

Report on Avian Impact Issues, Requirements, Status, and Costs Relating to
Potential Wind-Energy Projects in Accomack County

Version 1.1 – October 31, 2009

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This interim report is prepared in response to the request of the Economic and Community Development Director of Accomack County, according to the following Scope of Work:

1. Determine if reports, studies, or documents have been previously completed regarding wind energy issues and bird studies in Accomack.
2. Collect completed studies, if possible, and place documents in put them on County's Official Website.
3. Determine outline for official federal, state, or local requirements for bird studies regulations for wind turbines.
4. Determine the cost of typical bird study.
5. Provide summary of results of tasks 1-4.

Addendum:

1. Research possible grants or funding to do bird study.
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Report -- Results to date:

1. There appear to be no completed studies relating to the impact of potential wind-energy projects in Accomack or Northampton County on birds and bats. A study is presently under way at Wallops, for a demonstration coastal-zone project for this area. If NASA proceeds with the project there will be one or two turbines – each the 1+ megawatt range. A preconstruction bird- and bat-impact study has been under way for about 18 months. The basic methodology is counts of actual mortalities from two existing towers, a 345' un-guyed and a 165' guyed tower, as surrogates for the wind-turbines' tubular towers. The study methods include controls for strikes and for removal by scavengers. Echolocation is being used to listen for bats in the air; endangered/protected bats are not expected in this area. The plan is to prepare an assessment according to NEPA, then decide whether a full (Environmental Impact Statement) EIS is required, or have a Finding of No Significant Impact.
2. This is a dynamic area with an enormous output across the country. Much Federal money is available (see for example [Reference #19](#)), consistent with the pressure to reduce dependence on fossil fuels for electric power generation. The list of references below is misleadingly small: Not only is this a modest subset of the many documents available, but each of the larger papers has its own bibliography, and collectively they list not fewer than 300 reports. These studies and reports

will be placed on the County's website. A brief summary of several of the references is given below the list. The references themselves cover a range of topics, and those not specifically cited or summarized in this report may nonetheless be of interest. The consensus of the reports and of telephone discussions with several sources indicates that wind energy, while it can result in bird and bat deaths, is highly favored because recent and likely further advances in technology and technique can mitigate the damage, and because even without mitigation the net impact is generally less than that from energy derived conventionally from fossil fuel. See [References #12](#), [#15](#), and [#20](#). Requirements of the [Migratory Bird Treaty Act](#), the Endangered Species Act, and the Bald and Golden Eagle Protection Act must be met, but while this hurdle need not be insuperable there can be [severe penalties for flagrant violations](#).

3. Guidelines relevant to the Eastern Shore are discussed in #1, [Stemler](#), and in #3, the [FWS "Service Interim Guidelines"](#). [Wind-Farm Impact Assessment Guidelines for the Mountain Regions of Virginia](#) are discussed in #5, and while such Guidelines specific to the Eastern Shore have not yet been published, those guidelines will likely not be appreciably different for any land-based wind-energy installation. Off-shore projects will have different guidelines and a different permitting process. The definition of "offshore" is still open.
4. Costs for such pre-construction bird/bat impact studies will be in the few hundreds of thousands of dollars, as they must cover many dimensions and a full year, more under some circumstances (see checklists in [Reference #3](#)). A radar bird study could run \$150k, plus the cost of a bat echolocation study, if either method were to be used rather than, or in addition to, "body count" approaches. Specifics of cost are not readily available, but Bat Conservation International, a not-for-profit, has reportedly quoted a figure of \$16k/turbine/yr for post-construction surveys running from April through mid-November. Such surveys will likely also be required, to verify the pre-construction findings.

See [Reference #22](#) for 2009 amendment to the Code of Virginia the permitting process for small renewable energy facilities. Changes to the existing process will not be effective until 2011. While the VA DGIF published Guidelines recommend pre-construction studies of one to three years, under the new law the duration of any wildlife impact study will be limited to twelve months. In general, the thrust of these changes tend to make it easier and more economically feasible to site such facilities.

