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Understanding the Avian-Impact Offset Method—A Tutorial

Open-File Report 2022–1049

U.S. Department of the Interior
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A

B

C

D

Cover. *A*, Utility scale wind turbines at the Cedar Creek Wind Farm in Grover, Colorado. Photograph by Dennis Schroeder, National Renewable Energy Laboratory. *B*, Oil pump. Photograph by Lawrence D. Igl, U.S. Geological Survey. *C*, Gravel road. Photograph by Lawrence D. Igl, U.S. Geological Survey. *D*, Solar panel array. Photograph by Jessica K. Robertson, U.S. Geological Survey.

Understanding the Avian-Impact Offset Method—A Tutorial

By Jill A. Shaffer, Charles R. Loesch, and Deborah A. Buhl

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Shaffer, J.A., and Buhl, D.A., 2018, Effects of wind-energy facilities on breeding grassland bird distributions: U.S. Geological Survey data release, https://doi.org/10.5066/F7T43SDG.

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Contents

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
decimeter (dm)	3.937	inch (in.)
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
meter (m)	1.094	yard (yd)
	Area	
hectare (ha)	2.471	acre
hectare (ha)	0.003861	square mile (mi^2)

Understanding the Avian-Impact Offset Method—A Tutorial

By Jill A. Shaffer,[1] Charles R. Loesch,[2] and Deborah A. Buhl[1]

Abstract

Biodiversity offsetting, or compensatory mitigation, is increasingly being used in temperate grassland and wetland ecosystems to compensate for unavoidable environmental damage from anthropogenic disturbances such as energy development and road construction. Energy-extraction and -generation facilities continue to proliferate across the natural landscapes of the United States, yet mitigation tools to ameliorate the negative behavioral effects on wildlife from these types of facilities are rarely implemented. Scientists from the U.S. Geological Survey conducted a 10-year before-after-control-impact (commonly referred to as BACI) study that evaluated the displacement effects of wind facilities on breeding grassland birds. The study determined behavioral avoidance for 7 of 9 species. This research is notable because of its design, geographical scope, and duration, which allowed for the determination of immediate, short-term effects; delayed or sustained effects; and discrete distances at which effects occurred. In addition, the U.S. Fish and Wildlife Service and Ducks Unlimited conducted a 3-year concurrent-year paired-reference study to determine behavioral avoidance for five species of dabbling ducks. By quantifying displacement rate from these two studies, U.S. Geological Survey and U.S. Fish and Wildlife Service scientists developed the Avian-Impact Offset Method (AIOM) to quantify and compensate for loss in value of breeding habitat. The AIOM converts the biological value (that is, number of bird pairs) lost by way of avoidance and estimates the site-specific number of hectares of grasslands and number of wetlands needed to compensate for displaced pairs of grassland birds and waterfowl. By converting biological value to traditional units of measure in which land is described and purchased or sold, the AIOM lends itself readily to the delivery of offsetting measures such as easement protections and restoration projects. The AIOM tool is applicable to wind, solar, oil, gas, and transportation infrastructure.

This tutorial was designed to increase awareness of the AIOM and to promote its proper application. The tutorial is divided into four sections, each of which explains a discrete topic concerning aspects of behavioral displacement. The first section provides geographical and biological context, and the second section describes the field and statistical methods and results. The third section provides step-by-step instructions for applying the AIOM to several scenarios involving grassland birds or waterfowl at wind or oil facilities. The fourth section describes decision-support tools created to implement the AIOM. The appendices provide the actual field protocols constituting the methods for the research, provide detailed results by species and wind facility for that research, and provide detailed instructions for downloading and applying the decision-support tools.

Introduction

Expansion of the renewable energy industry to ameliorate climate change will continue to fuel the proliferation of anthropogenic structures, including wind and solar facilities and their associated roads and transmission lines. These structures are widely acknowledged to cause wildlife mortality and behavioral displacement (also referred to as “avoidance”). Compensatory mitigation is increasingly being used to offset effects from such anthropogenic disturbances, and the U.S. Geological Survey (USGS) and U.S. Fish and Wildlife Service (USFWS) have developed a tool to aid these efforts. To quantify and compensate for loss in value of avian breeding habitat, scientists with the USGS and USFWS developed the Avian-Impact Offset Method (AIOM), a tool that estimates the amount of grasslands and wetlands needed to support displaced pairs of grassland birds and waterfowl and that is applicable to wind, solar, oil, gas, and transportation infrastructure (Shaffer and others, 2019).

Development of the AIOM was possible because of two foundational studies that established behavioral displacement in grassland birds and waterfowl. For grassland birds, USGS scientists conducted a 10-year before-after-control-impact (BACI) study at three wind facilities in North Dakota and South Dakota (Shaffer and Buhl, 2016). This research is notable because of its study design, duration, and geographical scope. Although the BACI design is considered the optimal study design for observational studies because of its ability to make strong inference assessments, it is rarely applied owing to challenges in implementation. Furthermore, most displacement studies are short term and include only one wind facility. Based on the strength

[1]U.S. Geological Survey.

[2]U.S. Fish and Wildlife Service.

of the study design and duration, Shaffer and Buhl (2016) were able to document behavioral avoidance of energy infrastructure for 7 of 9 species by discrete distances, the magnitude of displacement, and displacement intensification (as opposed to habituation) over time. For these reasons, the Shaffer and Buhl (2016) research is nearly unprecedented in scope. To enhance understanding of the research, results, and application of the Shaffer and Buhl (2016) report, this tutorial will (1) explain how the BACI design was applied to the examination of passerine displacement, (2) document field methods by providing protocols, (3) explain results by species and wind facility, and (4) explain how results inform the AIOM.

Realizing that the difficulties of implementing a BACI design constrain its application, this tutorial provides an alternative—and perhaps, more feasible—approach to aid investigations into avian displacement in the form of a concurrent-year paired-reference (also referred to as “control”) approach as applied by Loesch and others (2013) to a 3-year collaborative research effort between the USFWS and Ducks Unlimited at two wind facilities in North Dakota. Loesch and others (2013) reported that five species of dabbling ducks exhibited behavioral displacement. The results of Loesch and others (2013) for waterfowl and the results from Shaffer and Buhl (2016) for grassland birds led to the determination that the average displacement rate in the northern mixed-grass prairies was 18 and 53 percent for waterfowl and grassland birds, respectively (Shaffer and others, 2019). The calculation of displacement rate catalyzed the development of the AIOM. The AIOM has been adopted by State wildlife agencies and wind developers to assess the effect of wind development, to guide the effort to reduce the impact on wetlands and grasslands, and to estimate the cost to mitigate for unavoidable impact.

To increase awareness of the AIOM and to promote its proper application, the authors have developed this tutorial to educate AIOM practitioners about the research methods and findings that are the foundation for the AIOM, as well as to highlight the AIOM’s applicability for mitigation. The tutorial is divided into four sections, each of which explains a discrete topic concerning aspects of behavioral displacement and mitigation for displacement. The first section provides background and context on the prairie ecosystem, the wind industry, and the focal grassland and waterfowl species whose behavior toward wind facilities was examined. The second section describes the methods and results from Shaffer and Buhl (2016) and Loesch and others (2013). This section is aimed at researchers who may have to implement a field research project to obtain values to populate the five metrics that constitute the AIOM. Thus, the second section discusses such factors as the BACI design and concurrent-year paired-reference study design, the field methods by which avian avoidance data were collected, detailed descriptions of pertinent definitions for analytic purposes, and detailed graphical and textual results for each species. The third section provides a step-by-step explanation of how the average percent displacement rate was calculated for grassland bird species, as reported in Shaffer and others (2019). The third section also provides step-by-step instructions for applying the AIOM to several scenarios: calculating habitat impacts to grassland birds owing to wind infrastructure, with one scenario depicting the case where the impacted site and the offset site are assumed to be of equal biological value and another scenario where the impacted site and the offset site are not of equal biological value; calculating habitat impacts to grassland birds owing to oil or gas infrastructure; and calculating habitat impacts to waterfowl owing to wind infrastructure. The fourth section describes decision-support tools created to implement the AIOM. These are ArcGIS-based spatial modules that can be used after infrastructure development to locate suitable areas for compensatory mitigation, or they can be used prior to development to provide estimates of the cost of habitat mitigation of potential developments. There is one decision-support tool for waterfowl and another for grassland birds. The appendixes provide the actual field protocols and diagrams constituting the methods for the Shaffer and Buhl (2016) research, species-specific results for the grassland birds, and instructions for accessing the decision-support tools.

Suggestions for Using this Tutorial

Jill Shaffer and Deb Buhl of the U.S. Geological Survey and Chuck Loesch of the U.S. Fish and Wildlife Service Habitat and Population Evaluation Team developed a method for quantifying the effect of energy facilities on grassland birds and waterfowl and how to offset displacement for grassland birds and waterfowl. That method is termed the Avian-Impact Offset Method (AIOM). This tutorial will explain the AIOM as well as the research that serves as its foundation. The AIOM was first published in Shaffer and others (2019), based on findings of avian displacement reported in Shaffer and Buhl (2016) and Loesch and others (2013). To facilitate the understanding of the AIOM, the authors suggest that readers familiarize themselves with these three papers. Their complete citation information is provided. The data that support this report are available as a USGS data release (Shaffer and Buhl, 2018).

- Loesch, C.R., Walker, J.A., Reynolds, R.E., Gleason, J.S., Niemuth, N.D., Stephens, S.E., and Erickson, M.A., 2013, Effect of wind energy development on breeding duck densities in the Prairie Pothole Region: The Journal of Wildlife Management, v. 77, no. 3, p. 587–598. [Also available at https://doi.org/10.1002/jwmg.481.]
- Shaffer, J.A., and Buhl, D.A., 2016, Effects of wind-energy facilities on breeding grassland bird distributions: Conservation Biology, v. 30, no. 1, p. 59–71. [Also available at https://doi.org/10.1111/cobi.12569.]
- Shaffer, J.A., Loesch, C.R., and Buhl, D.A., 2019, Estimating offsets for avian displacement effects of anthropogenic impacts: Ecological Applications, v. 29, no. 8, p. e01983. [Also available at https://doi.org/10.1002/eap.1983.]

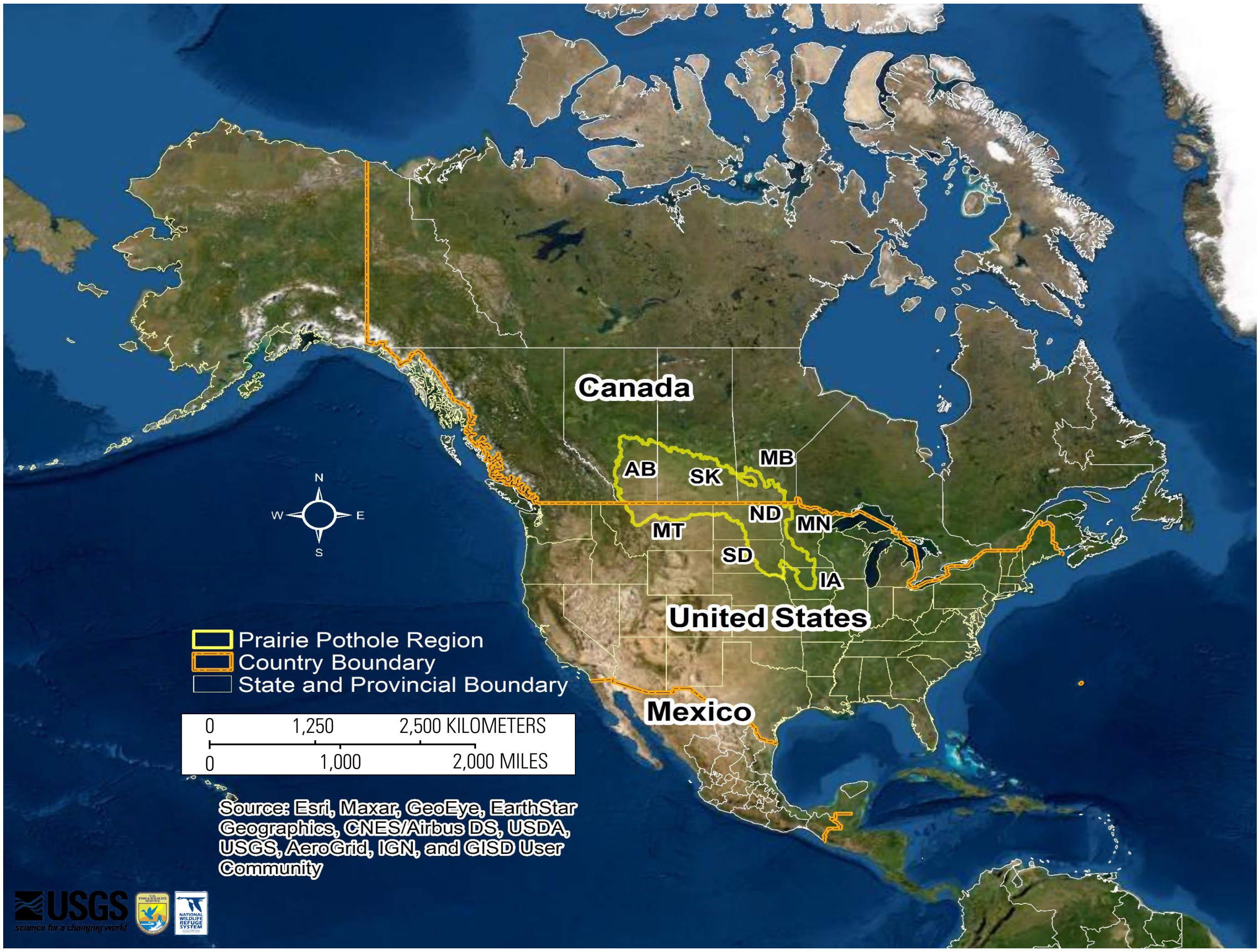
This tutorial is divided into four sections, each on a discrete topic. This format was chosen so that the reader could become familiar with the AIOM and the scientific underpinnings in stepwise fashion. Each section begins with an explanation of the core tenets to be discussed in that section and ends with a summary for validation that core concepts are understood. This summary provides the reader a logical stopping point between sections.

Section 1—Background Information

Section 1

Section 1 provides background and context on the prairie ecosystem, the wind industry, and the focal grassland and waterfowl species whose behavior toward wind facilities was examined.

