for regions within the wind corridors based on the above information.

D.1.c Materials: One hundred copies of the final report will be printed, with distribution to the organizations providing funding, the project cooperators, and others requesting the material. In addition, camera-ready-copies will be distributed to the funding and cooperating organizations for reproduction and dissemination at their discretion. NRRI cooperators will provide a copy of a final report of all activities conducted for objectives A, B, and C. The program manager will be responsible for reproducing and distributing the report. Any additional editing or synthesis of the report, reproduction, and distribution of these products will be done by the program manager.

D.1.d Budget:

LCMR Budget:	$5,000	
LCMR Balance:	0	
Match Budget:	5,000	
Match Balance:	0	
ACTIVITY BUDGET:		$10,000

D.1.e Timeline:

	7/95	10/95	5/96	10/96	5/97	12/97
Write avian assessment						*** ***

D.1.f. Final Workprogram Update: December 23, 1997

We compiled on annotated bibliography of national and international sources to identify factors that may affect avian activity relative to wind power development. See Attachment D for the avian assessment report. The bibliography is included as an attachment to our final report and is available from the Natural Resources Research Institute. In addition, an avian literature database is maintained by the National Wind Technology Center at www.nrel.gov/wind/avianlit.html . We gathered information on avian population data in this region from 10 sources for 43 counties within the three wind tiers. This information is included as an attachment to our final report and is also available from the Natural Resources Research Institute. One federally threatened species, the Bald Eagle is known to nest in this region. Because breeding bird activity for most species is completed at low elevations it is not likely that they would be directly affected by wind towers. Background information gathered indicated that migratory birds were likely to be most at risk from potential wind power development in the western portion of Minnesota. Information gathered on migratory bird activity on 18 sites in three wind regions over four seasons indicated that migratory activity was quite variable, was inconsistent across sites, and only a few differences were detected in number of migrants across the three regions. We observed fewer targets in the area (near Marshall) with the highest potential for wind development in spring 1996. This pattern was not found in the other seasons of observation (fall 1995 and 1996 and spring 1997) and this inconsistency makes it difficult or impossible to rank areas for potential wind development that integrates concerns for migrating

birds. Migratory bird activity in this region is quite variable and landscape features that birds respond to are not static. For example, daily movements of birds during staging are affected by local cropping patterns during both spring and fall periods and amount of winter snowfall affects distribution of water across the landscape during spring migration. We can be safe to recommend that tower construction in areas that bisect daily movement be avoided because these flights are generally done at lower altitudes than long-range migration and at an elevation that would be consistent with tower height. There is an inherent risk associated with construction of any tall structure and we can never be 100% certain that bird collisions can be avoided at any site. In general, it is impossible to calculate the simultaneous occurrence of birds migrating over a wind tower facility during bad weather. The annual incidence rate, however, would likely be lower than the number killed by vehicles or house cats.

Methods and techniques used to collect radar data in this study were applied to another study near Buffalo Ridge where additional wind towers are being constructed. Information gathered for this project was shared with Northern States Power. Project results were presented at the Midwest Wildlife Conference in December 1997. The avian assessment document will be distributed to interested state and national agencies and will be edited and submitted to a peer-reviewed journal for publication.

VI. Evaluation

The management team will establish a technical review panel of skilled, experienced and qualified ornithologists and environmentalists to review the on-going work on this project. These experts will typically be members of the cooperating organizations. In addition, interim progress reports will be distributed to other cooperators for their review, particularly the U.S. Department of Energy and the Avian Sub-Committee of the National Wind Energy Coordinating Committee. Recommendations of the technical review panel and other reviewers will be enacted as appropriate by the management team.

VII. Context Within Field

Wind power production is increasing world-wide on a monthly basis. Virtually all projects have been installed since 1980. Typical wind turbines are vastly different today than they were twenty or even ten years ago. Current installations are providing valuable experience in many areas, including the interaction between wind turbines and birds. The avian study in this project will utilize the most current experience and theory to document avian activity in the wind corridors of Minnesota. The methodology adopted in this project will likely be adopted by other entities desiring to establish a baseline avian population database in windy areas of their regions.

VIII. Budget Context

We are familiar with current avian research that is being conducted in the State and are not aware of other projects such as this that are currently being conducted, nor are any planned in Minnesota for the next biennium.

However, other types of wind/avian research is being conducted in other parts of the U.S. and North America. The U.S. Department of Energy expects to invest $5 million over the next two years into avian research, and private businesses, such as Kenetech Windpower, have invested over a million dollars researching the cause of collisions between birds and wind turbines.

Kenetech Windpower has also conducted a preliminary avian assessment in southwestern Minnesota in conjunction with the 25 MW wind power project they are operating, they are conducting an extensive assessment of any effect of the 73 existing wind turbines on local avian populations, and future wind developers supplying wind-generated electricity to Northern States Power (in compliance with the state law requiring NSP to use at least 425 MW of windpower on their grid) will need to conduct site specific avian assessments. These detailed evaluations are considerably more detailed and rigorous, however, than the baseline assessment that will be produced under this project.

IX. Dissemination

A copy of the final report will be provided to all cooperating entities. Each of the cooperating organizations will distribute the information to their own membership. In addition, participating organizations may elect to print and distribute additional copies of the final report at a cost which covers their expenses.

X. Time

In order to collect adequate biological data, the final field survey is scheduled to be completed in the spring and early summer of 1997. Inadequate time would remain between the conclusion of field surveys and the end of the biennium, 1997 June 30. Therefore, the management team on this project requests a no-cost extension to 1997 December 31 to complete the designated work, with the understanding that the final report will be written and produced as soon as practicable during the summer of 1997 after the last field surveys are completed.

XI. Cooperation

A. Ms. JoAnn Hanowski
Research Fellow, Center for Water and the Environment
Natural Resources Research Institute, University of Minnesota

An avian ecologist with 16 years of experience, Ms. Hanowski's role is to supervise the implementation of the overall project (Objectives A, B, C, and D). Ms. Hanowski will commit 20% of her time during the biennium to this project. Several staff and graduate students will be working on this project under her direction.