Even before a wildlife-impact study is undertaken the economic suitability of any proposed site must be established, including a wind-mapping project to verify sufficiency of annual average wind speeds in the sweep area of turbine rotors. Without sufficient wind, insufficient saleable power will be generated to justify the project. Only a site with economic potential would ever require an avian/bat impact study.

See for example [Reference #8](#), the map of wind at 50 meters altitude above and off-shore of Virginia. While this map indicates that over land the average wind at 50m is insufficient, this may not be the true picture. The critical altitude interval for land-based wind-energy turbines is from about 70 m to about 170 m – this defines the sweep diameter of the turbine blades for a modern turbine atop a 120 m tall tower. Wind speed generally increases with altitude -- a rate often cited is the 1/7th power – and blows steadier at higher altitudes.

A wind study proposal that would gather data and model the wind at the “sweet spot” altitudes is in preparation as of early October, 2009. The study would cover Somerset County, MD, as well as Accomack County, and would run about \$100k plus instrumentation costs and rental of the anemometer locations, the costs to be split by the counties.

5. Exploration of potential grants or funding will be undertaken next. In particular, funding assistance should be sought for the two-County wind study.

References: – all to be posted on County website

1. Stemler, J. “Wind Power Siting, Incentives, And Wildlife Guidelines in the United States”. Association of Fish and Wildlife Agencies, USFWS. October, 2007.
2. Kunz, T. H., et al. “Assessing Impacts of Wind-Energy Development on Nocturnally Active Birds and Bats: A Guidance Document.” *Journal of Wildlife Management* 71(8): 2449–2486; 2007
3. “Service Interim Guidance on Avoiding and Minimizing Wildlife Impacts from Wind Turbines”. USFWS. May 13, 2003
4. Erickson, W. P., et al. “Avian Collisions with Wind Turbines: A Summary of Existing Studies and Comparisons to Other Sources of Avian Collision Mortality in the United States”. National Wind Coordinating Committee. August, 2001.
5. “Guidelines for Wildlife (birds and bats) Impact Assessment, Monitoring, and Mitigation at Proposed Wind-Energy Facilities in Virginia: Mountain Regions”. VA DGIF. June, 2009
6. Weed, C. “Summary of Wind Turbine Environmental Issues”. Centerville Township Commercial Wind Ordinance Committee. September 24, 2006
7. Curry & Kerlinger, LLC. “Birds and Wind Power”.
<http://www.currykerlinger.com/windpower.htm>
8. “Virginia Wind Resource Map” USDOE.
http://www.windpoweringamerica.gov/maps_template.asp?stateab=va
9. Ruth, J. M., et al. “Advancing Migratory Bird Conservation and Management by Using Radar: An Interagency Collaboration”. Open File Report 2005-1173. US Geological Survey, 2005.
10. Gauthreaux, S. A., Jr. and Belser, C. G. “Radar Ornithology and the Conservation of Migratory Birds”. In: Ralph, C. J., and Rich, T. D., eds. 2005. *Bird Conservation Implementation and Integration in the Americas: Proceedings of the Third International Partners in Flight Conference*. March 20-24, 2002; Pp.871-875. Asilomar, California; Volume 2. Gen. Tech. Rep. PSW-GTR-191.

- Albany, CA:Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture
11. Watts, B. D., et al., “Exploring Patch-Level and Landscape-Level Stopover Patterns Using NPOL Radar along the Lower Delmarva Peninsula”. 2009?
 12. American Wind Energy Association. “Facts about Wind Energy and Birds”. Date uncertain, probably 1990s.
 13. McClaren, S. B. Letter to Virginia Secretary of Natural Resources Preston Bryant American Society of Mammologists. August 7, 2008.
 14. Resolution: “Effects of Wind-Energy Facilities on Bats and Other Wildlife”. American Society of Mammologists. June, 2008.
 15. Militana, T., “Wind Energy Finds Fix for Exploding Bats”. The Washington Times, March 23, 2009
 16. “Tilting toward wind off Virginia's coast”. The Virginian-Pilot, February 8, 2009
 17. Erickson, W., et al. “Synthesis and Comparison of Baseline Avian and Bat Use, Raptor Nesting, and Mortality Information from Proposed and Existing Wind Developments”. Bonneville Power Administration. December, 2002.
 18. “Utility Giant to Pay Millions for Eagle Protection”. USFWS. July 10, 2009
 19. U.S. Department of Energy. “DOE Announces Nearly \$14 Million to go to 28 New Wind Energy Projects”. July 16, 2009
 20. Laumer, J. “Common Eco-Myth: Wind Turbines Kill Birds”. http://www.treehugger.com/feeds/authors/John_Laumer.xml , 2006.
 21. ”Migratory Bird Treaty Act of 1918”. 16 U.S.C. 703-712 and amendments, Cited in Digest of Federal Resource Laws of Interest to the U.S. Fish and Wildlife Service. <http://www.fws.gov/laws/lawsdigest/migtrea.html>
 22. Code of Virginia Title 10.1, 2009 Amendment to Chapter 11.1, revising permitting process for small renewable energy plant.