Readers who are unfamiliar with the Prairie Pothole Region of the Northern Great Plains, and the serious conservation issues facing birds and native habitats, will find Section 1 informative. Readers who are well-informed on these issues can begin with Section 2.

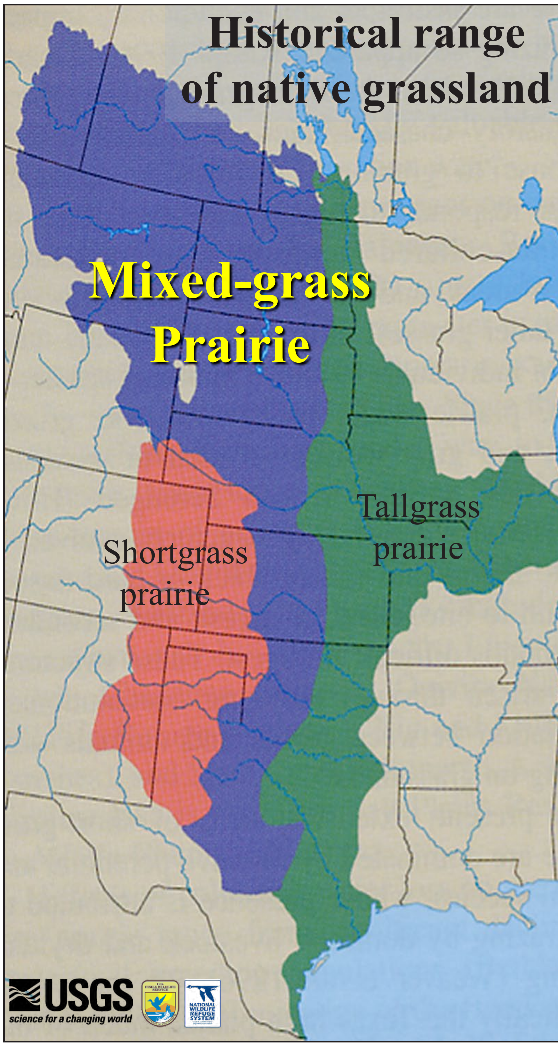


The research discussed in this tutorial occurred in mixed-grass prairies in North Dakota and South Dakota within the Great Plains of North America. The Northern Great Plains is an ecoregion that encompasses the southern Canadian Provinces of Alberta, Saskatchewan, and Manitoba and the States of Montana, North Dakota, South Dakota, Wyoming, and Nebraska.

The Prairie Pothole Region is internationally called “the duck factory of North America” for its pivotal role in producing waterfowl (Lynch, 1984).

The Prairie Pothole Region historically evolved as a mixed-grass and tallgrass prairie landscape in which millions of wetlands and expansive grasslands formed an interconnected world of multiple habitats, including wetlands of varying water permanence, mesic and xeric grasslands, and isolated treed ravines, to form a highly biodiverse area (Mac and others, 1998).

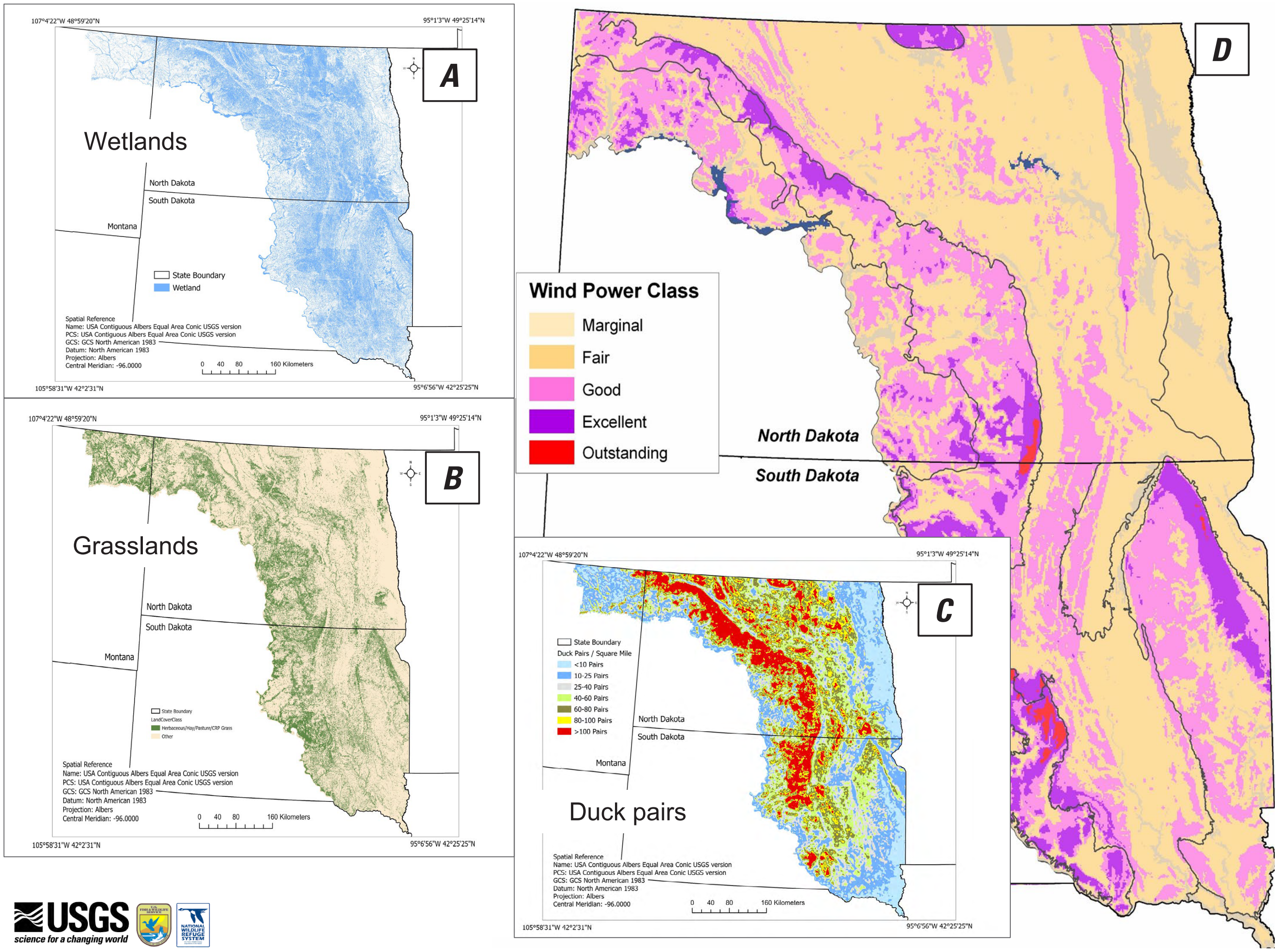
These photographs show some of the habitat diversity present within the Prairie Pothole Region: wetlands within mixed-grass prairie (upper left), tallgrass prairie (lower left), and wooded riparian areas (right).



Prairie Conversion in the Northern Great Plains

Provinces/ States	Past area (million hectares)	Current area (million hectares)	Decline (percent)
Alberta	8.7	3.4	60.9
Manitoba	0.6	trace	99.9
Saskatchewan	13.4	2.5	81.3
North Dakota	14.2	4.5	68.3
South Dakota	1.6	0.5	70.0

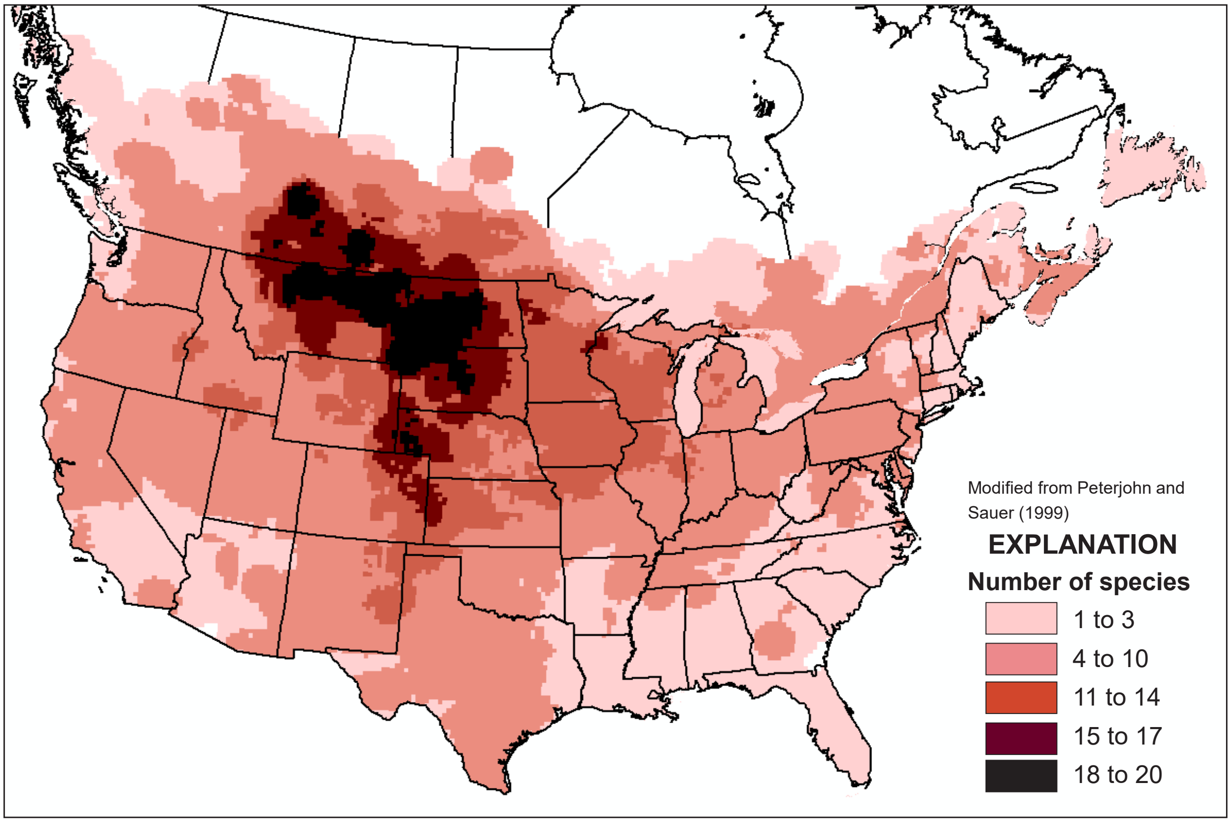
The mixed-grass prairie stretches north to south in the United States and began to be plowed under with the arrival of European settlers (Mac and others, 1998). Using North Dakota as an example, Mac and others (1998) estimated the loss of about 70 percent of historical levels of native grasslands, which were those grasslands here prior to European settlement. The continuation of grassland conversion to cropland drives higher losses of native grassland in contemporary times (Lark and others, 2015). The map image is modified from Mac and others (1998).



These maps depict the portions of North Dakota and South Dakota east of the Missouri River. Areas with the highest wind potential (fig. *D*) intersect areas with substantial amounts of wetlands (fig. *A*) and grasslands (fig. *B*), and subsequently, abundant wildlife resources (fig. *C*). Image *D* is a wind-resource map from the National Renewable Energy Laboratory, showing the categories of wind power class at 200 meters above ground. Images *A*, *B*, and *C* were created by the U.S. Fish and Wildlife Service.

The newest anthropogenic change to the landscape is the proliferation of energy development, especially wind facilities. Wind-resource potential is very high in North and South Dakota, and the construction of wind facilities is expected to continue.

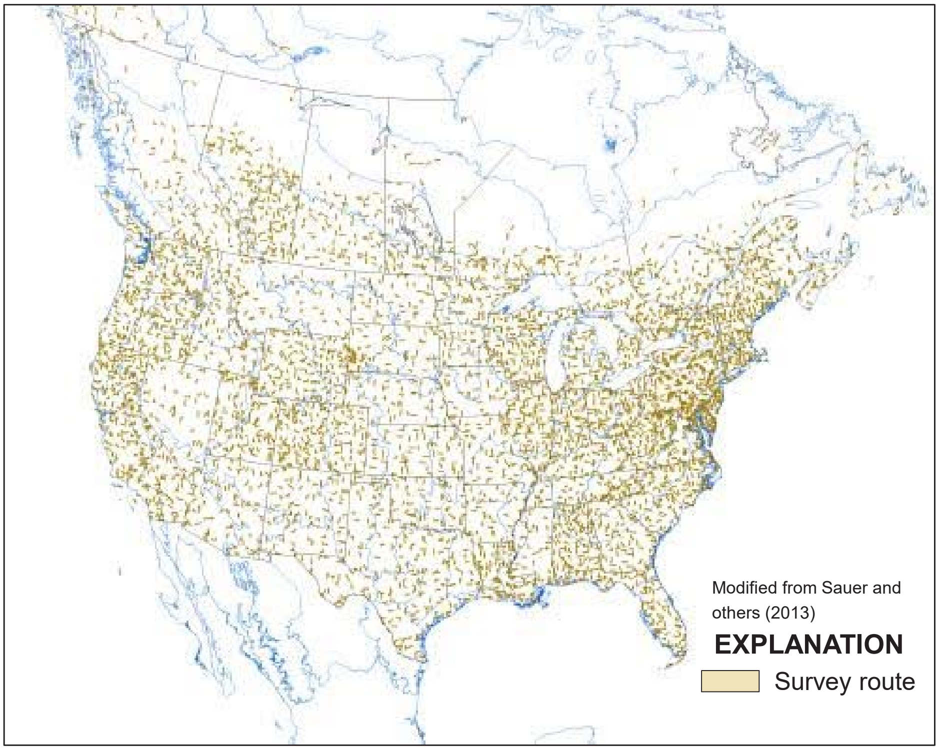
Prairie Pothole Region has highest richness of grassland bird species in North America



The proliferation of energy development is a concern because this area of the Northern Great Plains, the Prairie Pothole Region, is important to many species of wildlife. Not only is the region the “duck factory of North America” (Lynch, 1984), but as this map shows, this area also has the highest richness of grassland bird species in North America (Peterjohn and Sauer, 1999). Therefore, this area could justifiably also be called the “grassland bird factory of North America.” However, grassland birds have experienced steeper, more consistent, and more widespread population declines than any other bird group in North America. The map image is modified from Peterjohn and Sauer (1999).