The project will be administered by the American Wind Energy Association. Cooperators on this project include:

American Wind Energy Association*, United States Department of Energy, Kenetech Windpower, Northern States Power, Minnesota Department of Natural Resources*, Minnesota Audubon

Council*, Izaak Walton League*, Minnesota Chapter of The Nature Conservancy, Union of Concerned Scientists, Sierra Club*, Minnesota Ornithologists Union.
(* Members of the project Management Team)

This project will be conducted under contract by qualified ornithologists, supervised by management team comprised of representatives of key organizations supporting this research. They are:

Don Arnosti, Minnesota Director, National Audubon Society
John Dunlop, Regional Manger, American Wind Energy Association
William Grant, Midwest Office, Izaak Walton League of America
Harriet Likken, Sierra Club, Minnesota Chapter
Bill Penning, Minnesota Department of Natural Resources

Members of the project management team are providing in-kind service to guide this project. However, administration of project is expected to require 0.1 FTE from the Great Plains office of AWEA. Funds will be administered through the national office of the American Wind Energy Association, Washington, DC, which will retain 12% of the funds handled for general and administrative expenses.

XII. Reporting Requirements

Semiannual six-month workprogram update reports will be submitted not later than January 1, 1996, July 1, 1996, January 1, 1997 and a final six-month workprogram update and final report by June 30, 1997.

XIII. Attachments

A. Qualifications of Project Manager and Principal Investigator

JoAnn M. Hanowski (Principal Investigator)
Center for Water and the Environment
Natural Resources Research Institute
University of Minnesota
Duluth, Minnesota 55811

Ms. Hanowski, an avian ecologist has had over 16 years of experience documenting breeding and migrating birds in the upper Midwest. Over this time period she has acted as the principal or co-principal investigator on over 15 research projects. The majority of her research endeavors have been relative to assessing effects of environmental perturbations of bird species' populations and behavior. She has designed and implemented several long-term studies during this period. These include a 10 year study on the effects of extremely low frequency electromagnetic fields on breeding and migrating bird populations and a seven year study on the effects of mosquito control agents on populations and breeding biology of wetland bird communities. Results of these research projects have been published in over 25 peer reviewed publications and more than 35 reports.

B. Attachment B: Wind Project Bibliography

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C: Attachment C: Avian population data sources.

Codes for avian population data sources

1 - Natural Heritage database - MN Department of Natural Resources (DNR) Natural Heritage and Nongame Research Program
2 - Colonial waterbird database - MNDNR Natural Heritage and Nongame Research Program
3 - Bird and Mammal Usage of Hybrid Poplar Plantations Progress Report 1994
4 - Breeding bird densities in CRP land - Northern Prairie Science Center, U.S. Fish and Wildlife Service
5 - Migratory bird point counts - U.S. Fish and Wildlife Service
6 - Breeding Bird Survey data - U.S. Fish and Wildlife Service
7 - Waterfowl Breeding Population and Production Estimate Summary Report - U.S. Fish and Wildlife Service
8 - Waterfowl fall migration surveys - MNDNR
9 - The Loon data, 1990-1994 - MN Ornithologists' Union
10 - Christmas bird count data, 1986 - 1990

County	Waterfowl	Raptors	Colonial Waterbirds	Passerines	Threatened - fed	Special concern - fed	Endangered - state	Threatened - state	Special concern - state
Kittson	5,6,9	6,9	9	6,9	1		1	1	1
Roseau	7,5,6,8,9	6,10,9	9	6,10,9	1		1	1	1
Marshall	5,6,8,9	6,10,9	6,9	6,10,9	1		1	1	1
Pennington	5,6,9	6,9	6,9	6,9	1			1	1
Red Lake	5,6,9	6,9	6	3,6,9					1
Polk	5,6,9	6,9	6,9	6,9	1		1	1	1
Norman	5,9	9		3,9				1	1
Mahnomen	5,9	9	9	9	1		1	1	1
Clay	7,5,6,9	6,9	6,9	3,6,9			1	1	1
Becker	5,6,8,9	6,9	6,9	3,6,9	1				1
Wilkin	5,6,9	6,9	6,9	6,9			1	1	1
Ottertail	7,5,6,8,9	6,10,9	6,9	3,6,10,9	1				1
Traverse	5,9	9	9	9			1		1
Grant	5,6,8,9	6,9,4	6,9,2	6,9,4	1	1		1	1
Stevens	7,5,6,9	6,9	6,9,2	6,9			1		1
Pope	5,9	9	9,2	9			1	1	1
Big Stone	5,8,9	9	9	9			1	1	1
Lac Qui Parle	5,6,8,9	6,10,9	6,9,2	6,10,9		1	1	1	1
Swift	5,6,8,9	6,9	6,9,2	6,9	1			1	1
Kandiyohi	5,9	9	9,2	9	1			1	1
Chippewa	5,6,8,9	6,10,9	6,9	6,10,9	1	1	1	1	1
Yellow Medicine	5,6,9	6,9	6,9,2	6,9	1		1	1	1
Renville	5,6,9	6,9	9	6,9					
Redwood	5,6,9	6,9	9	6,9	1	1		1	

County	Waterfowl	Raptors	Colonial Waterbirds	Passerines	Threatened - fed	Special concern - fed	Endangered - state	Threatened - state	Special concern - state
Lyon	5,6,9	6,10,9	9,2	6,10,9		1	1	1	
Lincoln	5,9	9	9,2	9		1		1	1
Pipestone	5,9	9	9	9			1	1	
Murray	5,8,9	9	9,2	9		1		1	1
Cottonwood	7,5,8,9	10,9	9	10,9			1		1
Brown	5,6,9	10,9	6,9	6,10,9	1				1
Nicollet	5,6,8,9	9	6,9	6,9	1		1		1
Watonwan	5,9	9	9	9					
Blue Earth	5,9	9	9	9	1		1	1	1
Waseca	5,9	9		9					1
Steele	9	10,9		10,9					
Dodge	9	9		9				1	
Mower	9	10,9	9	10,9					
Freeborn	5,6,9	6,10,9	9	6,10,9					1
Faribault	5,9	9	9	9					
Martin	5,6,9	6,9	9	3,6,9			1		
Jackson	5,8,9	9	9,2	9					1
Nobles	5,8,9	9	9	9					1
Rock	5,6,9	6,9	9	6,9			1		1