Summary of selected references.

1. Stemler, J. Wind Power Siting, Incentives, And Wildlife Guidelines in the United States. 2007.

Note #1: This reference, while still useful as of October, 2009, will become increasingly obsolete. Editing and notes are inserted to reflect significant changes to the permitting process arising from 2009 amendments to the Virginia Code. The reference is retained because the changes will not become effective until 2011, but will not apply to any project for which a permit application is made prior to the effective date.

VIRGINIA

BACKGROUND

Contact: Rick Reynolds, Virginia Department of Game and Inland Fisheries, (540) 248-9360, Rick.Reynolds@dgif.virginia.gov, P.O. Box 996, Verona, VA 24482

Incentives for Industrial or “Big Wind” Production: None.

ENERGY SITING PROCESS

Power Siting Authority: The Virginia State Corporation Commission provides a certificate of convenience and necessity for siting new public utility facilities.

Note #2: – see Reference #22: In 2009 the legislature amended the permitting process for renewable-energy facilities of under 100 MW. Responsibility passes to the DEQ, and new permits are being developed by a working group comprised of government agencies, NGOs, and industry,

Wind Specific Siting Authority? No

Code or Regulations: Power Siting Law - 56-265.1 to 9.

Note #3: See Reference #22. DEQ is now to have primary responsibility for permitting small projects; the SCC will no longer be involved from 2011.

Role of State Fish & Wildlife Agency: With respect to wildlife, the VA State Corporation Commission (SCC) has an MOU with the VA Dept. of Environmental Quality to review and consider environmental issues concerning power projects in VA. DEQ compiles comments from the other state natural resource agencies and provides these to the SCC for their consideration.

How wildlife laws are applied: Same as any other development/utility project, State Threatened and Endangered Species law and state code prohibits unauthorized take of wildlife. State cannot require mitigation.

STATE ENVIRONMENTAL POLICY ACT:

Code of Virginia §10.11188 through 1192, 1973.

Note #4: See Reference #22. The Code is amended by addition of sections 10.1-1197.5 through 10.1-1197.11 .

Overview:

The purpose of environmental review is to identify and evaluate the environmental effects of proposed state facilities, and to guide facility siting and design decisions in order to protect important environmental resources. The analysis needed to prepare an environmental impact report helps agencies to assess the effects of development proposals, and to consider alternative actions and mitigating measures to avoid or reduce adverse impacts. Information requirements include the environmental impacts of the project, adverse environmental effects that are unavoidable, measures taken to minimize impacts, any alternatives to the proposed construction and irreversible environmental changes.

Projects Affected by Law:

The law applies to State agencies, boards, commissions, authorities, any branch of State government, and state supported institutions of higher learning. State agencies are required to prepare and submit environmental impact reports for construction of facilities that will cost \$100,000 or more. The requirement also covers acquisition of land for construction, which includes leases, and expansion of existing facilities.

Public Participation Provisions:

Public input is not directly solicited for projects. An environmental review is circulated among state agencies as well as to localities and district commissions.

Applicability to Wind Development?

No - the law only applies to state built facilities.

Implementing Agency:

The DEQ's Office of Environmental Impact Review coordinates the review process and prepares a single state response for consideration by the Secretary of Administration, representing the Governor.