North American Breeding Bird Survey

Volunteer-run routes, 50 stops per route; 3 countries

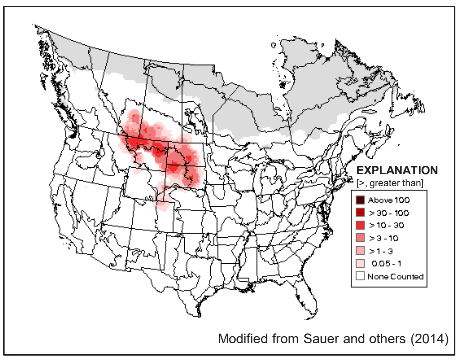


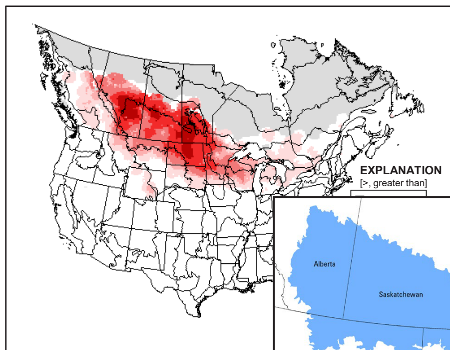
For grassland bird species, the breeding ranges and population trends are based on data collected by the North American Breeding Bird Survey, which is a roadside survey of breeding birds that was started in 1966 (Sauer and others, 2013). It is based on counts; run by volunteers; and conducted in the United States, Canada, and—since 2008—Mexico. Because of its scope and longevity, Breeding Bird Survey data provide an unparalleled source of information on spatial and temporal patterns of population change for North American birds. The map image is modified from Sauer and others (2013).

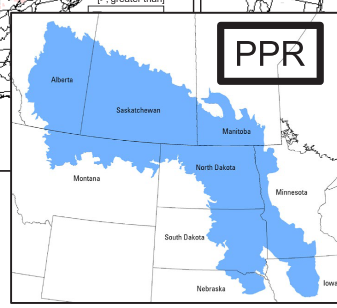
Chestnut-collared Longspur
Calcarius ornatus

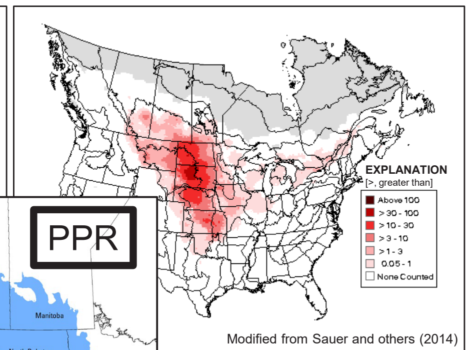
Clay-colored Sparrow
Spizella pallida

Upland Sandpiper
Bartramia longicauda

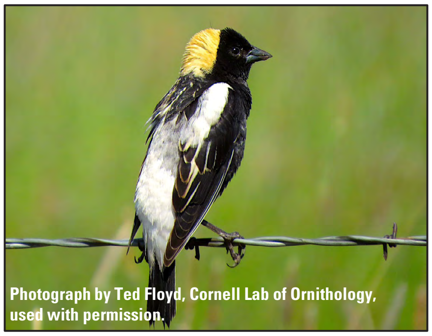




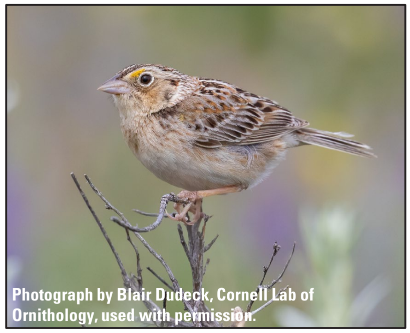




In Shaffer and Buhl (2016), nine grassland bird species were evaluated for their response to wind infrastructure. Loesch and others (2013) evaluated five species of waterfowl. The breeding ranges and population trends of these focal species will be described on the following pages. The nine focal grassland bird species are presented in order of the degree of endemism to the Prairie Pothole Region (PPR; that is, highest-to-lowest degree of endemism). The maps show Bird Conservation Regions (North American Bird Conservation Initiative, 2000), with the inset map highlighting the Prairie Pothole Region. The maps depict the average number of individuals detected per North American Breeding Bird Survey route per year, 2008–12, thus indicating where a species is most abundant and where core areas are located (Sauer and others, 2014). The grasslands within the Prairie Pothole Region harbor high abundances of the three species featured on this page. Of these three species, the ranges of the chestnut-collared longspur (*Calcarius ornatus*) and clay-colored sparrow (*Spizella pallida*) are primarily within the Prairie Pothole Region, whereas the range of the upland sandpiper (*Bartramia longicauda*) extends further south.

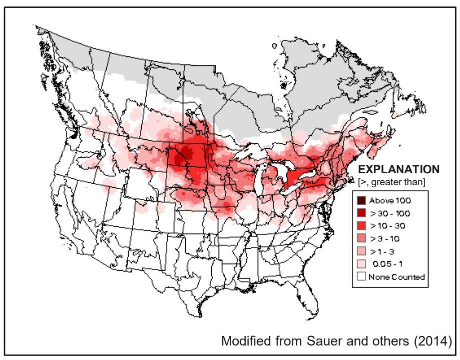


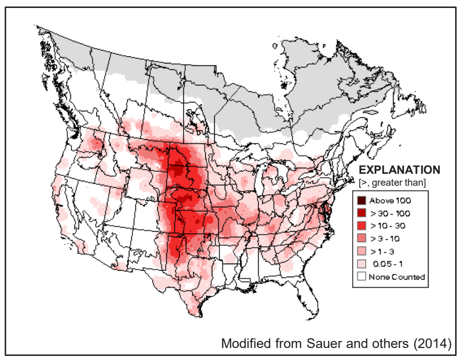
Bobolink
Dolichonyx oryzivorus

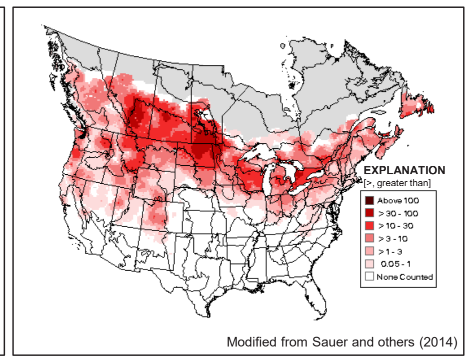


Grasshopper Sparrow
Ammodramus savannarum

Savannah Sparrow
Passerculus sandwichensis







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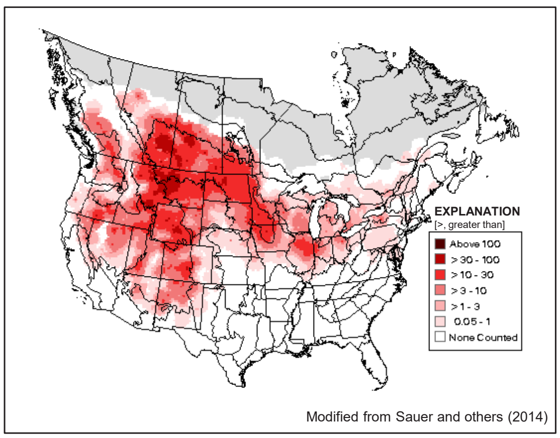
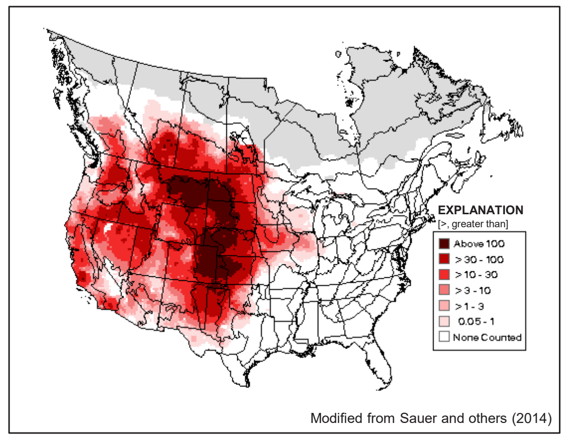
These three species have broader ranges than the three bird species depicted in the previous image. Portions of the Prairie Pothole Region still constitute the core of the ranges for the bobolink (*Dolichonyx oryzivorus*) and the Savannah sparrow (*Passerculus sandwichensis*), whereas the core of the grasshopper sparrow (*Ammodramus savannarum*) range is just south of the Prairie Pothole Region. The maps show Bird Conservation Regions (North American Bird Conservation Initiative, 2000). The maps depict the average number of individuals detected per North American Breeding Bird Survey route per year, 2008–12, thus indicating where a species is most abundant and where core areas are located (Sauer and others, 2014).

Vesper Sparrow
Pooecetes gramineus

Western Meadowlark
Sturnella neglecta





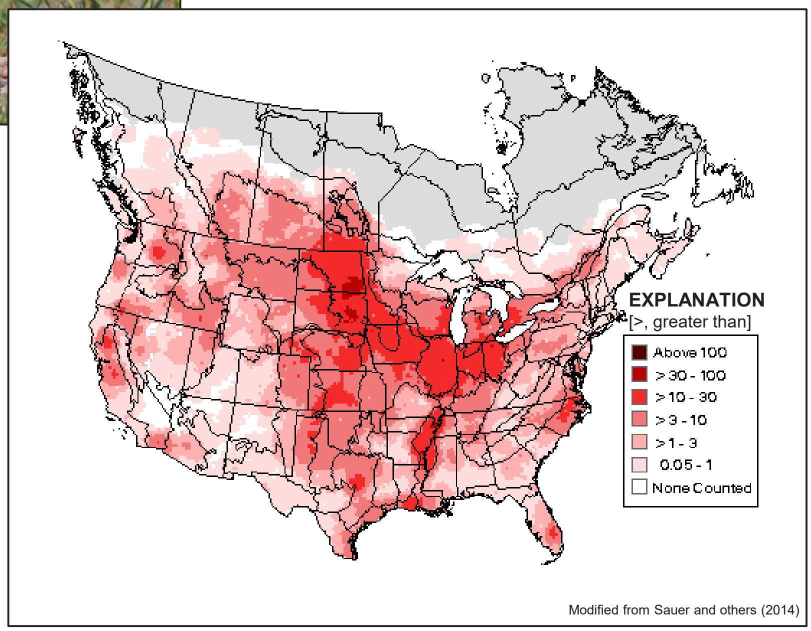
The vesper sparrow (*Pooecetes gramineus*) and the western meadowlark (*Sturnella neglecta*) have even broader ranges than the bird species depicted in the previous images, but the grasslands within the Prairie Pothole Region are still an important resource. The maps show Bird Conservation Regions (North American Bird Conservation Initiative, 2000). The maps depict the average number of individuals detected per North American Breeding Bird Survey route per year, 2008–12, thus indicating where a species is most abundant and where core areas are located (Sauer and others, 2014).

Photograph by Davey Walters, Cornell Lab of Ornithology, used with permission.