LOON DATA

County	Season	Waterfowl	Raptors	Colonial Waterbirds	Passerines
Kittson	Sp	92,91	92,91	91	92
	Su	93,91	92,91	92,91	94,93,92,91
	F				93,92,90
	W		91-92,89-90		89-90
Roseau	Sp	94,91	94,93,92,91,90	94,86	94,93,92
	Su	94,93,92,91,90	94,93,92,91	94,92,91,90	94,92,91
	F	93,92,91,90	93,92,91,90	92,91,90	93,92,91,90
	W		93-94,91-92,89-90		93-94,92-93,91-92,90-91,89-90
Marshall	Sp	94,92,91,90	94,93,92	94,92,91,86	94,93,92
	Su	94,93,92,91,90	94,93,92,91	94,93,92,91,90	93,92,91,90
	F	90	91	90	93,92,91,90
	W	92-93	91-92,89-90		91-92,90-91,89-90
Pennington	Sp	93,92	94,93,92,91,90		94,93,92,91,90
	Su	94,92,90	92	93,92,91	94,93,92,91,90
	F	93,92,91,90	93,92,91,90	91,90	93,92,91,90
	W		93-94,92-93,91-92,90-91,89-90		93-94,92-93,90-91,89-90
Red Lake	Sp		92		93,92,90
	Su	92	92		94,92,91
	F	91,90			93,92
	W				93-94
Polk	Sp	92	94,93,92,90		94,93,92,90
	Su	92,90	94,93,92,90	92,91	93,92,91,90
	F	93,92	93,92,90	93,92,90	93,92,91,90
	W	92-93,89-90	92-93,91-92,90-91		93-94,90-91
Norman	Sp	92,91	93,92,91		94,93,92,90
	Su	94,92			94,93,92,91,90
	F	92,90	92,91,90		92,91
	W		92-93,90-91		93-94,90-91
Mahnomen	Sp	93	94,91,90		94,92,91,90
	Su		92,91		93,90
	F		90	90	92,90
	W				
Clay	Sp	94,93,92,91,90	94,93,92,91,90	93,91,90	94,93,92,90
	Su	92,90	93,91,90	93,91,90	94,93,92,91,90
	F	93,92,91,90	92,91,90	92,91,90	93,92,91
	W		93-94,91-92,90-91,89-90		93-94,92-93,91-92,90-91,89-90
Becker	Sp	94,93,92,91	94,93,92,91,90	94,93,92,91	94,93,92,91,90
	Su	94,93,92,91,90	94,93,91,90	93,92,91,90	94,93,92,91,90
	F	93,92,91,90	93,92,91	93,92,91	93,92,91,90

County	Season	Waterfowl	Raptors	Colonial Waterbirds	Passerines
	W	93-94,91-92,89-90	93-94,92-93,91-92,90-91	91-92	93-94,92-93,91-92,90-91
Wilkin	Sp	94,93,92,91,90	94,93,92,91,90	93	94,93,92,90
	Su	93,92,90			94,93,92,91,90
	F	92,90	92,91,90	92,90	93,92,91,90
	W		93-94,92-93,91-92,90-91,89-90		93-94,92-93,91-92,90-91,89-90
Ottertail	Sp	94,93,92,91,90	94,93,92,91,90	94,93,92,90	94,93,92,91,90
	Su	94,93,92,90	94,93,92,91,90	94,93,92,91,90	94,93,92,90
	F	93,92,91,90	93,92,91,90	93,92,91,90	93,92,91
	W	93-94,92-93,91-92,90-91,89-90	93-94,92-93,91-92,90-91,89-90	92-93,90-91	93-94,92-93,91-92,90-91,89-90
Traverse	Sp	94,93,92,91	94,93	93,91,90,86	94,93,91,90
	Su	93,91	94,91,90	93,91	91
	F	91		91	92,91
	W				
Grant	Sp	94,93,92,91,90	90	94,93,92,91,90,86	94,93,92,91
	Su	94		92,91,90	94
	F	93,	92,91	91	92,91
	W				
Stevens	Sp	94,92	94,93		93,92,90
	Su	93		93	93
	F	91	91		92,91,90
	W				
Pope	Sp	94	93,91	94	93,90
	Su	93		94	93
	F				
	W				
Big Stone	Sp	94,93,91,90,81	94,81	92,91,86,81	94,93,92,91,90,81
	Su	94,93,91,81	94,81	94,91,81	91,90,81
	F	92,90,81	81	81	92,91,81
	W	81	81	81	81
Lac Qui Parle	Sp	94,93,92,91,90	94,93,92,91,90	94,93,92,91,90,86	94,93,92,91,90
	Su	94,93,91	94,91,90	94,93,91,90	94,93,91,90
	F	91,90	92	93,92,91,90	93,92,91,90
	W	92-93,91-92,90-91	92-93,91-92,90-91,89-90		92-93,91-92,90-91,89-90
Swift	Sp	90	93,90	94	94,91
	Su				
	F		92		93,92,91,90
	W				89-90
Kandiyohi	Sp	91		91	94,93,91
	Su	94,93,92,918	94,92,91	94,92,91	94,92,91

County	Season	Waterfowl	Raptors	Colonial Waterbirds	Passerines
	F	93,92,91	93,92,91	92,91	93,92,91,90
	W	93-94,91-92	92-93,91-92,89-90		93-94,91-92,89-90
Chippewa	Sp	93,91	92		94,92,91,90
	Su		90		91
	F	93,91,90	91	93,92	93,92,91,90
	W		91-92,90-91		
Yellow Medicine	Sp	94,91,90	94,93	93,90,86	94,93,92,91,90
	Su	93,91	92	94	93,92,91
	F	93,92		92	91,90
	W		92-93,90-91		92-93,89-90
Renville	Sp	93,91	91		91,90
	Su	93,91		93,92,90	92,91,90
	F				92
	W		93-94,90-91		92-93
Redwood	Sp	94	86		93,91,90
	Su	94,90		90	91,90
	F				92
	W	90-91	92-93,90-91		90-91,89-90
Lyon	Sp	92,91	93,92,91,90,86	93,90	94,93,92,91,90
	Su	94,93,92,91,90	94,92,91	94,93	94,93,92,91,90
	F	90	93,92,91,90	93,91	93,92,91,90
	W	92-93	92-93,90-91	92-93,89-90	93-94,92-93,91-92,90-91,89-90
Lincoln	Sp	94,93,92,90	94,93,91,90	94	94,93,92,91
	Su	93			
	F	90	90	93	91
	W				
Pipestone	Sp	92,91,90	93,92,91	93	94,93,92,91,90
	Su	92,90		93	93,92,91,90
	F		93,91,90	93,90	93,92,91,90
	W				91-92
Murray	Sp	90	93,92,90,86	93	93,92,91,90
	Su	94,93	94,93,92,90	93	94,93,92,91
	F		91	93,92	93,92,91,90
	W		91-92,89-90		91-92,89-90
Cottonwood	Sp	93,92,91,90	93,92,90	93,92	93,92,91,90
	Su	94,93,92	93,92	94,93	94,93,92,91
	F	93,92,91,90	93,92,91,90	93,91,90	93,92,91
	W	93-94,90-91,89-90	92-93,91-92,90-91,89-90		93-94,92-93,91-92,90-91,89-90
Brown	Sp	94,90	90	92,90	94,93,92,91