WILDLIFE GUIDELINES FOR WIND

Wildlife Guidelines for Wind Power Siting: No state guidelines; the state has been required to develop potential siting areas and fish & wildlife considerations are expected to be part of that.

Note #5: In June, 2009, VA DGIF published guidelines for Mountain Regions, Reference #5. The Guidelines for ESVA will most likely be the same for on-shore facilities, but are yet to be considered for offshore. Permits for on-shore and off-shore facilities will be developed separately during Q4 2009 and through 2010 by DEQ.

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2. Kunz, T. H., et al. Assessing Impacts of Wind-Energy Development on Nocturnally Active Birds and Bats: A Guidance Document. 2007.

Generating information useful to aid in evaluating potential and actual impacts of wind power development on nocturnally active birds and bats. Guidance to methods and measures for investigating these animals for utility-scale wind-energy development. Objectives of such studies include 1) assess potential impacts, 2) quantify fatality rates, 3) determine the causes of fatalities, and 4) provide methods for assessing risks to bird and bat populations and habitats. Methods and tools, their limitations, assumptions, data interpretation, case studies, suggestions for improving studies. Each real study will differ. Choices of methods and measures depend on objectives, risks to bird and bat populations, and budgetary and logistical considerations. Complements and extends the existing National Wind Coordinating Committee document "Methods and Metrics for Assessing Impacts of Wind Energy Facilities on Wildlife" (Anderson et al. 1999). Target audience is the wind [power] industry, decision-makers, and the public, in the permitting process for 1) complying with permit data requirements, 2) evaluating potential sites, 3) assessing operational, and 4) mitigating impacts on the target animals.

About 200 references are cited.

3. USFWS. Service Interim Guidance on Avoiding and Minimizing Wildlife Impacts from Wind Turbines. 2003

Rationale:

Service personnel may become involved in the review of potential wind energy developments on public lands through National Environmental Policy Act review (sections 1501.6, *opportunity as a cooperating agency*, and section 1503.4, *duty to comment on federally-licensed activities for agencies with jurisdiction by law*, i.e., the Migratory Bird Treaty Act and Bald and Golden Eagle Protection Act); or because of special expertise. The National Wildlife Refuge System Improvement Act requires that any activity on Refuge lands be determined to be compatible with the Refuge system mission and Refuge purpose(s). In addition, the Service is required by the Endangered Species Act to assist other Federal agencies in ensuring that any action they authorize, implement, or fund will not jeopardize the continued existence of any federally endangered or threatened species. Service biologists have also received requests from industry for consultation on wildlife impacts of proposed wind energy developments on private lands.

Implementation of Service recommendations provided in accordance with these guidelines by the wind energy industry is voluntary. Field offices have discretion in the use of these guidelines on a case-by-case basis, and may also have additional recommendations to add which are specific to their geographic area.

[T]his guidance is intended to assist the wind energy industry in avoiding or minimizing impacts to wildlife [in particular, birds and bats] and their habitats. This is accomplished through: (1) proper evaluation of potential Wind Resource Areas (WRAs), (2) proper location and design of turbines and associated structures within WRAs selected for development, and (3) pre- and post-construction research and monitoring to identify and/or assess impacts to wildlife. These guidelines are based on current science and will be updated as new information becomes available.

The Service is guided by the Fish and Wildlife Service Mitigation Policy (Federal Register 46 (15), January 1981) ... [which] ... follows ... the Council on Environmental Quality's Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act (NEPA) in seeking to avoid [or mitigate] negative impacts. ... Mitigation does not apply to "take" of species under the Migratory Bird Treaty Act, Bald and Golden Eagle Protection Act, or Endangered Species Act. The goal of the Service under these laws is the elimination of loss of migratory birds and endangered and threatened species due to wind energy development. [emphasis added]

[Additional analyses may be required for] projects on federally owned lands ... , lands where a Federal permit is required for development ... , or lands where Federal funds were used for purchase or improvement

The guidelines contain a site evaluation process with checklists for pre-development evaluations of potential terrestrial wind energy development sites ... Any site evaluations conducted by teams that do not include Federal and/or State agency wildlife professionals will not be considered valid evaluations by the Service.