Killdeer

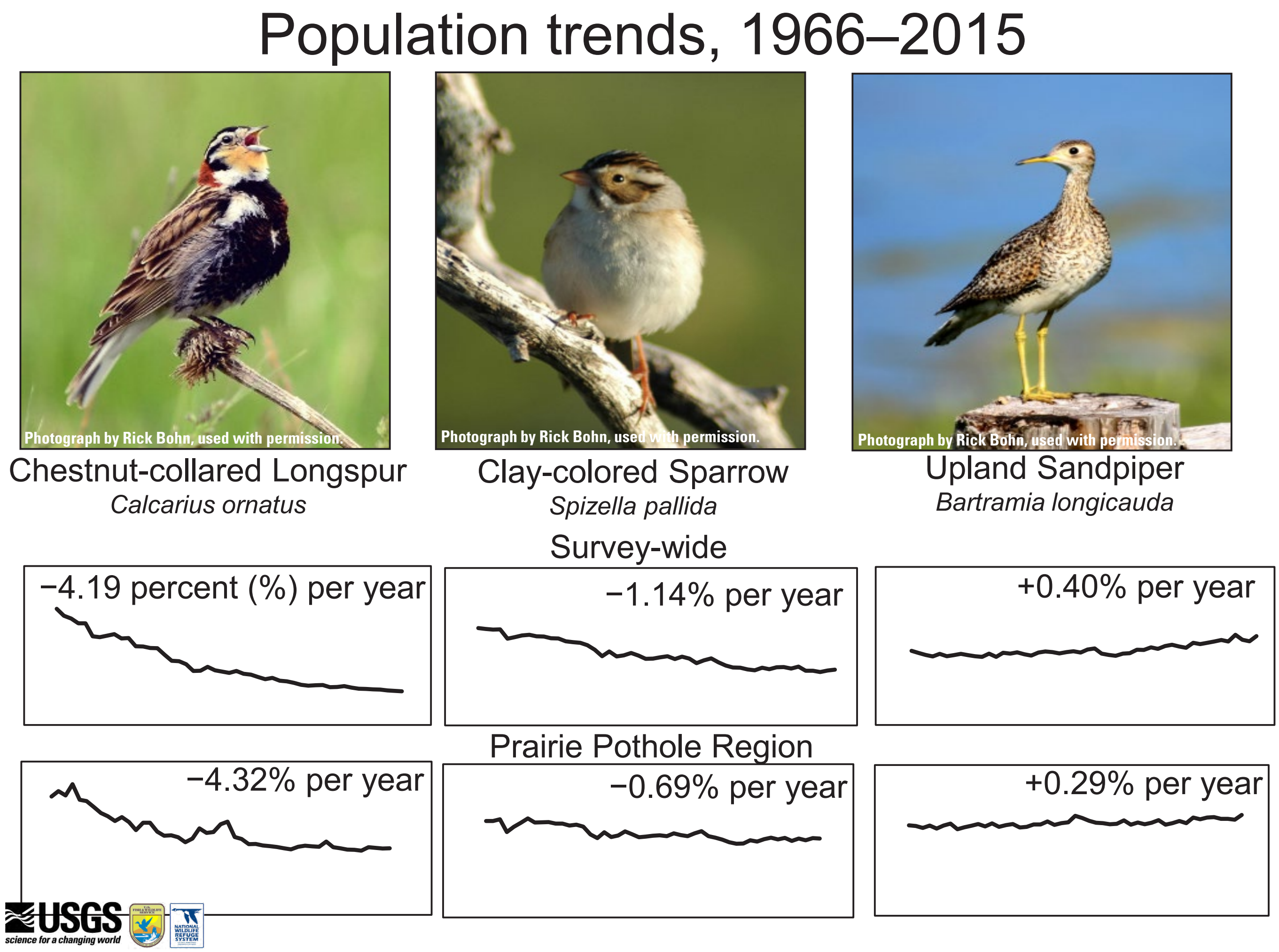
Charadrius vociferous

Generalist species

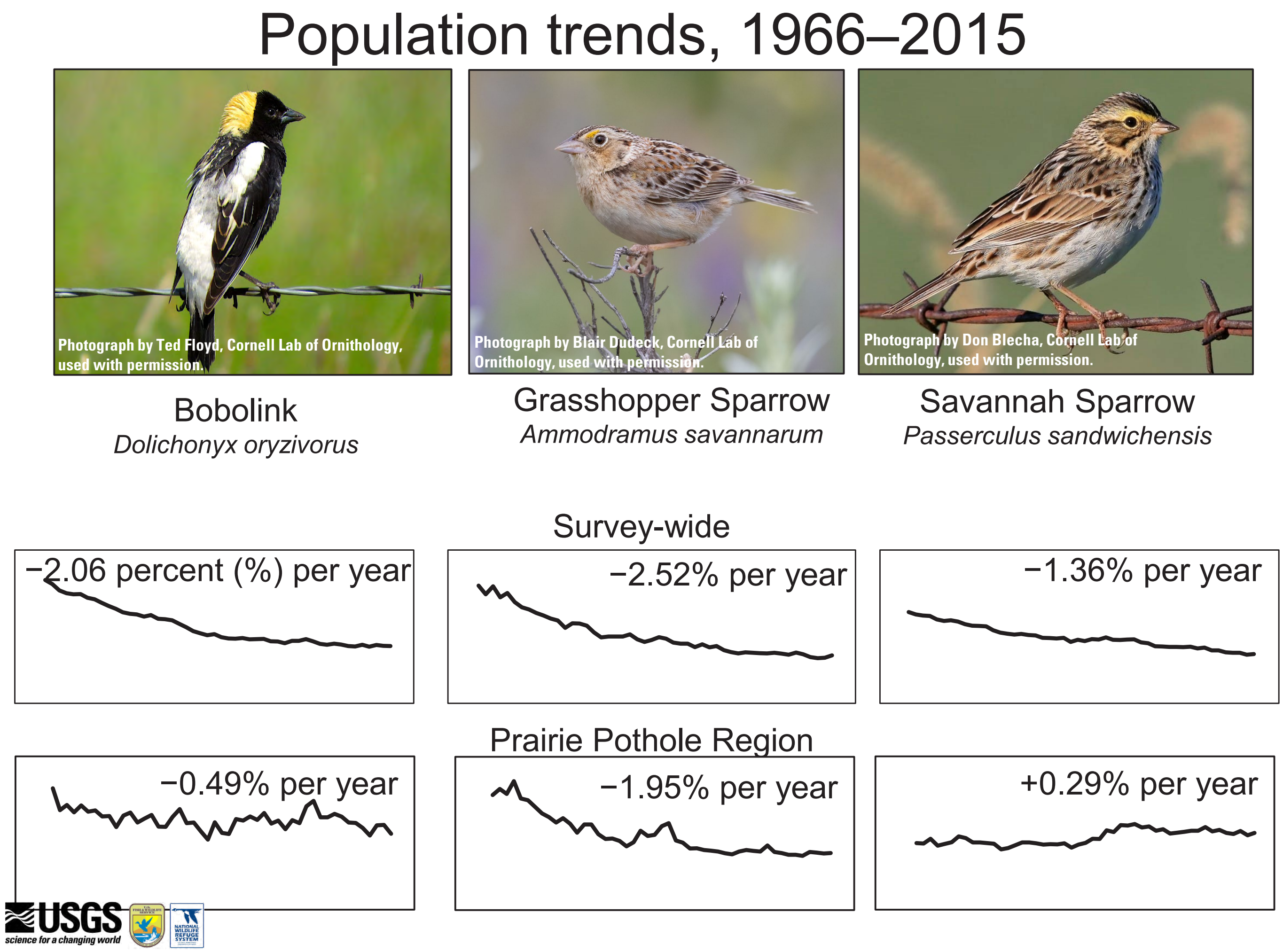


Modified from Sauer and others (2014)

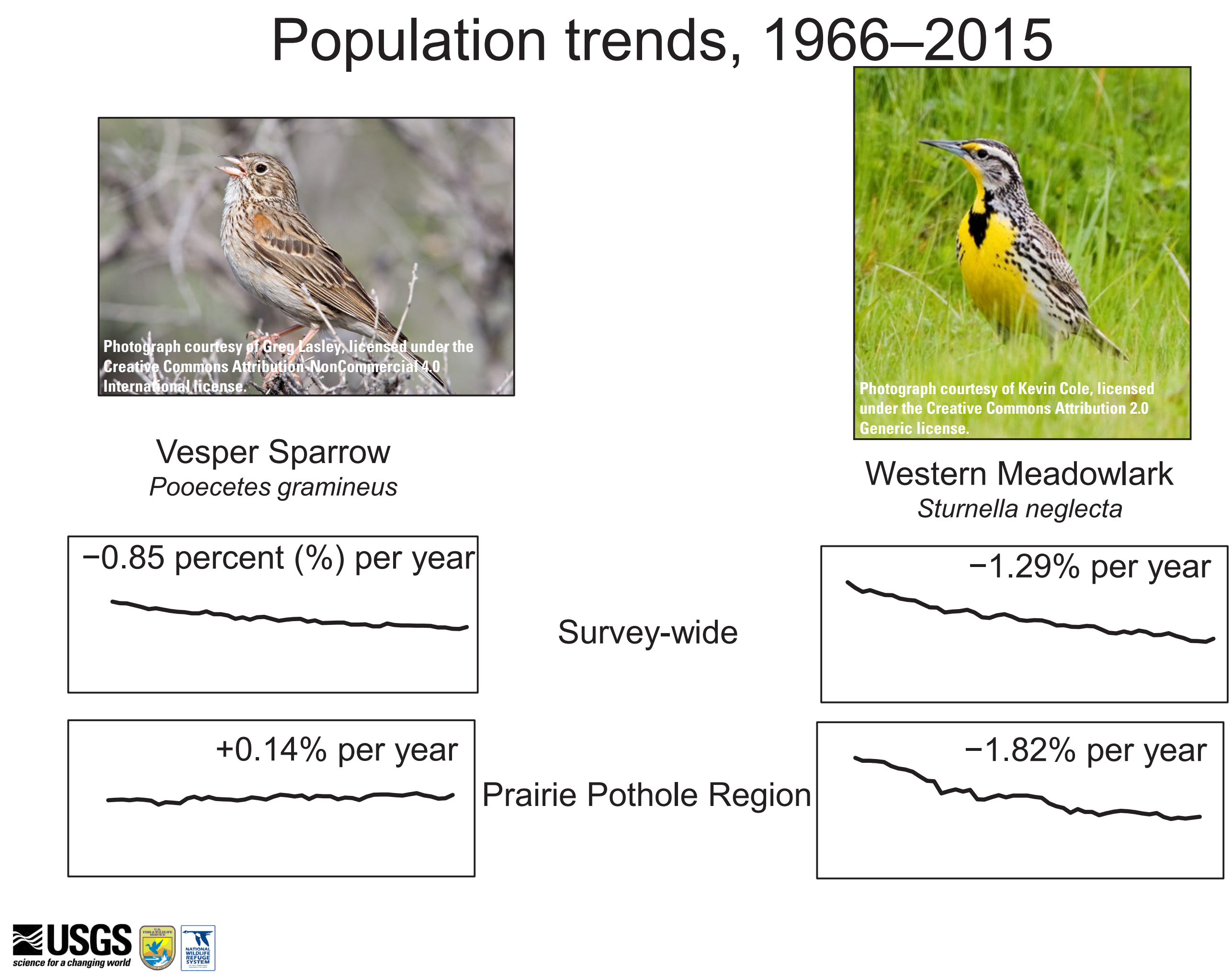
The killdeer (*Charadrius vociferus*) is a grassland species, although not a grassland-obligate species as are the other eight species. The core of the killdeer breeding range is within the Prairie Pothole Region. The map shows Bird Conservation Regions (North American Bird Conservation Initiative, 2000). The map depicts the average number of individuals detected per North American Breeding Bird Survey route per year, 2008–12, thus indicating where a species is most abundant and where core areas are located (Sauer and others, 2014).



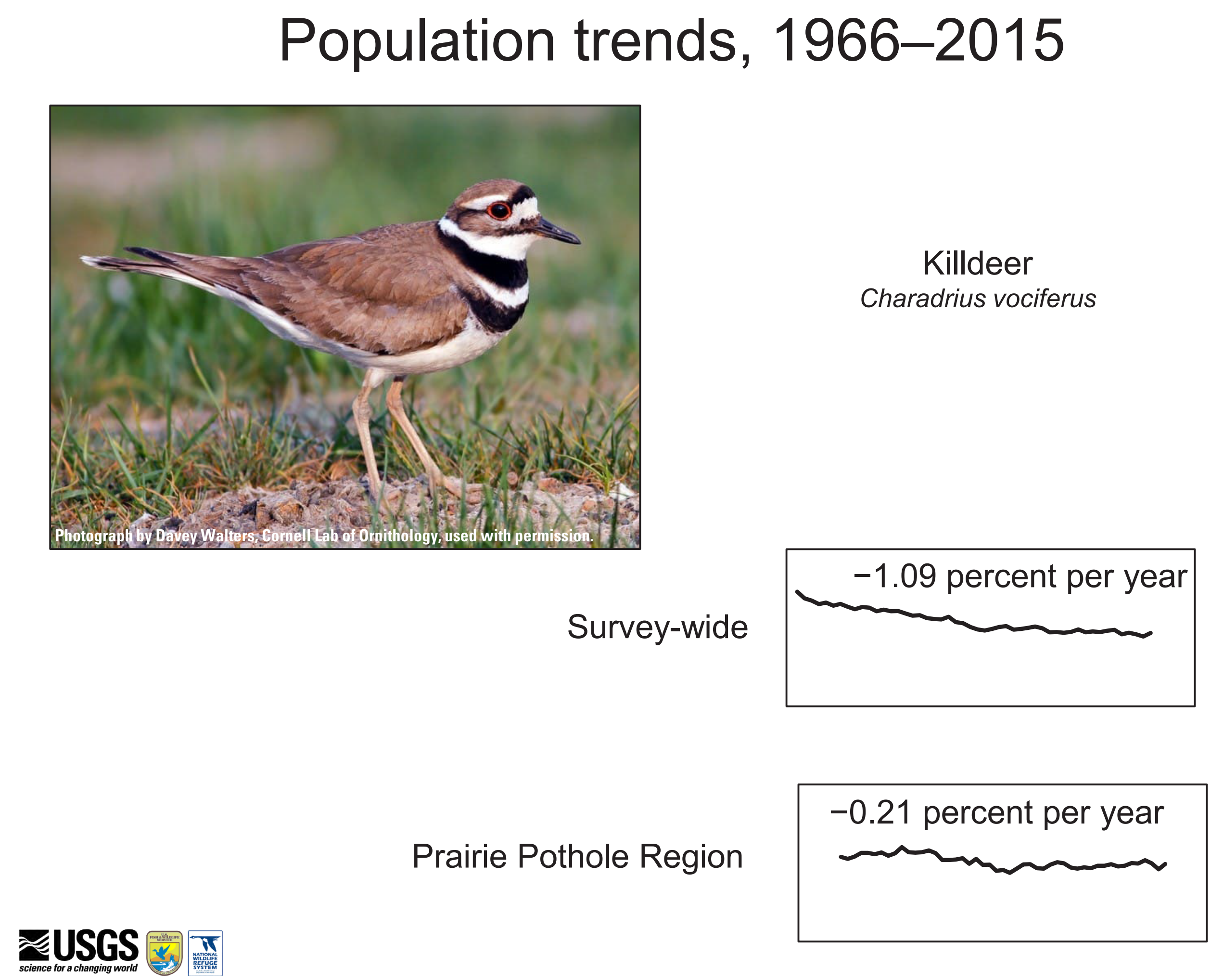
An examination of population trends shows that the chestnut-collared longspur and the clay-colored sparrow exhibit long-term, persistent decreases, whereas the upland sandpiper exhibits a small increase. For those species whose ranges are largely contained within the Prairie Pothole Region, the national and regional trends are similar (data derived from a raw dataset from Pardieck and others, 2020). Note the prevalence of negative population trends and especially that the chestnut-collared longspur, whose range is primarily within the Prairie Pothole Region, has a strong downward population trend.



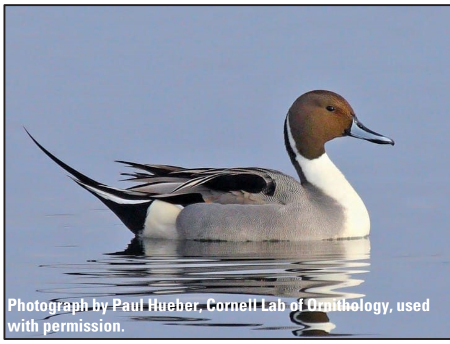
Similar to the population trends of the species in the previous image, the population trends for the three species on this image are also negative, except for the Savannah sparrow in the Prairie Pothole Region.



The population trend of the vesper sparrow shows a slight upward trend in the Prairie Pothole Region, in contrast to the western meadowlark, which is experiencing a greater downward population trend regionally than nationally.



Similar to population trends seen for most of the grassland bird species in this study, population trends of the killdeer are also in decline in both the Prairie Pothole Region and nationally.



Photograph by Paul Hueber, Cornell Lab of Ornithology, used with permission.

Photograph by Jay McGowan, Cornell Lab of Ornithology, used with permission.