County	Season	Waterfowl	Raptors	Colonial Waterbirds	Passerines
	Su		94,93,92,91,90	90	94,93,92,91,90
	F	90	93,92,91,90		93,92,91,90
	W		93-94,92-93	89-90	93-94,92-93,91-92,89-90
Nicollet	Sp	93,92,90	94,91,86	94,93,92	94,93,91,90
	Su	92,91	94	93	94,93,92,91,90
	F	92,91	93,91		93,92,91,90
	W	92-93,91-92,89-90	90-91	93-94	91-92,89-90
Watonwan	Sp	94,92,90	91,90		94,91
	Su	94		91	
	F		93,92,90	93	92
	W				
Blue Earth	Sp	91,90	93,91,90	90	94,93,91,90
	Su	94,92,91,90	91,90		94,93,92,91,90
	F	90	93,92	90	93,92,91
	W	89-90	91-92	92-93	90-91,89-90
Waseca	Sp	91	90		94,93,92
	Su				94
	F		90		92,90
	W				
Steele	Sp	94,91,90	90		93,92,91,90
	Su	94	93,91		91
	F	90			
	W				90-91,89-90
Dodge	Sp	91			92,91,90
	Su		94		
	F		93		91
	W		93-94,89-90		93-94
Mower	Sp	94,92	94,93,92,91,90	94,92,90	94,93,92,91,90
	Su	93,92,91	94,93,92,91		94,93,91,90
	F	92	93	90	93,91,90
	W	91-92,90-91,89-90	90-91		92-93,91-92,89-90
Freeborn	Sp	94,91	94	94,93,92	93,91,90
	Su			90	94
	F	93		93	93
	W		89-90	93-94,92-93,90-91	91-92
Faribault	Sp	90			94,93
	Su	94,92		94,90	94,92,91,90
	F	93			
	W	91-92,89-90	91-92,89-90	89-90	92-93,89-90

County	Season	Waterfowl	Raptors	Colonial Waterbirds	Passerines
Martin	Sp	94,93,91,90	94,92,91,90	90	94,93,92,91,90
	Su	93,90		90	93,91,90
	F	92,90	93,92,91,90	93	93,92,91,90
	W	91-92,89-90			93-94,91-92,90-91,89-90
Jackson	Sp	93,92	94,90	94,91	94,93,91
	Su				93
	F	90	93,90	91	93,92
	W		92-93,90-91	93	91-92,90-91
Nobles	Sp	92,91,90	94,92,91,90	92	94,93,92
	Su	93,91	90	94	93,92,91,90
	F	90	93,90		93,92,91,90
	W				91-92
Rock	Sp	91,90	92,91,90	92	94,93,92,91,90
	Su	92	93,91,90	93,91	94,92,91,90
	F	93	91		93,92,91
	W		93-94,		92-93,91-92

AVIAN ASSESSMENT DOCUMENT: AVIAN POPULATION ANALYSIS FOR WIND POWER GENERATION REGIONS--012

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SUMMARY

Our objective was to gather avian information for potential wind power development areas in western Minnesota to assist in the siting of wind energy facilities in Minnesota. We compiled an annotated bibliography of national and international sources to identify factors that may affect avian activity relative to wind power development. We gathered information on avian population data in this region from 10 sources for 43 counties within the three wind tiers. One federally threatened species, the Bald Eagle (*Haliaeetus leucocephalus)* is known to nest in this region. Because breeding bird activity for most species is completed at low elevations it is not likely that they would be directly affected by wind towers. Background information gathered indicated that migratory birds were likely to be most at risk from potential wind power development in the western portion of Minnesota. Information gathered on migratory bird activity on 18 sites in three wind regions over four seasons indicated that migratory activity was quite variable, was inconsistent across sites, and only a few differences were detected in number of migrants across the three regions. We observed fewer targets in the area (near Marshall) with the highest potential for wind development in spring 1996. This pattern was not found in the other seasons of observation (fall 1995 and 1996 and spring 1997) and this inconsistency makes it difficult or impossible to rank areas for potential wind development that integrates concerns for migrating birds. Migratory bird activity in this region is quite variable and landscape features that birds respond to are not static. For example, daily movements of birds during staging are affected by local cropping patterns during both spring and fall periods and amount of winter snowfall affects distribution of water across the landscape during spring migration. We can be safe to recommend that tower construction in areas that bisect daily movement be avoided because these flights are generally done at lower altitudes than long-range migration and at an elevation that would be consistent with tower height. There is an inherent risk associated with construction of any tall structure and we can never be 100% certain that bird collisions can be avoided at any site. In general, it is impossible to calculate the simultaneous occurrence of birds migrating over a wind tower facility during bad weather. The annual incidence rate, however, would likely be lower than the number killed by vehicles or house cats.

INTRODUCTION

Significant commercial scale wind energy development began in the United States in the early 1970's and is a viable energy source in 13 states (Johnson et al. 1997). Development was initiated in Minnesota in 1993, where wind power is a dependable source of energy and a demand for supplemental power exists. Wind power is economical and environmentally superior to hydrocarbon energy sources (Hansen et al. 1992). A possible environmental conflict is that wind turbines or other large structures (i.e., towers) cause bird mortality when they collide with structures (Avery et al. 1976, Crawford 1981, Winkelman 1985, Ivanov and Sedunova 1993, Roberts and Tambkorski 1993, Davidson 1994). Incidence of collisions are influenced by avian abundance and species composition, seasonal distribution, food sources, hunting or foraging patterns (i.e., flocking behavior), geographic area, number of natural and man-made perches in the area, and specific characteristics of the structures. Migrant and wintering birds, especially raptors, may be more vulnerable than breeding birds because they fly at turbine altitude. Although research is being conducted to determine causes of collisions and reduce the number of interactions, information that could be used to predict potential avian/turbine interactions in areas with suitable wind power potential would help mitigate site level impacts.