Appendix 1: PROTOCOL TO RANK POTENTIAL TERRESTRIAL WIND ENERGY DEVELOPMENT SITES BY IMPACTS ON WILDLIFE. See reference for details, including checklist forms and instructions.

Appendix 3: WILDLIFE LAWS RELEVANT TO WIND POWER DEVELOPMENT PROJECTS

1. **The Migratory Bird Treaty Act** (16 U.S.C. 703-712; MBTA), -- administered by the Fish and Wildlife Service (FWS). Strict liability.
2. **The Endangered Species Act** (16 U.S.C. 1531-1544; ESA) -- administered by the Interior Department's FWS and the Commerce Department's National Marine Fisheries Service (NMFS). FWS has primary responsibility for terrestrial ... organisms (including birds and bats).
3. **The National Environmental Policy Act** of 1969 (42 U.S.C. 4371 et seq.; NEPA) -- NEPA [may require] review [by other agencies such as FWS] ... as a cooperating agency ..., or because of a duty to comment on federally-licensed activities for which the agency has jurisdiction by law (Section 1503.4). ... Federal agencies [must] prepare an environmental impact statement (EIS) for Federal actions significantly affecting the quality of the human environment.
4. **The National Wildlife Refuge System Administration Act** (16 U.S.C. 668dd), ... applies to any proposed development of wind energy on Refuge System lands ...
5. **The National Historic Preservation Act** of 1966 (16 U.S.C. 470-470b, 470c-470n) -- functions [like] NEPA, requiring ... evaluation of the effects of proposed developments (such as wind energy facilities) ... if the facility would be .. funded, licensed or permitted by a Federal agency... includes State lands purchased or improved with Federal Aid in Wildlife Restoration funds.

See also the **Bald and Golden Eagle Protection Act** (BGEPA) (16 U.S.C. 668). BGEPA liability is, as with MBTA, strict.

Note from **Appendix 7: KNOWN AND SUSPECTED IMPACTS OF WIND TURBINES ON WILDLIFE**. In 1999, the Avian Subcommittee (now called the Wildlife Work Group) of the the National Wind Coordinating Committee published a *Metrics and Methods* document to study turbine impacts on birds (Anderson et al. 1999) and ESA-liated bats for proposed wind farms.

Appendix 8: LITERATURE CITED About 50 citations.

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6. Guidelines for Wildlife (birds and bats) Impact Assessment, Monitoring, and Mitigation at Proposed Wind-Energy Facilities in Virginia: Mountain Regions

While the comparable Guidelines for ESVA have not yet been issued, it is reasonable to infer that there will be similarities in the applicable laws and in the principles underlying the guidelines themselves.

Applicable Virginia Wildlife Laws and Regulations:

- Unlawful to hunt, trap, possess, sell . . . (29.1-521.10).
- Possession, importation, sale, etc., of wild animals (4 VAC 15-30-10).
- Virginia Endangered Species Act (29.1-563 - 29.1-570)

Applicable Federal laws are cited in Reference #3 above.

Note especially the following, emphasis added, which cites Reference #2, Kuntz:

...

Pre- and Post-Construction Data Collection, Surveys, and Monitoring

As presented in the Department's comprehensive testimony to the State Corporation Commission regarding Virginia's first proposed wind-energy facility (Highland New Wind Development, Case No. PUE 2005-10010 @ <http://docket.scc.virginia.gov/vaprod/main.asp>) and confirmed in the SCC Final Order (SCC 2007), **robust monitoring of birds and bats at wind-energy facilities is essential to understanding and effectively reducing fatalities at these installations. In their recently-published Guidance Document, Kunz et al. (2007a) ...**

...The duration of pre-construction surveys will be a minimum of 1 year, but 2-3 years of pre-project surveys are recommended and strongly encouraged. Additional surveys may be warranted due to the presence of sensitive habitats; the likelihood of occurrence of Threatened or Endangered species...

Figures for annual allowable “take” of various species will be the measure that will trigger mitigation actions.

Post-construction surveys will be required for the life of the project, but frequency and actions will depend on whether the trigger level was reached in the previous period.