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Northern Pintail
Anas acuta

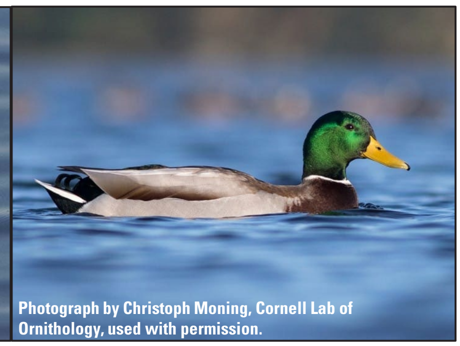
Blue-winged Teal
Spatula discors

Northern Shoveler
Spatula clypeata

Gadwall
Mareca strepera

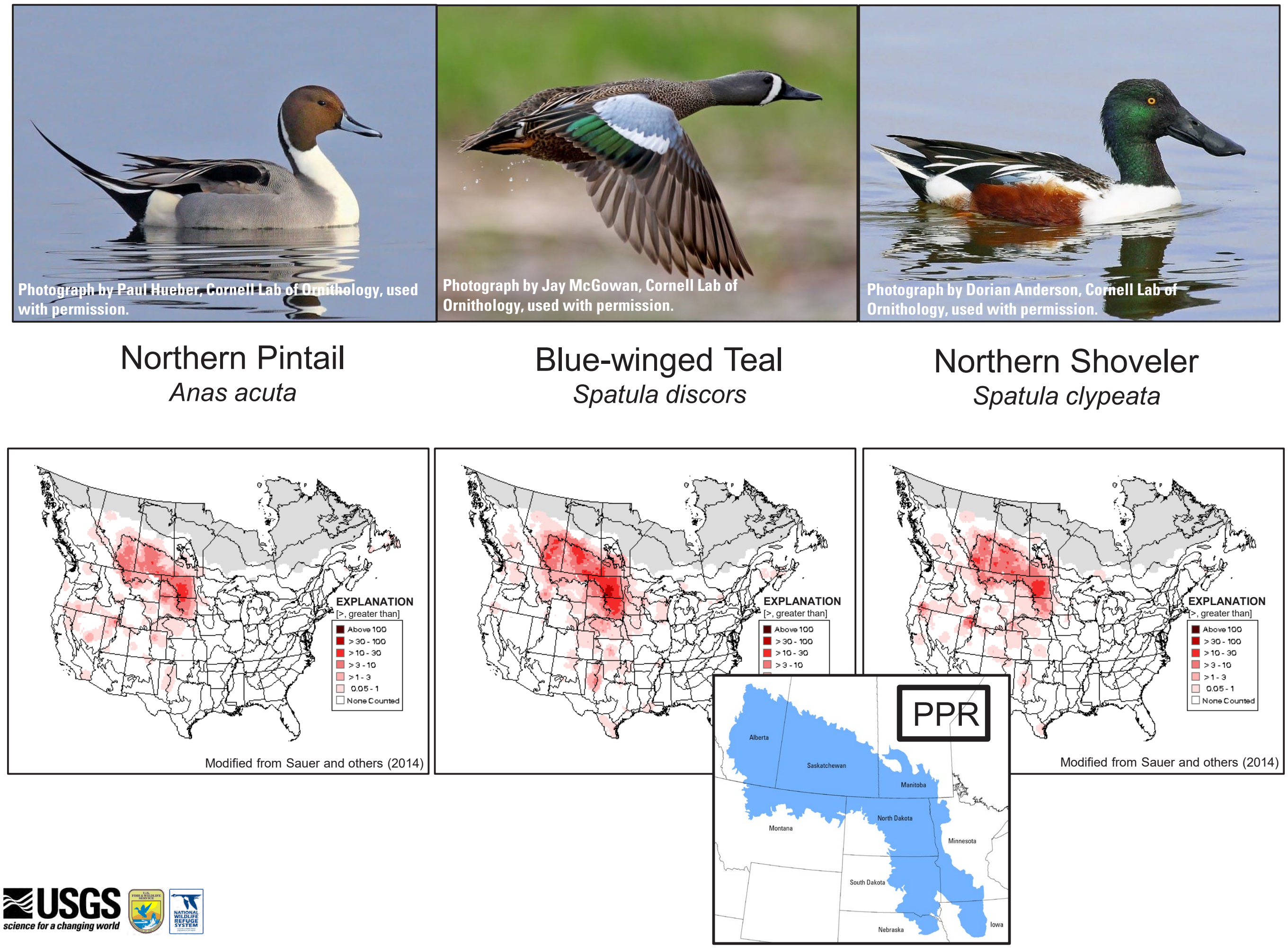
Mallard
Anas platyrhynchos

Photograph courtesy of Alan Wilson, licensed under the Creative Commons Attribution-3.0 license.

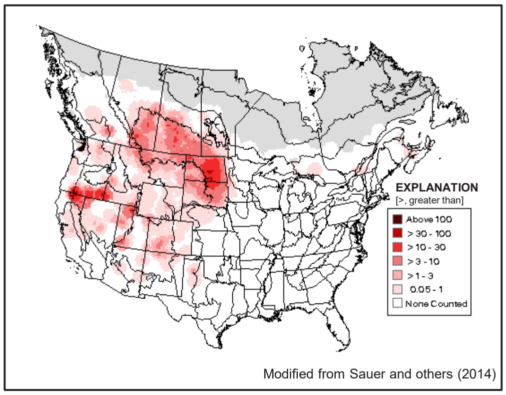


Photograph by Christoph Moning, Cornell Lab of Ornithology, used with permission.

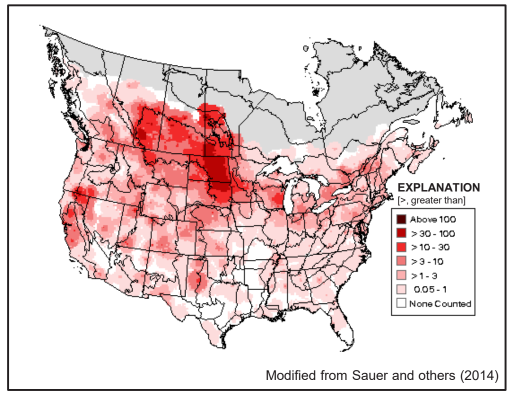
Loesch and others (2013) investigated the impact of wind facilities on five species of dabbling ducks. These species are produced in large numbers in the Prairie Pothole Region. Waterfowl are not experiencing the same long-term declines as grassland birds, but waterfowl are valuable for their recreational and economic value. Waterfowl hunters provide substantial funding for habitat acquisition and management through purchases of the Federal Duck Stamp, State license sales, and excise taxes on arms and ammunition (North American Waterfowl Management Plan, 2012). Thus, waterfowl species are important not only as huntable game but also as primary drivers of conservation funding in the Prairie Pothole Region (North American Waterfowl Management Plan, 2012).



Most young of these three species are produced in the Prairie Pothole Region (PPR).



Modified from Sauer and others (2014)

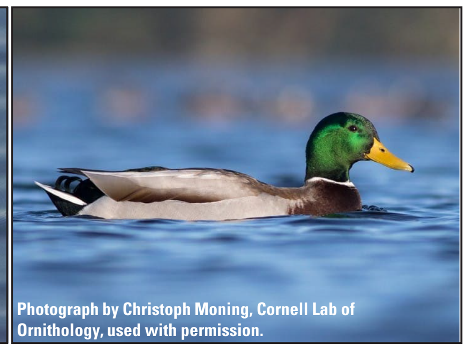


Modified from Sauer and others (2014)

Gadwall
Mareca strepera

Mallard
Anas platyrhynchos


Photograph courtesy of Alan Wilson, licensed under the Creative Commons Attribution-3.0 license.


Photograph by Christoph Moning, Cornell Lab of Ornithology, used with permission.

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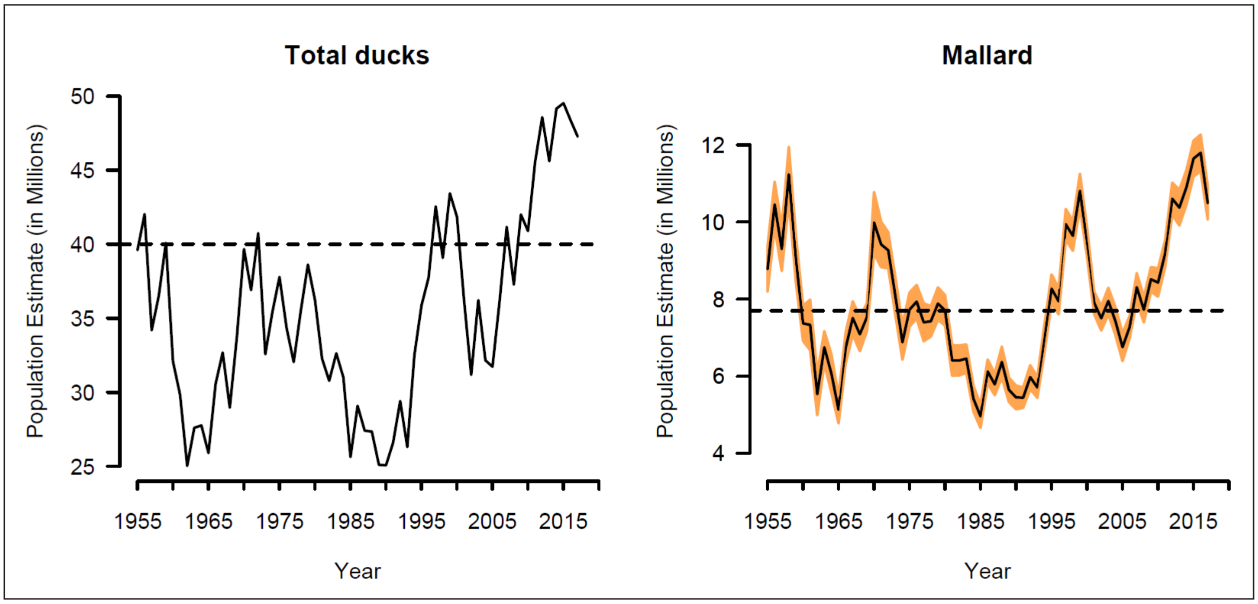
The gadwall (*Mareca strepera*) and the mallard (*Anas platyrhynchos*) have a broader range than the three waterfowl species shown in the previous image, but the Prairie Pothole Region forms the core of their respective ranges.

Population trends, 1955–2015



Graphs excerpted from Figure 3 in Zimpfer and others, 2015

Although the North American Breeding Bird Survey monitors the population trends of waterfowl species, more localized annual surveys are conducted by the U.S. Fish and Wildlife Service and the Canadian Wildlife Service. The results of these surveys typically are used for monitoring population trends of waterfowl. The population trends reported in Zimpfer and others (2015) indicate that, in general, waterfowl are faring well in the Prairie Pothole Region.

Section 1 Summary

The Prairie Pothole Region (PPR) is a highly important and productive area for grassland birds and waterfowl.

Prairie ecosystems within the PPR are endangered owing to conversion, primarily to agricultural uses, that has occurred over decades.

Many populations of grassland birds with core breeding areas within the PPR are declining.

Waterfowl populations are stable and are important in bringing in conservation dollars through the sale of duck stamps.

Energy-conversion facilities, such as wind, represent a contemporary anthropogenic impact on native ecosystems and wildlife.

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After completing Section 1, take a moment to reflect on the contents.

Section 2—Displacement Research

The objective of Shaffer and Buhl (2016) was to determine whether grassland birds exhibited behavioral displacement owing to wind facilities. Loesch and others (2013) examined this question for waterfowl. Displacement is defined as the decrease in density of breeding pairs of grassland birds and waterfowl as measured over distance from energy infrastructure. Shaffer and Buhl (2016) employed a before-after-control-impact study design. Although the before-after-control-impact study is considered to be an optimal design for strong inference assessments, it is a difficult design to implement in practice because of the difficulty in obtaining the "before" (that is, pretreatment) data. The research by Loesch and others (2013) illustrates an alternative approach that employs a concurrent-year, paired-reference (that is, control) site approach.

Section 2

Section 2 provides information on the study design, field and statistical methods, and research results of Loesch and others (2013), Shaffer and Buhl (2016), and Shaffer and others (2019).