Our objective was to document bird activity in regions of Minnesota that have a high potential for wind energy development (southwestern and west-central parts of the state). We summarized existing data on breeding bird abundance and distribution, occurrence of endangered and threatened species, and collected information on migrating birds during four seasons from 1995 to 1997. Regions within the wind corridor area were then evaluated for possible avian conflicts based on: (1) distribution of federal and state listed species; (2) density of breeding birds; and (3) number of migrant birds detected.

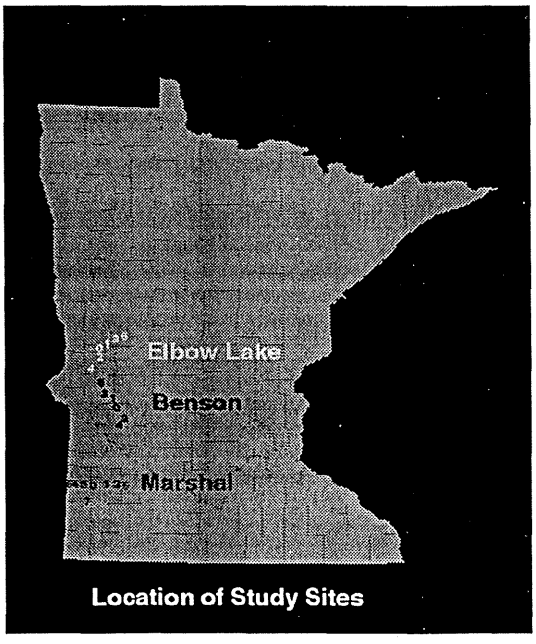

Figure 1. Location of study sites.

STUDY AREAS

We used a map of Minnesota that identified areas with the greatest wind resource potential. Within this area, three wind tiers were identified based on wind energy potential. Tier 1 included nine counties and had highest potential, tier

2 included five counties, and tier 3, (seven counties) had the lowest potential for wind energy development. We selected three study areas (Marshall in tier 1, Benson in tier 2, and Elbow Lake in tier 3) (Figure 1), by randomly selecting a county within each wind tier and then randomly selecting a National Wildlife Refuge (NWR) or Wildlife Management Area (WMA) within each county.

We stratified six sites in each study area site by distance to either the NWR or WMA because we felt that distance to staging or resting areas may be an important factor in determining migratory activity. The distance between sites insured that data collected at the 3 nautical mile (nm) range setting (5.6 km) were independent. Site 0 was placed closest to the refuge; sites 1 and 2 were located approximately 7 miles (11 km) from site 0; sites 3 and 4 were located approximately 14 miles (22 km) from site 0; and site 5 placed at least 21 miles (34 km) from site 0. It was possible to control for distance to lakes, rivers, or wetlands in our study site selection in the Benson and Marshall study areas. The Elbow Lake study area is in a landscape of rolling hills interspersed with lakes and wetlands and it was difficult to locate any site more than 10 miles from a lake, river, or wetland.

METHODS

Distribution of Listed Species. The most recent breeding locations of endangered, threatened or special concern (ETS) bird species (federal or state) were provided by Minnesota Natural Heritage and Nongame Research Program staff. We also searched the Minnesota Natural Heritage Information System to determine locations of rare birds. Supplemental sightings of rare species were obtained from records of local amateur ornithologists and from seasonal summaries in *The Loon*, the journal of the Minnesota Ornithologists's Union.

Density of Breeding Birds. We gathered information on avian population data from 10 sources for 43 counties within the three wind tiers. Distributions and densities of breeding passerines were obtained from Breeding Bird Survey (BBS) routes and censuses of Conservation Reserve Program (CRP) lands. Distributions and relative abundances of breeding passerines within hybrid poplar plantations in this region, compiled from an independently-funded census conducted by NRRI, were included with these data. These records were augmented with manuscripts and seasonal bird summaries published in *The Loon* as well as personal records of accomplished birders.

Estimates of breeding waterfowl and production information from 1987 to 1994 in the Prairie Pothole

Region within Minnesota were provided by the U.S. Fish and Wildlife Service. These data were summarized by Wetland Management District. The locations of colonial waterbirds (e.g., herons, egrets) were acquired from the colonial waterbird database which is part of the Minnesota Natural Heritage Information System. These records were also augmented with records from published reports from *The Loon* and personal records of birders.

Migratory patterns and timing of waterfowl and passerine migration were compiled from published reports as well as personal communication with National Wildlife Refuge and Northern Prairie Science Center personnel. Seasonal counts of migratory waterfowl from 1990-1994 within National Wildlife Refuges, Wildlife Management Areas, and other wetland areas in Minnesota were obtained from Minnesota DNR personnel. Estimates of migratory birds within Wetland Management Districts and other National Wildlife Refuges were provided by the U.S. Fish and Wildlife Service. Summaries of fall and spring raptor and passerines migration were compiled from *The Loon*. Distributions of wintering raptors and passerines were compiled for the counties within the wind regions of Minnesota from Christmas Bird Counts.

Number of Migrant Birds. Quantitative data on migrating birds in the three wind tier regions was insufficient so migratory data was collected with a portable radar system. Radar field surveys were conducted during a 48 day period which encompassed peak migration dates for a variety of bird species (i.e., waterfowl, passerines, and raptors) based on spring and fall migration data collected in Minnesota and South Dakota (Janssen 1987) (Table 1). Literature on bird migration indicates that weather is the most important factor in determining numbers of migrant birds at each site. Affects of weather cannot be included in an experimental design, but can be controlled for by 1) conducting multiple samples at each site including multiple days and time periods and 2) using weather variables as covariates to adjust migration counts.

Table 1. Sampling periods for the radar field surveys

Season/year	Dates
Fall 1995	September 15 - October 21
Spring 1996	April 1 - May 8
Fall 1996	September 12 - October 29
Spring 1997	March 26 - May 12

A surveillance radar (Furuno Model FR-7111, Furuno Electric Company, Nishinomiya, Japan) was operated with the antenna in a fixed horizontal position at range settings of .075 nm (1.4 km) (short-range surveillance) and 3.0 nm (5.6 km) (long-range surveillance). At the .075 nm range, the radar can detect an individual passerine-sized bird, (e.g., robin) and a gull-sized bird can be detected at the 3.0 nm range.

Ground clutter, which are echos from radar energy reflected from the ground and other objects surrounding the radar unit, was reduced on the radar screen by parking the radar truck in a depression. The slope of the surrounding landscape serves as a "radar fence" that the radar cannot "see" through and only objects above this "fence" are detected. Since topography varied from site to site, we quantified ground clutter at each site by tracing amounts on paper and then using a map wheel to determine area. In most instances, targets passed through the entire radar screen and therefore, ground clutter was not a factor in detecting number of targets.