The Guidelines also rely on the following book: National Research Council, Committee on Environmental Impacts of Wind Energy Projects. 2007. Environmental impacts of wind-energy projects. The National Academies Press, Washington, D.C. 376 pp.

Literature Cited:

1. Arnett, E.B., J.P. Hayes, and M.P. Huso. 2006. Patterns of pre-construction bat activity at a proposed wind facility in south-central Pennsylvania. An annual report to the Bats and Wind Energy Cooperative. Bat Conservation International, Austin, Texas, USA.
<http://www.batcon.org/wind/BWEC%202005%20Annual%20Report.pdf>
2. Arnett, E.B., M. Schirmacher, M.M.P. Huso, and J.P. Hayes. 2009. Effectiveness of changing wind turbine cut-in speed to reduce bat fatalities at wind facilities. An annual report submitted to the Bats and Wind Energy Cooperative. Bat Conservation International. Austin, Texas, USA. 45 pp.
3. Baerwald, E.F. 2008. Variation in the activity and fatality of migratory bats at wind energy facilities in southern Alberta: causes and consequences. Unpubl. M.S. Thesis, University of Calgary, Calgary, Alberta, Canada. 117 pp.
4. Kunz, T.H., E.B. Arnett, B.M. Cooper, W.P. Erickson, R.P. Larkin, T. Mabee, M.L. Morrison, M.D. Strickland, and J.M. Szewczak. 2007a. Assessing impacts of wind-energy development on nocturnally active birds and bats: a guidance document. *Journal of Wildlife Management* 71:2449-2486.
5. Kunz, T.H., E.B. Arnett, W.P. Erickson, A.R. Hoar, G.D. Johnson, R.P. Larkin, M.D. Strickland, R.W. Thresher, and M.D. Tuttle. 2007b. Ecological impacts of wind energy development on bats: questions, research needs, and hypotheses. *Frontiers in Ecology and the Environment* 5:315-324.
6. National Research Council, Committee on Environmental Impacts of Wind Energy Projects. 2007. Environmental impacts of wind-energy projects. The National Academies Press, Washington, D.C. 376 pp.
7. National Wind Coordinating Committee. 2004. Wind turbine interactions with birds and bats: a summary of research results and remaining questions. Washington, D.C.
8. Reynolds, D.S. 2006. Monitoring the potential impact of a wind development site on bats in the northeast. *Journal of Wildlife Management* 70:1219-1227
9. United States Government Accountability Office. 2005. Wind power: impacts on Wildlife and government responsibilities for regulating development and protecting wildlife. United States Government Accountability Office, Washington, D.C.
10. Virginia State Corporation Commission. 2007. Final Order: Highland New Wind

Development. Case No. PUE 2005-100101.

[Http://docket.scc.virginia.gov/vaproduct/main.asp](http://docket.scc.virginia.gov/vaproduct/main.asp).

11. Virginia Department of Game and Inland Fisheries. 2005. Virginia's comprehensive wildlife conservation strategy. Virginia Department of Game and Inland Fisheries, Richmond, Virginia. <http://bewildvirginia.org/wildlifeplan/plan.asp>

9. Ruth et al.

Promising tool for deciphering migratory travels: radar-based studies of movements and habitat use patterns in songbirds, waterfowl, and bats. The U.S. system of Doppler weather radars provides continental coverage, similar to the scale of bird migration. Data stored from weather radar represent perhaps the second largest biological data archive in the world, use is limited to biologists who can handle the obscure data formats. Complementary mobile radar units and thermal and acoustic monitoring are also used in site-specific studies.

Intent: Identify migratory pathways and stopover sites for conservation, mitigation, and landscape planning ... unobstructed airspaces for migrating wildlife -- enable use of radar by the ... wind power, and related communities ... [so that] [1]and managers and industry may ... optimize the siting of energy projects.