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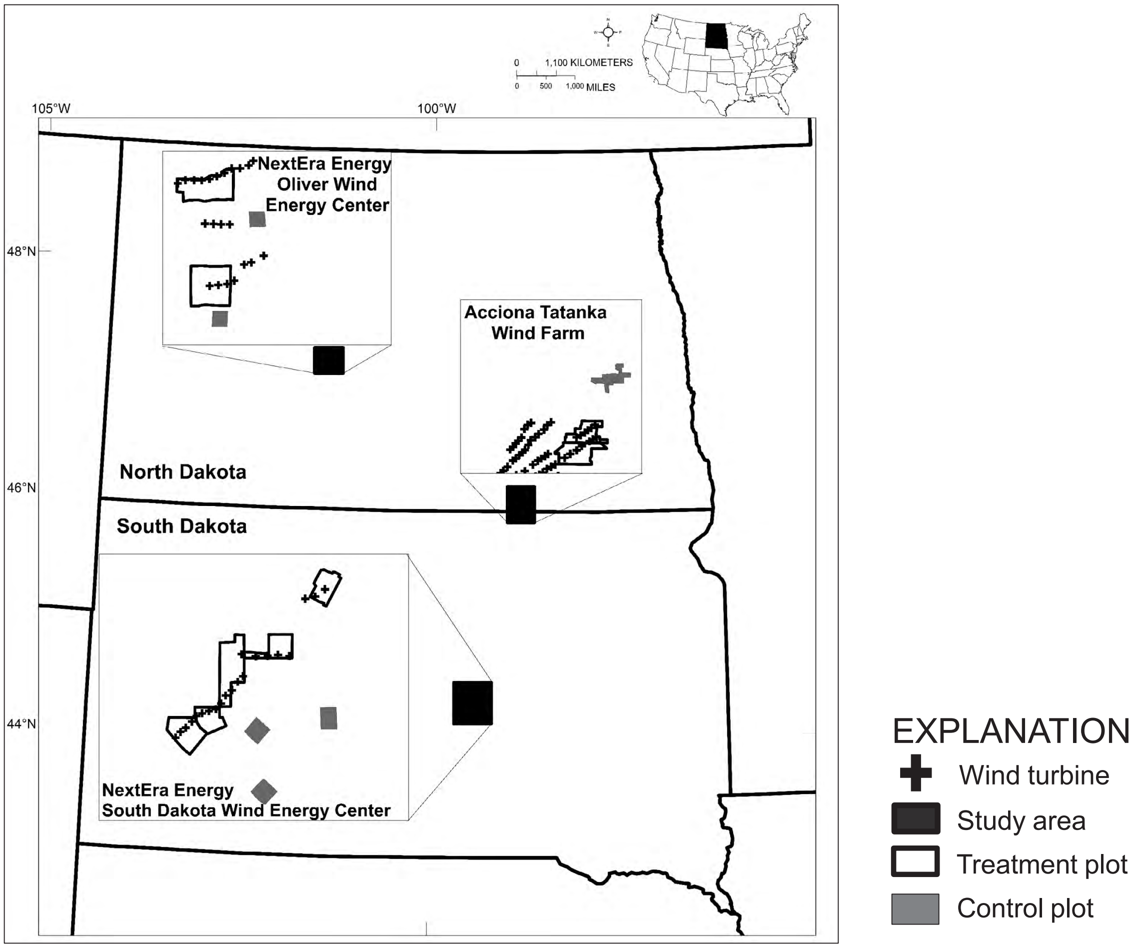
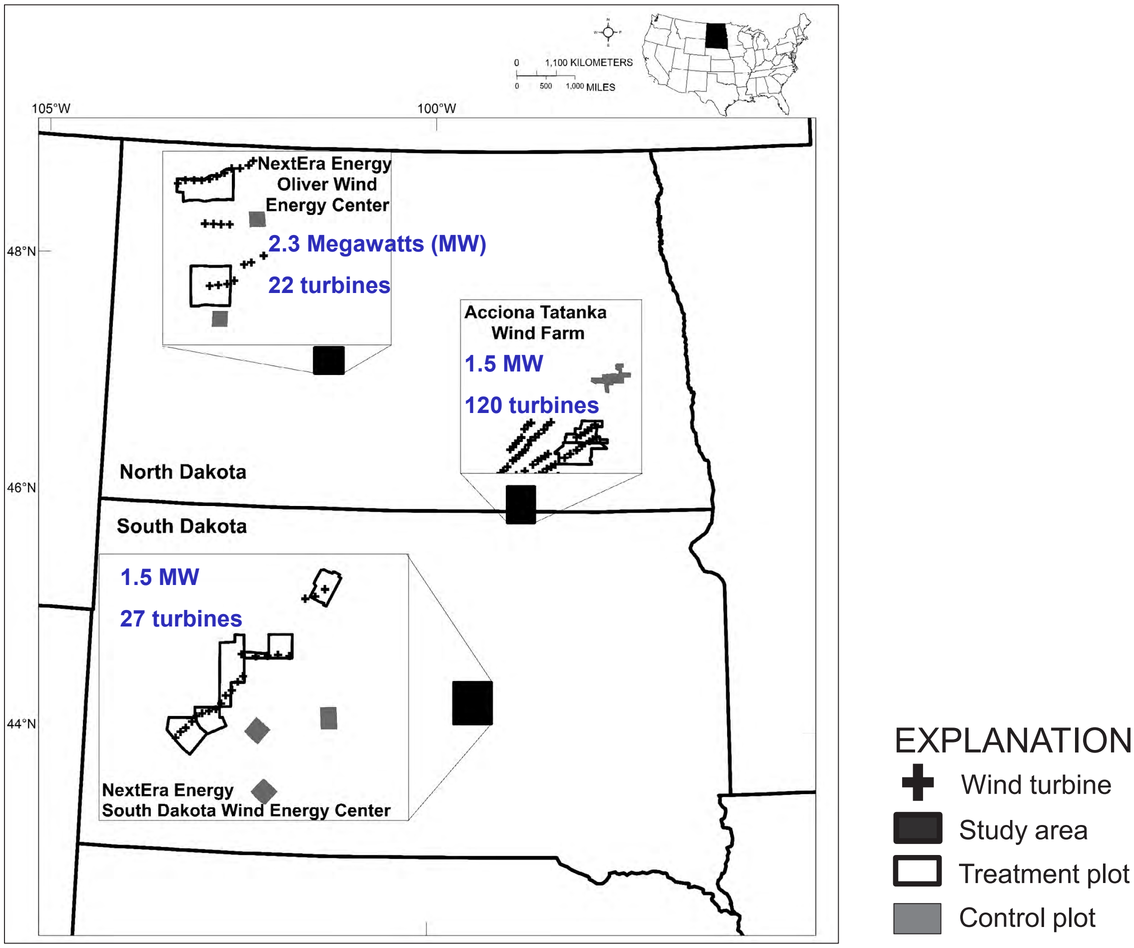
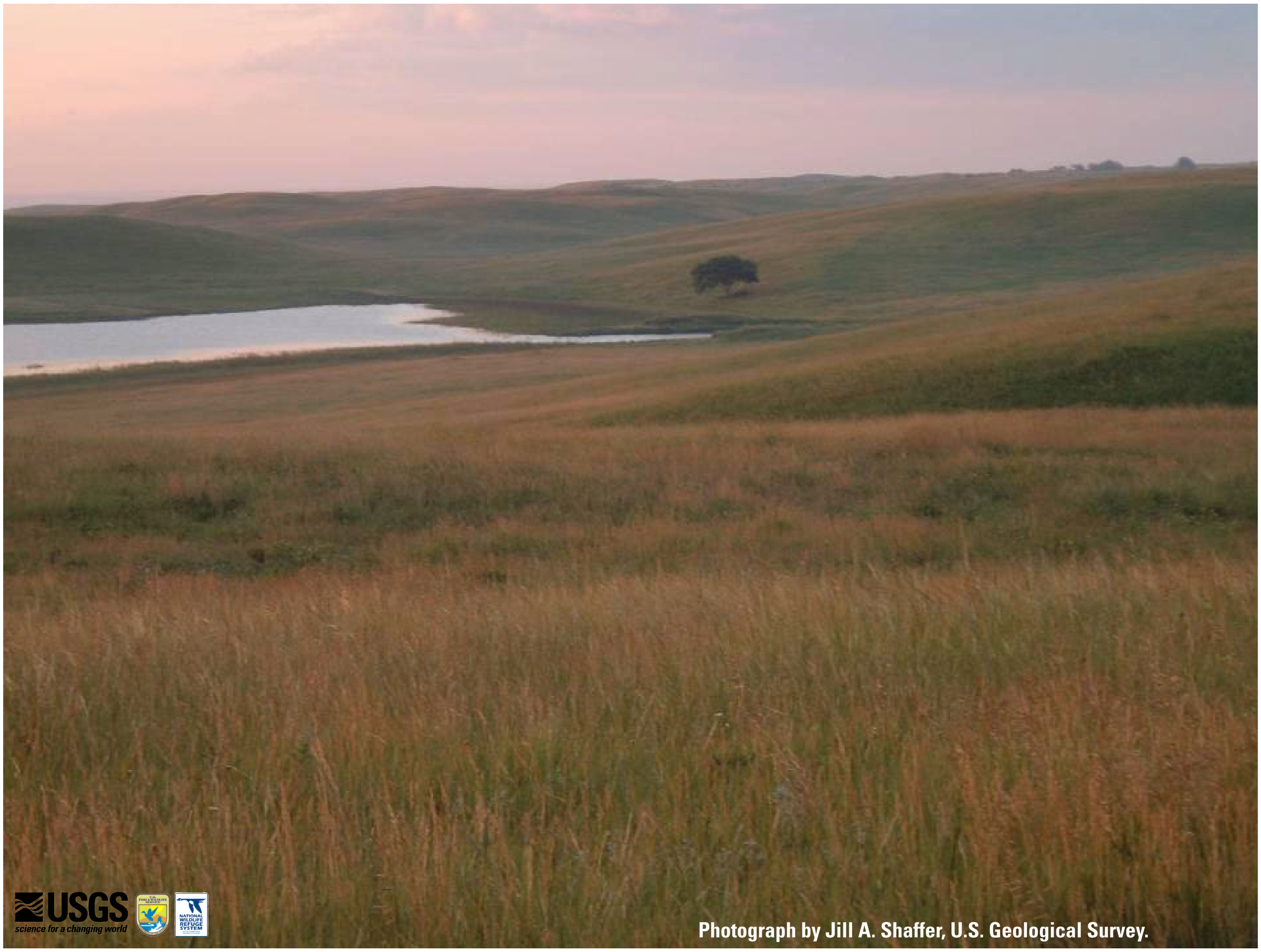
The before-after-control-impact study design, methods, and results will be discussed for the Shaffer and Buhl (2016) report, to be followed by the study design, methods, and results for the Loesch and others (2013) paper.



The displacement research of Shaffer and Buhl (2016) occurred at three wind facilities: NextEra Energy's Oliver Wind Energy Center in west-central North Dakota, their South Dakota Wind Energy Center in central South Dakota, and Acciona's Tatanka Wind Farm that straddles the two States. The map image is modified from Shaffer and Buhl (2016) and used with permission.



The two NextEra Energy facilities had a similar number of wind turbines. Although Acciona's Tatanka facility had 120 turbines, only turbines on the North Dakota side of this two-State facility were incorporated into the study. The map image is modified from Shaffer and Buhl (2016) and used with permission.



Photograph by Jill A. Shaffer, U.S. Geological Survey.

All three wind facilities were built in mixed-grass prairie, and all study areas were grazed by cattle; thus, land use was consistent. Analyses on vegetation structure indicated no significant differences between turbine (that is, the impact or treatment areas) and control (that is, reference) sites at each wind facility.

This photograph shows an aerial view of the Tatanka Wind Farm straddling the North Dakota and South Dakota State lines.

Before-After-Control-Impact (BACI)

Before: Before turbines are
(Pre) constructed, survey birds in areas where turbines will be constructed and in control areas where turbines will not be constructed

After: Conduct surveys in the same
(Post) locations in the years after construction

Photographs by Jill A. Shaffer, U.S. Geological Survey.

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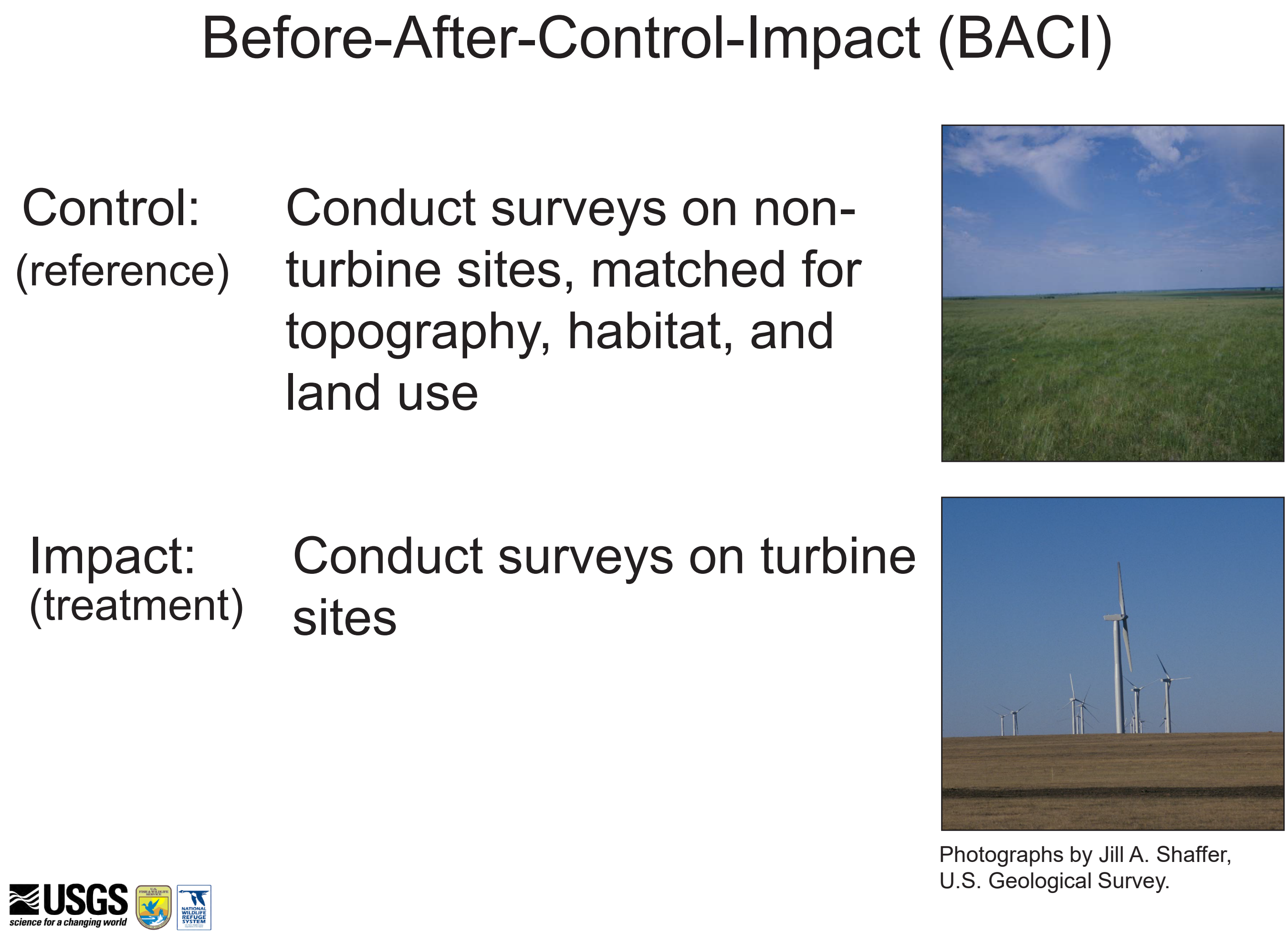
For observational studies, the before-after-control-impact (BACI) design is considered the optimal study design and is the preferred method to determine displacement of wildlife from wind facilities. A BACI design allows researchers to account for differences in bird abundance that may exist prior to turbine construction between areas slated for future construction of wind turbines (that is, the impact or treatment areas) and control (that is, reference) areas not slated for construction. Although differences in abundance may persist after turbine construction, the history of abundance prior to construction provides information that could indicate that differences after construction may not be owing to the wind facility. For example, a decline in bird abundance might be related to a degradation in habitat quality following a year of drought. The BACI design allows these naturally occurring differences to be separated from differences owing to turbine construction.

The “before-after” component of the BACI design means that bird surveys were conducted on areas slated for wind development before the wind-facility construction occurred (pretreatment), as well as on control areas not slated for any turbine construction (the pretreatment surveys constitute the ‘before’ portion of the BACI design). Bird surveys were conducted within the wind facility and control areas for several years after construction (the posttreatment surveys constitute the “after” portion of the BACI design).



Bird surveys were conducted on areas not slated for wind development (the "control" portion of the BACI design) as well as on areas within the wind facility (the "impact" portion), both prior to construction and for several years after construction.