We visited each site eight times in each sampling period, regardless of weather conditions. A sample was either 4 hours (fall 95) or ~3.5 hours (spring, fall 95 and fall 96) in duration and collected within a 16 hour period during optimal migrations periods (e.g., crepuscular, nocturnal, and early diurnal hours). After the first season, sampling time was reduced from 4 to 3.5 hours to allow more time to drive between sites, and we eliminated sampling between 1500 and 1700 hrs when migration was comparatively low. In each hour we recorded targets at the 3 nm setting for 40 minutes followed by a 5 minute break, and then at the 0.75 nm setting for 10 minutes. The last half hour of each survey included 25 minutes of sampling at the 3 nm radius and 5 minutes at the 0.75 nm radius (Table 2). We defined a target as a distinguishable paint on the radar screen and recorded: time of sighting; starting direction; direction of movement; flight behavior; and when time allowed, minimum and maximum distance at which the target was seen (Table 3). Radar images were augmented by visual observations during daylight hours. Data were handwritten and entered into a computer during the fall 1995 season and entered directly into a computer in the field during the remaining three seasons.

Table 2. Sampling schedule for one hour and half hour time intervals.

Observation period	Range setting
0000 - 0040	long-range surveillance (3 nm)
0040 - 0045	break
0045-0055	short-range surveillance (0.75 nm)
0055-0000	break
0000 - 0025	long-range surveillance (3 nm)
0025 - 0030	short-range surveillance (0.75 nm)

Table 3. Information recorded for each target.

Starting flight direction	Direction of movement	Flight behavior
north (n), south (s), east (e), west (w), ne, se, nw, sw	north (n), south (s), east (e), west (w), ne, se, nw, sw	directional - straight-line flight circling - slow, circling flight erratic - flight with no discernible direction

Statistical analyses. We tested two null hypotheses: (1) there is no difference in number of targets among the three wind tiers and (2) there is no difference in number of targets at three distances away from a NWR or equivalent. We summarized data as number of targets/hour because we were not always able to differentiate between flocks and individuals. Weather data for each study area was obtained from the Minnesota State Climatology Office (Table 4). We did all subsets multiple regression analysis using the natural logarithm of number of targets/hour as the dependent variable and time and weather parameters (Table 4) as independent variables. Weather variables explained about 40% of the variation in number of targets observed (Table 5). We used the weather variables selected in the regression as covariates in two repeated measure analysis of covariance (RMANCOVA) tests, from each season and range. The repeated measure in the analysis was site visit (n = 8). The fixed effect was wind tier (n=3) or distance (n=4).

Table 4. Variables used in multiple regression analysis to model migration rate. Weather data obtained from the Minnesota State Climatology Office. For each observation period, the mean value or mode (most frequent) value of the variables was determined. The mean or mode value of the four-4 hr surveys represented the sample in the analysis.

Description	Units	Codes	Derivation
julian date (SDATE)			mode
sample time - minutes after midnight (S_TIME)	minutes		median
time before/after sunrise/sunset (DELTA_S)	minutes		median
daily precipitation (PPT)	inches		mean
daily high temperature (HI)	Fahrenheit		mean
daily low temperature (LO)	Fahrenheit		mean
air temperature at sample time (AIR)	Fahrenheit		mean
dew point temperature at sample time (DEW)	Fahrenheit		mean
wind speed at sample time (W_SP)	knots		mean
barometric pressure (PR)	millibars		mean
air temp 24 hrs prior to sample (AIR24)	Fahrenheit		mean
dew point 24 hrs prior to sample (DEW24)	Fahrenheit		mean
wind speed 24 hrs prior to sample (W_SP24)	knots		mean
pressure at time of sample - pressure 24 hrs prior (DELTA_P)	millibars		mean
high daily temp - air temp 24 hrs prior (DELTA_H)	Fahrenheit		mean
sky conditions:			
clear skies (CLR)		1,0*	mode
scattered (10-50% sky covered) (SCT)		1,0	mode
broken (60-90% sky covered) (BKN)		1,0	mode
overcast (100% cloud)		1,0	mode
wind direction:			
calm - no wind (CA)		1,0	mode
north wind (NORTH)		1,0	mode
northeast (NE)		1,0	mode
northwest (NW)		1,0	mode
north wind (SOUTH)		1,0	mode
southeast (SE)		1,0	mode
southwest (SW)		1,0	mode
east wind (EAST)		1,0	mode
west wind (WEST)		1,0	mode

* 1 = clear; 0 = not.

Table 5. "Best models" for multiple regression using all possible subsets of variables (Table 4). Rate is targets/hour and LOC is wind tier.

Season	Range (nm)	Model	R^2
Fall 1995	0.75	rate = LO PPT S_TIME	14.34*
	3.0	rate = LO PPT S_TIME DELTA_S DELTA_S*LOC	23.33*
Spring 1996	0.75	rate = AIR DEW W_SP24 PR EAST SE SDATE S_TIME DELTA_S	30.78
	3.0	rate = NE NW CLR WEST NORTH PPT SDATE CA DELTA_S S_TIME	32.38
Fall 1996	0.75	rate = DELTA_P SCT DELTA_S W_SP AIR	42.56
	3.0	rate = SCT DELTA_P CLR NW SOUTH S_TIME WEST	42.99
Spring 1997	0.75	rate = DELTA_H CLR SE LO	42.32
	3.0	rate = PPT CLR NORTH NE DELTA_H	36.97

*, indicates an incomplete model due to insufficient weather data.

RESULTS

Breeding bird surveys at Buffalo Ridge, Minnesota, the site of a 25 MW wind power project in the southwestern part of the state, indicated that breeding birds are likely not affected by wind turbines (Johnson et al. 1997). Birds, nesting locally, may not be vulnerable to collisions with wind turbines because they have daily flight patterns below the level of the turbines, and are more stationary than migratory bird.

Distribution of ETS species was not different among counties within the three wind tiers. The Bald Eagle, a federally listed threatened species is the only listed bird species under the Federal Endangered Species Law that has a breeding distribution within the study areas. Two endangered species listed under the Minnesota Endangered Species Law have breeding distributions in the study areas, the Burrowing Owl (*Athene cunicularia*) is found in tiers 1 and 2 and the Henslow's Sparrow (*Ammodramus henslowii*) in tier 1. The Loggerhead Shrike (*Lanius ludovicianus*) and Upland Sandpiper (*Bartramia longicauda*) (two state listed threatened species) are found in all three wind tiers. Two state listed species of special concern, the American Bittern (*Botaurus llentiginosus*) and Marbled Godwit (*Limosa fedoa*), have breeding distributions in tiers 2 and 3. The Short-eared Owl (*Asio flammeus*), also a species of special concern, breeds only within counties in tier 2. Colonial nesting waterbirds have breeding colonies in all three tiers.