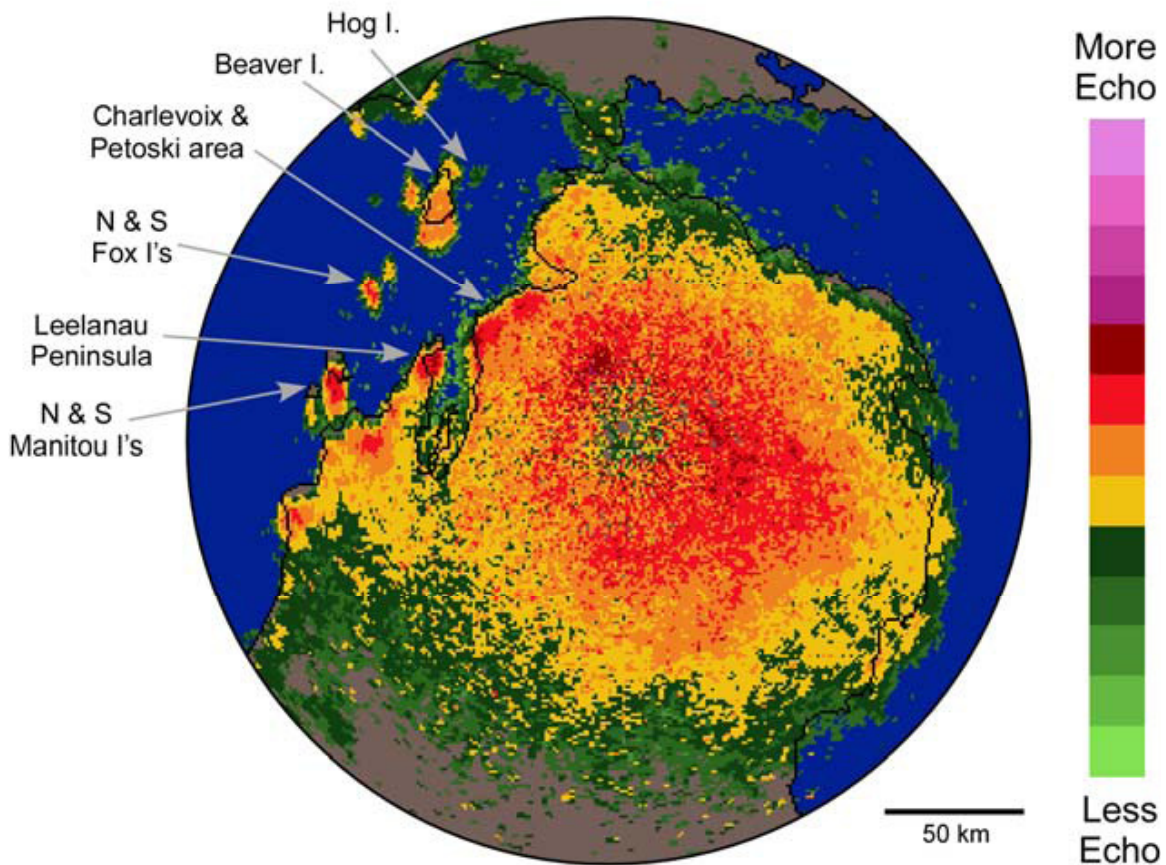


Figure 3. Songbirds initiate southward migration throughout the northern lower peninsula of Michigan on August 15, 2000, at 8:31 p.m. CDT. Radar echoes show birds concentrated in coastal habitats near Charlevoix, Petoski, and Leelanau. Departures from numerous islands in northern Lake Michigan (labeled) are clearly visible.