Site	Before construction	After construction
Oliver Wind Energy Center	2006	2007, 2009, 2011
Acciona Wind Farm	2007	2009, 2010, 2012
South Dakota Wind Energy Center	2003	2004–2006 2008, 2010, 2012

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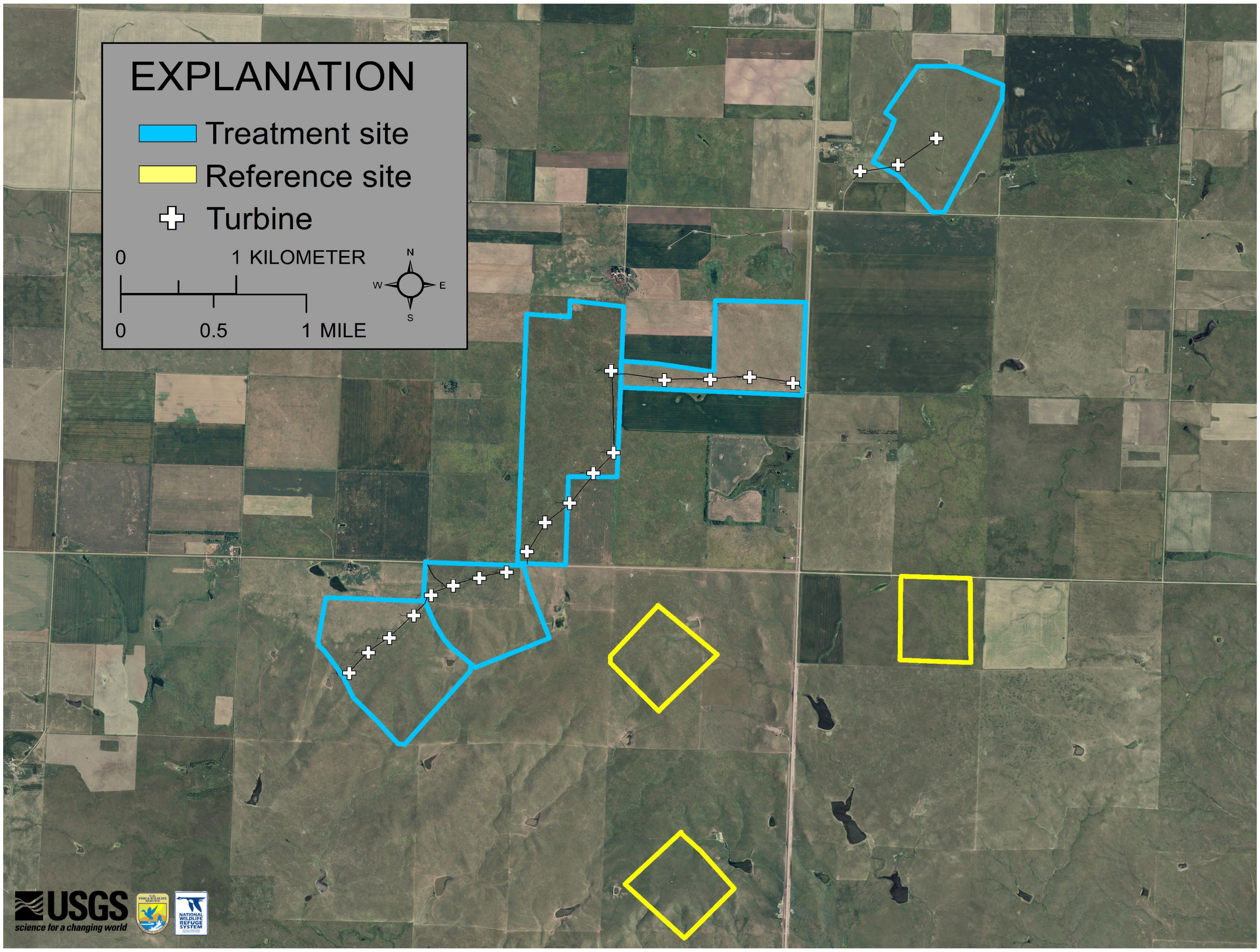
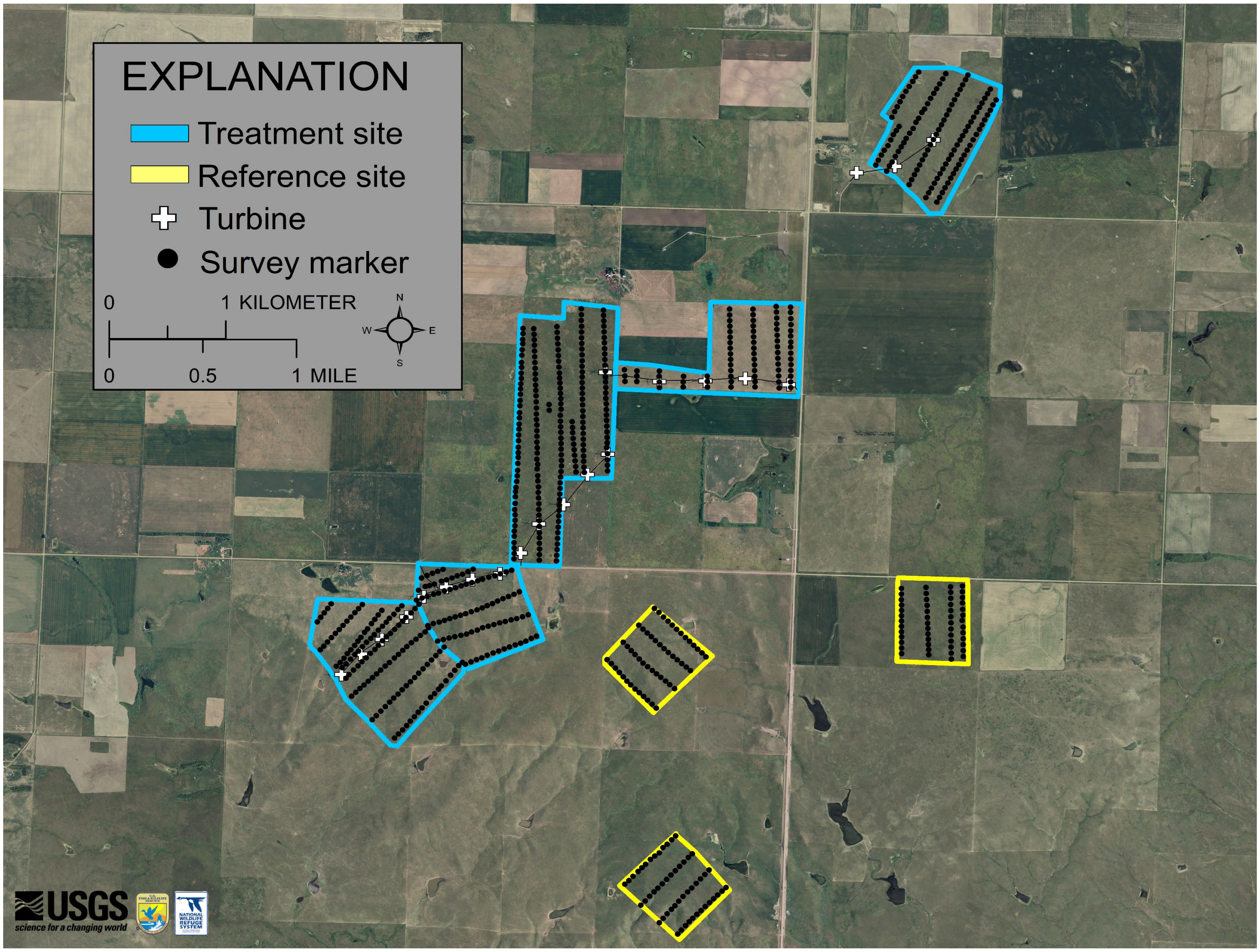
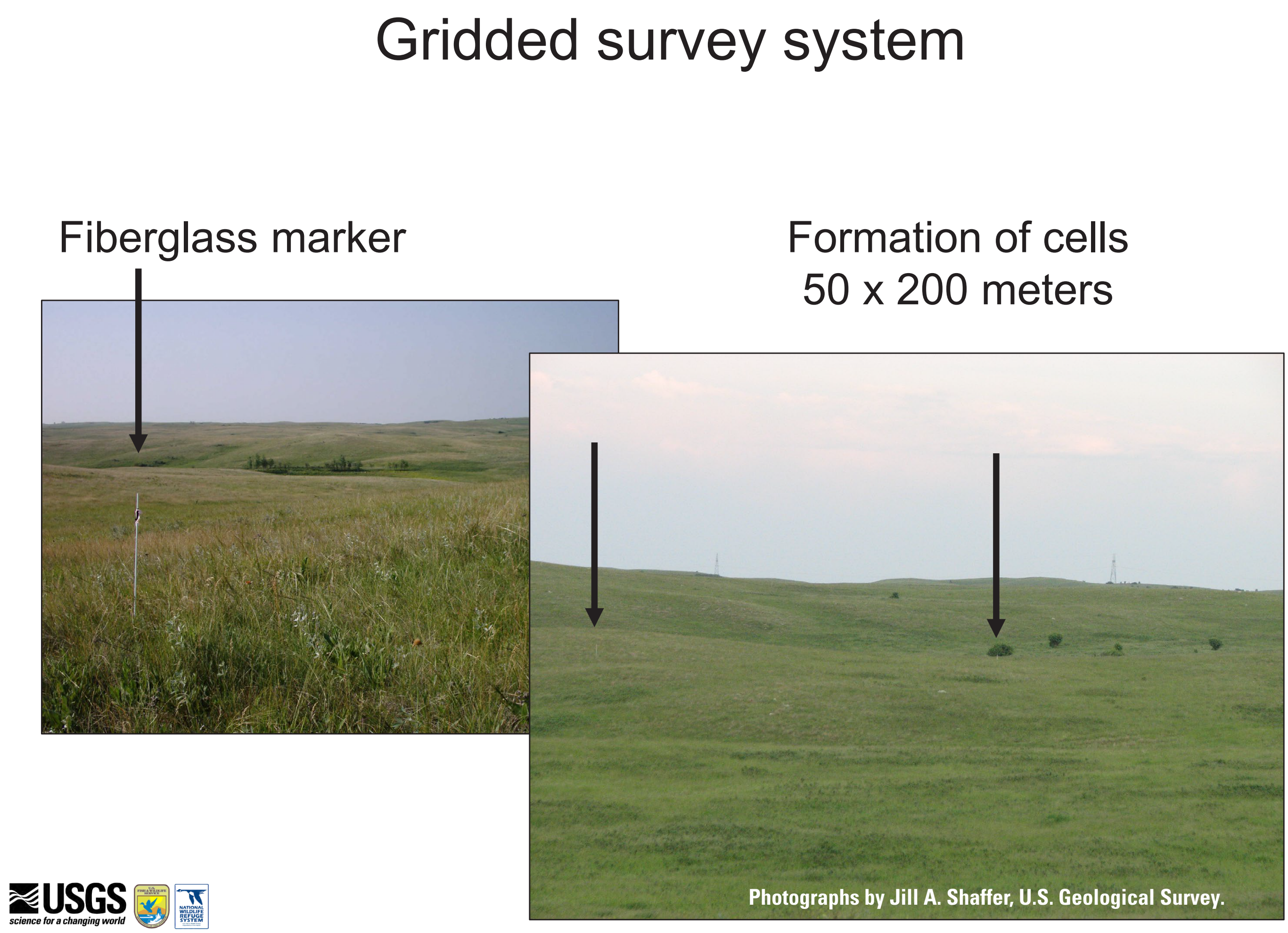
Data were gathered for 1 year at each wind facility prior to construction (the pretreatment year), and multiple years of data after construction (the posttreatment years). The "before" (or pretreatment) year was always the breeding season immediately prior to construction of the wind infrastructure. The "after" (or posttreatment) years were not always consecutive. At the Oliver Wind Energy Center and Acciona Wind Farm, there were three posttreatment years, whereas at the South Dakota Wind Energy Center, there were six posttreatment years.



This National Agriculture Imagery Program (U.S. Department of Agriculture, 2019) imagery shows NextEra Energy's South Dakota Wind Energy Center study area in Hyde County.

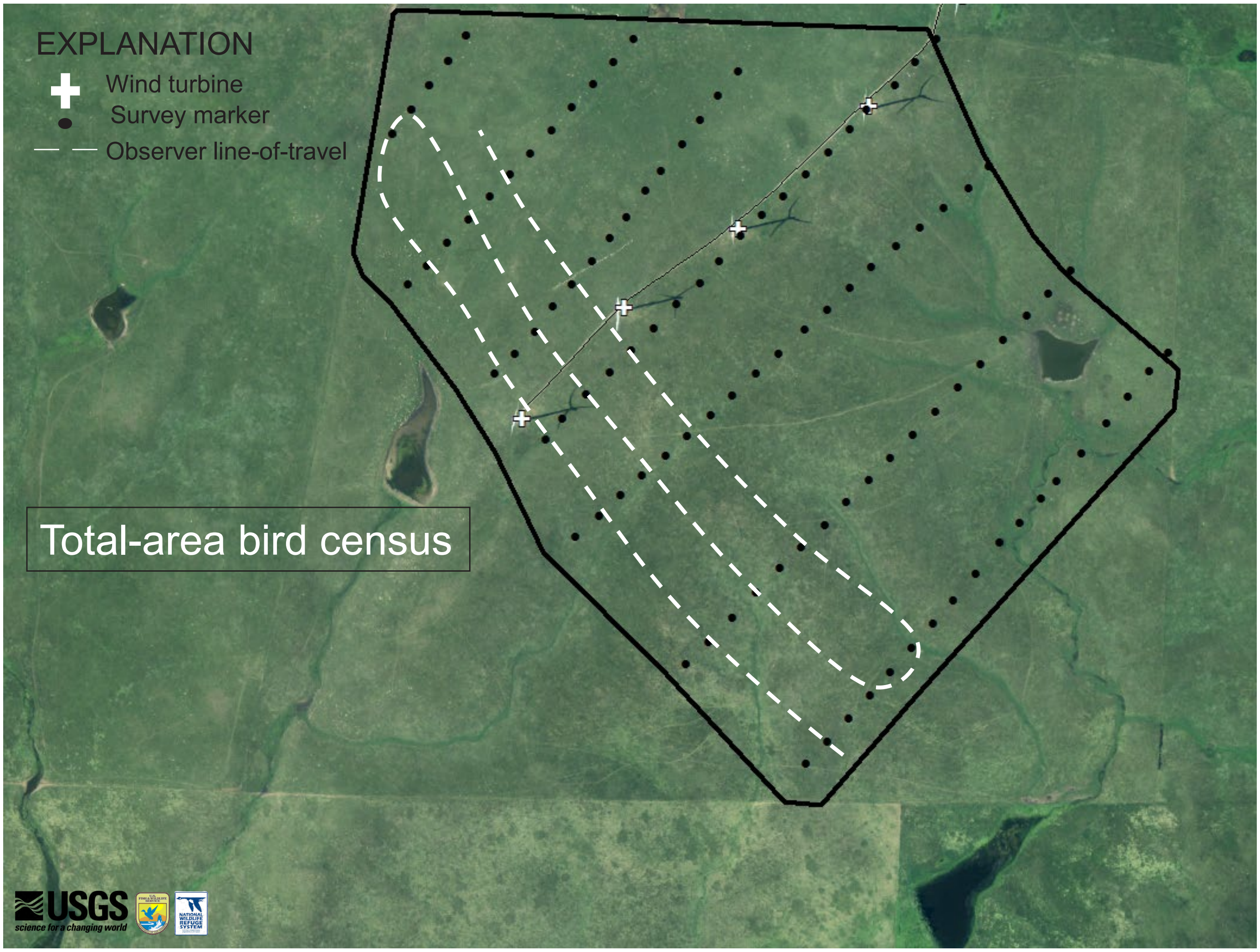


This National Agriculture Imagery Program (U.S. Department of Agriculture, 2019) imagery shows NextEra Energy's South Dakota Wind Energy Center study area in Hyde County with the addition of locations of fiberglass fence posts and survey markers that created a gridded system within each study plot.