Number of targets observed/hour in each tier was similar at both ranges for each season (Figures 2, 3, 4, and 5). A significant difference was detected in the spring 96 season (Figure 3), and results indicated that tier 3 sites (Elbow Lake) had more targets at 3.0 nm than sites in tier 1 or 2. More targets were observed at

0.75 nm in all seasons and tiers than at 3.0 nm except tier 3 during the spring 96 season (Figures 2, 3, 4, and 5).

Table 6. Mean rates (targets/hr) corrected for weather for each site. Marshall sites are in tier 1, Benson sites are in tier 2, and Elbow Lake sites are in tier 3. Marshall 6 and 7 are sites near Buffalo Ridge, the site of an existing wind power project.

	Fall 1995		Spring 1996		Fall 1996		Spring 1997	
	Range (nm)		Range (nm)		Range (nm)		Range (nm)	
Site	0.75	3.0	0.75	3.0	0.75	3.0	0.75	3.0
Marshall 0	132.9	93.4	156.6	189.2	196.1	80.7	250.7	236.5
Marshall 1	66.6	48.0	94.2	135.2	288.3	117.0	227.7	312.9
Marshall 2	98.1	56.2	114.3	217.3	271.1	150.3	425.6	264.5
Marshall 3	106.1	31.3	83.7	85.7	267.8	105.4	271.8	212.9
Marshall 4	90.5	48.2	191.1	188.0	243.8	156.0	288.1	204.6
Marshall 5	49.8	29.2	85.8	140.7	194.1	195.7	326.6	217.5
Marshall 6					319.7	66.0	293.4	172.5
Marshall 7					233.6	111.8	226.8	257.6
Benson 0	72.2	50.8	109.8	174.0	451.4	138.9	249.2	252.6
Benson 1	67.0	44.5	195.5	164.7	283.0	126.7	297.9	269.7
Benson 2	41.8	27.2	163.5	157.6	278.2	117.9	266.6	202.1
Benson 3	152.5	96.2	258.6	211.2	695.7	286.3	341.0	263.3
Benson 4	76.2	24.2	268.5	214.7	219.8	126.5	330.0	138.8
Benson 5	89.7	51.8	109.6	65.1	479.5	151.8	345.8	300.2
Elbow Lake 0	122.6	79.6	208.9	150.8	487.8	248.3	233.2	194.2
Elbow Lake 1	106.3	75.4	174.8	145.6	447.7	270.1	276.5	169.7
Elbwe Lake 2	103.5	72.9	279.7	207.3	709.9	294.3	184.8	64.4
Elbow Lake 3	54.6	37.3	190.6	127.8	226.7	210.1	127.4	125.2
Elbow Lake 4	63.9	40.8	327.9	211.9	577.6	151.2	256.3	76.2
Elbow Lake 5	93.8	50.9	136.0	92.3	291.8	199.3	309.0	240.4

Table 7. Results of (1) multiple regression analysis performed with number of targets/hr as dependent variable and time and weather parameters (Table 4) as independent variables, (2) Repeated Measure Analysis of Covariance (RMANCOVA) test using wind tier as fixed effect and (3) RMANCOVA using distance of site from NWR site as fixed effect. *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$.

Season	Range (nm)	Multiple Regression *p*-value	RMANCOVA fixed effect=tier F-value	RMANCOVA fixed effect=tier *p*-value	RMANCOVA fixed effect=site F-value	RMANCOVA fixed effect=site *p*-value
Fall 95	0.75	0.093	0.44	0.695	0.60	0.657
	3.0	0.038*	0.37	0.727	1.19	0.445
Spring 96	0.75	0.220	0.75	0.571	2.20	0.267
	3.0	0.595	26.33	0.037*	2.66	0.221
Fall 96	0.75	0.005**	0.59	0.631	0.15	0.921
	3.0	0.001***	2.05	0.328	0.17	0.908
Spring 97	0.75	0.005**	0.52	0.657	0.21	0.887
	3.0	0.851	1.00	0.499	0.18	0.907

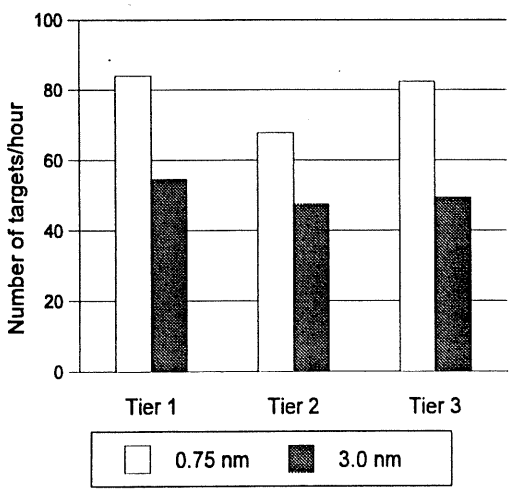

Figure 2. Number of targets/hour for the three wind tiers for fall 95 season. Values are corrected for weather.

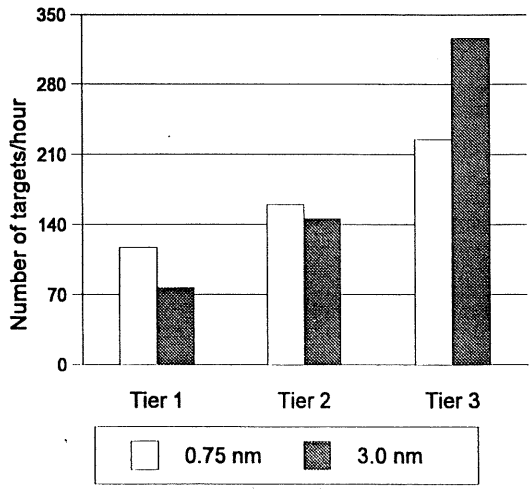

Figure 3. Number of targets/hour for the three wind tiers for spring 96 season. * Tier 3 had significantly more targets than tier 1 or 2 at 3.0 nm. Values are corrected for weather.