Suggested Reading List

- Bruderer, B., 1997, The study of bird migration by radar, Part 1: The technical basis: *Naturwissenschaften*, v. 84, p. 1–8.
- Bruderer, B., 1997, The study of bird migration by radar, Part 2: Major achievements: *Naturwissenschaften*, v. 84, p. 45–54.
- Crum, T., Evancho, C., Horvat, C., Istok, M., and Blanchard, W., 2003, An update on NEXRAD program plans for collecting and distributing WSR-88D base data in near real time: 19th International Conference on Interactive Information Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology, Long Beach, California, American Meteorological Society.
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- Diehl, R., 2003, Landscape associations of birds during migratory stopover: University of Illinois, Champaign-Urbana, Ph.D. dissertation, Department of Ecology, Ethology, and Evolution, 142 p. Diehl, R.H., Larkin, R.P., and Black, J.E., 2003, Radar observations of bird migration over the Great Lakes: *Auk*, v. 120, p. 278–290.
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- Gauthreaux, Jr., S.A., Belser, C.G., and Van Blaricom, D., 2003, Using a network of WSR-88D weather surveillance radars to define patterns of bird migration at large spatial scales, in Berthold, P., Gwinner, E., and Sonnenschein, E., eds.: *Avian migration*, p. 335–346.
- Gauthreaux, Jr., S.A., Mizrahi, D.S., and Belser, C.G., 1998, Bird migration and bias of WSR-88D wind estimates: *Weather and Forecasting*, v. 13, p. 465–481. Larkin, R.P., in press, Radar techniques for wildlife: *Techniques for Wildlife Investigations and Management* (6th ed.), Wildlife Society. Larkin, R.P., and Diehl, R.H., in press, Spectral width of birds and insects on pulsed Doppler radar: *IEEE Transactions on Geoscience and Remote Sensing*. Larkin, R.P., Evans, W.R., and Diehl, R.H., 2002, Nocturnal flight calls of Dickcissels and Doppler radar echoes over south Texas in spring: *Journal of Field Ornithology*, v. 73, p. 2–8.
- Russell, K.R., Mizrahi, D.S., and Gauthreaux, S.A., Jr., 1998, Large-scale mapping of Purple Martin pre-migratory roosts using WSR-88D weather surveillance radar: *Journal of Field Ornithology*, v. 69, p. 316–325.

10. Gauthreaux et al.

Surveillance radar may be used to study movements of migrating birds at different spatial scales. Within a range of 6 kilometers surveillance radar (e.g. BIRD RAD) can detect the departure of migrants from different types of habitat within a few kilometers of the radar, and sample the flight speeds to try to classify birds by their velocities. At the scale of 10-60 kilometers, Doppler weather surveillance radar (WSR-88D) can be used to measure the density of birds in the radar beam as they begin a (nocturnal, e.g.) migratory movement within 60 kilometers of the radar, plus information on the migration stopover areas. Continental-scale information is also available.

Preliminary findings suggest that most stopover areas along the Gulf and Atlantic Coasts are associated with floodplain topography and upland areas are used less. Forested wetlands are used almost exclusively as important stopover areas and extensive pine flatlands are rarely used (Gauthreaux, unpubl. data).

Bertram, D. F., L. Cowen, and A. E. Burger. 1999. **Use of radar for monitoring colonial burrow-nesting seabirds.** *Journal of Field Ornithology* 70: 145-157.

Burger, A. E. 2001. **Using radar to estimate populations and assess habitat associations of marbled murrelets.** *Journal of Wildlife Management* 65: 696-715.

Casement, M. B. 1966. **Migration across the Mediterranean observed by radar.** *Ibis* 108: 461-491.

Cooper B. A., R. H. Day, R. J. Ritchie, and C. L. Cranor. 1991. **An improved marine radar system for studies of bird migration.** *Journal of Field Ornithology* 62: 367-377.

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Flock, W. L. 1968. **Monitoring bird movements by radar.** *IEEE Spectrum* 5:62-66.

Flock, W. L. 1972. **Flight safety aspects of precision radar near air bases in bird-aircraft collision avoidance.** Technical Report No. AFWL-TR-72-25. Kirtland Air Force Base, NM: Air Force Weapons Laboratory, Air Force Systems Command; 66 p.

Gauthreaux, S. A., Jr. 1970. **Weather radar quantification of bird migration.** *BioScience* 20: 17-20.

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Regional or continental scale maps of migrant stopover densities would be desirable have far reaching ecological and conservation implications. Weather surveillance radar to map migratory exodus and infer stopover patterns has long been researched. The present US weather radar network used limits the resolution of kilometers-landscape features. The NASA polarimetric radar (NPOL), with higher resolution than the present weather network, was used on the lower Delmarva Peninsula during the fall 2004 migration to to learn its value in resolving exodus variation at the patch and landscape scales. Mean reflectivities for geographic areas (landscape scale) and habitat types (patch scale) that support very different migrant densities were measured. Reflectivities differentiate geographic areas but not habitat types, possibly due to inadequate radar scan rate for this fine-grained landscape.

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