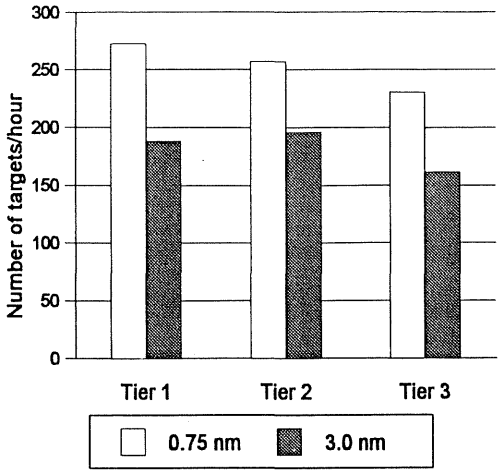

Figure 5. Number of targets/hour for the three wind tiers for spring 97 season Values are corrected for weather.

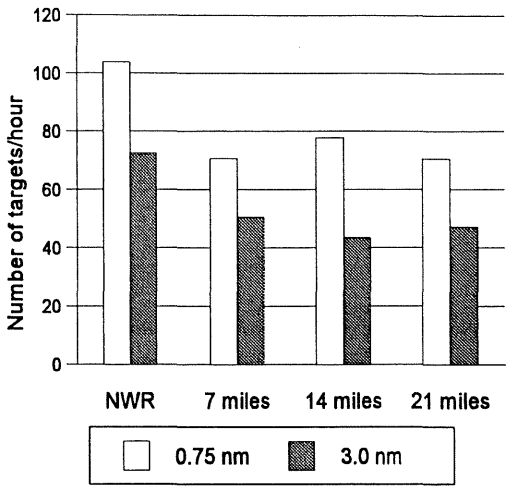

Figure 6. Number of targets/hour at three distances from a National Wildlife Refuge (NWR) for fall 95 season. Values are corrected for weather.

Number of targets observed on a site basis was not related to distance of the site from a NWR or its equivalent. Results of the second RMANCOVA indicated no significant difference for any distance from the NWR site at any range for any season (Figures 6, 7, 8, and 9). During the fall 95 season, more targets were observed at the NWR site at both ranges, but the difference was not significant (Figure 6). The highest number of targets observed at 0.75 nm and 3.0 nm during spring 96 were 14 and 7 miles from the NWR site, respectively and were slightly higher than the number observed at the NWR site (Figure 7). The lack of correlation between number of targets observed and distance from the NWR site is reflected in

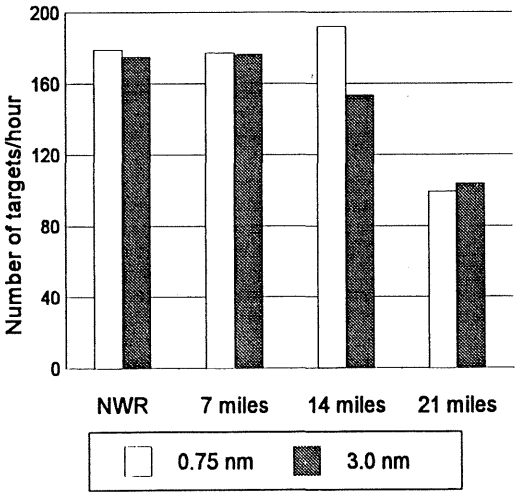

Figure 7. Number of targets/hour at three distances from a National Wildlife Refuge (NWR) for spring 96 season.

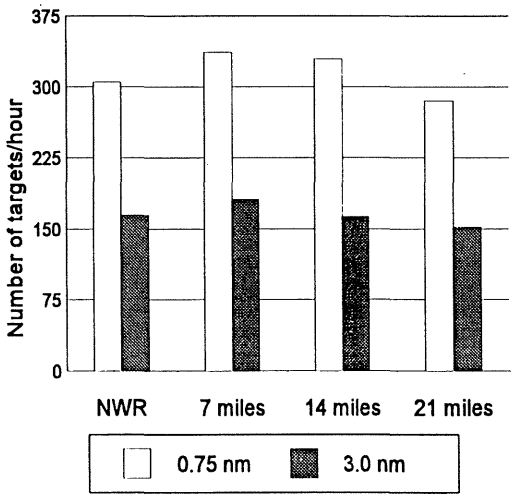

Figure 8. Number of targets/hour at three distances from a National Wildlife Refuge (NWR) for fall 96 season. Values are corrected for weather.

the variation in abundance patterns for individual sites (Table 6). Birds are likely responding to additional landscape features, (e.g., elevation, location of food sources), within the study areas.

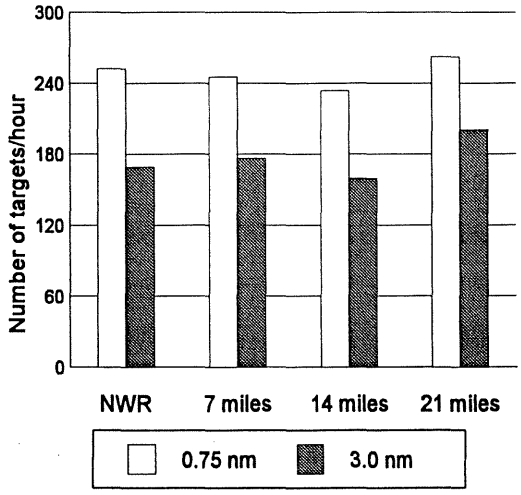

Figure 9. Number of targets/hour at three distances from a National Wildlife Refuge (NWR) for spring 97 season. Values are corrected for weather.

CONCLUSION

Based on evaluation of distribution of listed species, density of breeding birds, and migratory activity within the three study areas, we determined that there are insufficient differences in avian activities between the three wind tiers to rank the sites. Distribution of ETS listed species was similar between the three wind tiers and breeding birds density is not an important factor that influences bird and wind turbine interactions. Results of our radar surveys indicated that migratory activity was not different between the three wind tiers and was not related to distance to NWR or its equivalent. The great amount of variation seen in the migratory data for individual sites may reflect differences in daily and seasonal movement patterns. Daily movements are likely to vary from year to year and season to season. For example, many agricultural fields within the study areas that were dry during the spring 96 season were flooded in spring 97, thus, providing additional feeding and resting areas for waterfowl that influenced their daily activities. Geographic Information System (GIS) analysis of the surveillance area surrounding individual sites would provide information on relationships between migratory activity and to landscape features, (e.g., elevation, area of wetlands), within the study area. Results of this investigation indicate that site level assessments are required.

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