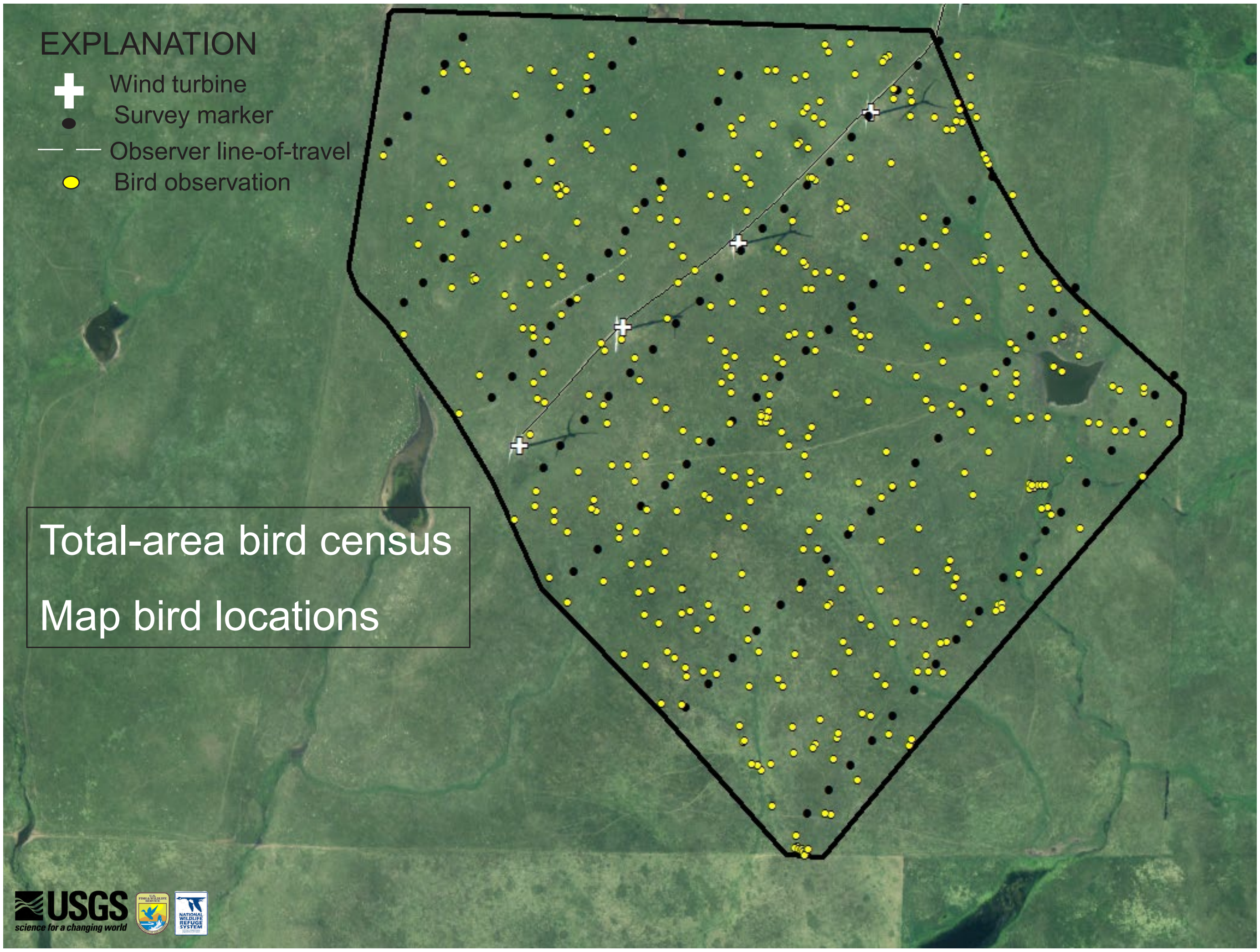


Gridded survey plots were established using fiberglass posts arranged in parallel lines spaced 200 meters (m) apart. Within a line, fiberglass posts were spaced 50 m apart. A detailed description of plot design is discussed in appendix 1. Line length, and therefore area of the census grid, varied based on habitat. The grid ended at an obvious change in land treatment (for example, a change from grazed mixed-grass prairie to cropland or hayland), or until the grid was 800 m (0.5 mile) from the turbine. Ends of lines were established using fiberglass survey markers. Grid-point coordinates were recorded using Global Positioning System Units. Vegetation was also measured within this gridded system to determine if there were differences in vegetation characteristics among study plots (appendix 1).

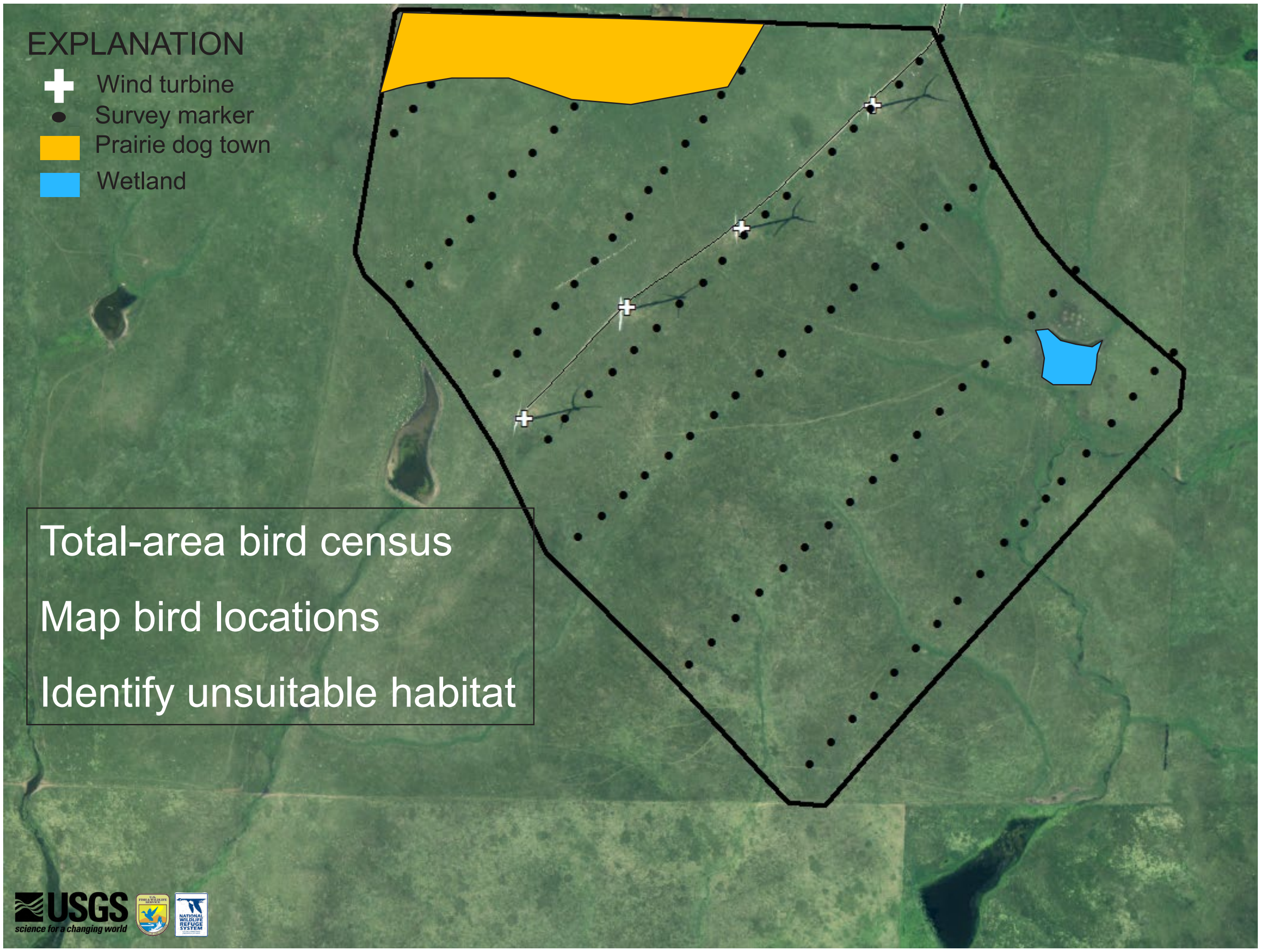
Transect lines were established 100 m apart perpendicular to the grid lines. Observers recorded all birds seen and heard within 50 m of transects. Observations were recorded on datasheets with National Agriculture Imagery Program (U.S. Department of Agriculture, 2019) images overlaid by grid and turbine locations. Datasheets were made that reflected the size and shape of each census grid.



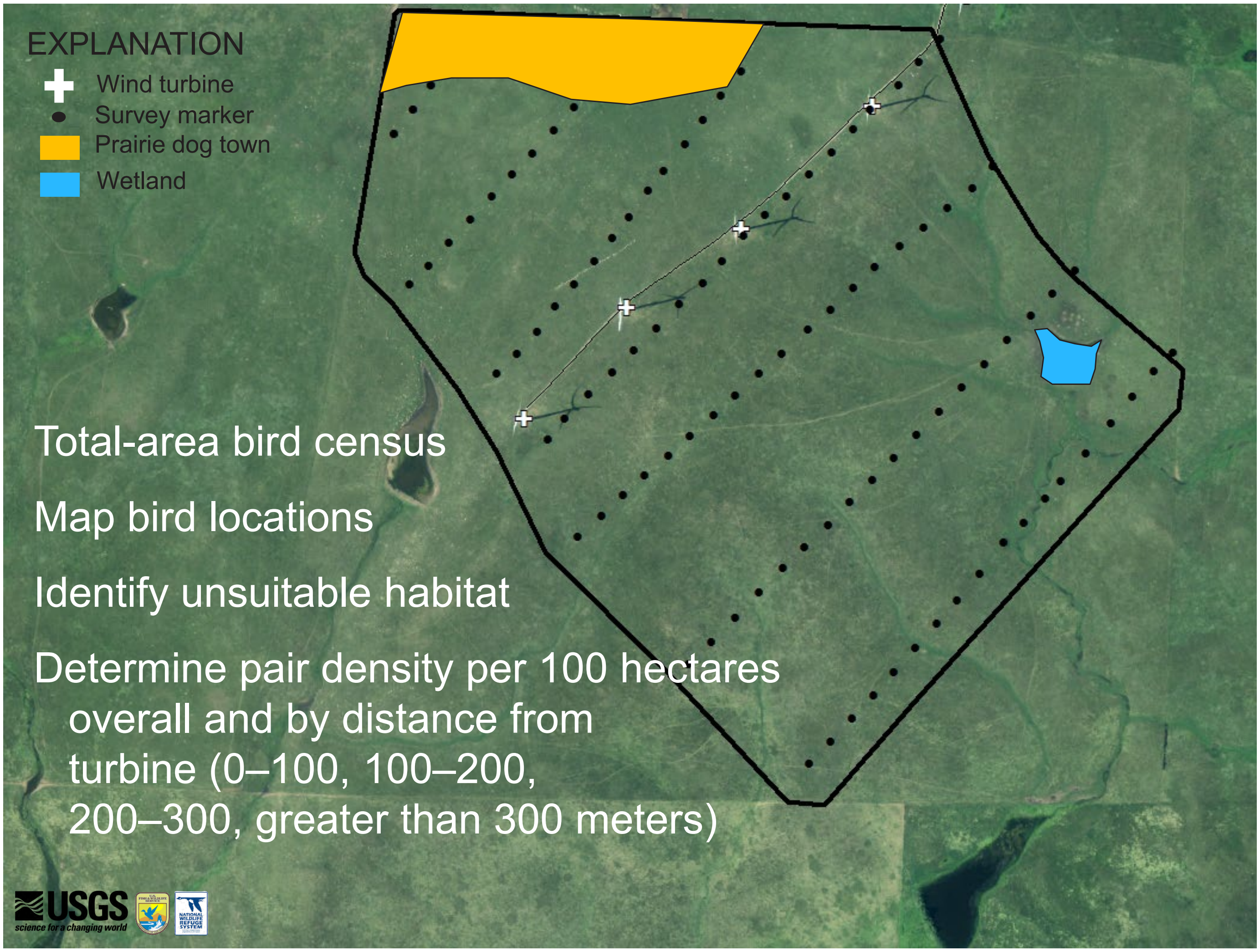
Shaffer and Buhl (2016) employed a gridded system (not point counts, as indicated in some literature), which—although labor intensive—is advantageous in that it allows one to maximize the area around a turbine that is surveyed. Birds were surveyed in the entire area within the gridded system. Birds were recorded from 0 to 50 meters on either side of the line-of-travel walked by the observers. Two surveys were conducted from mid-May to late June.



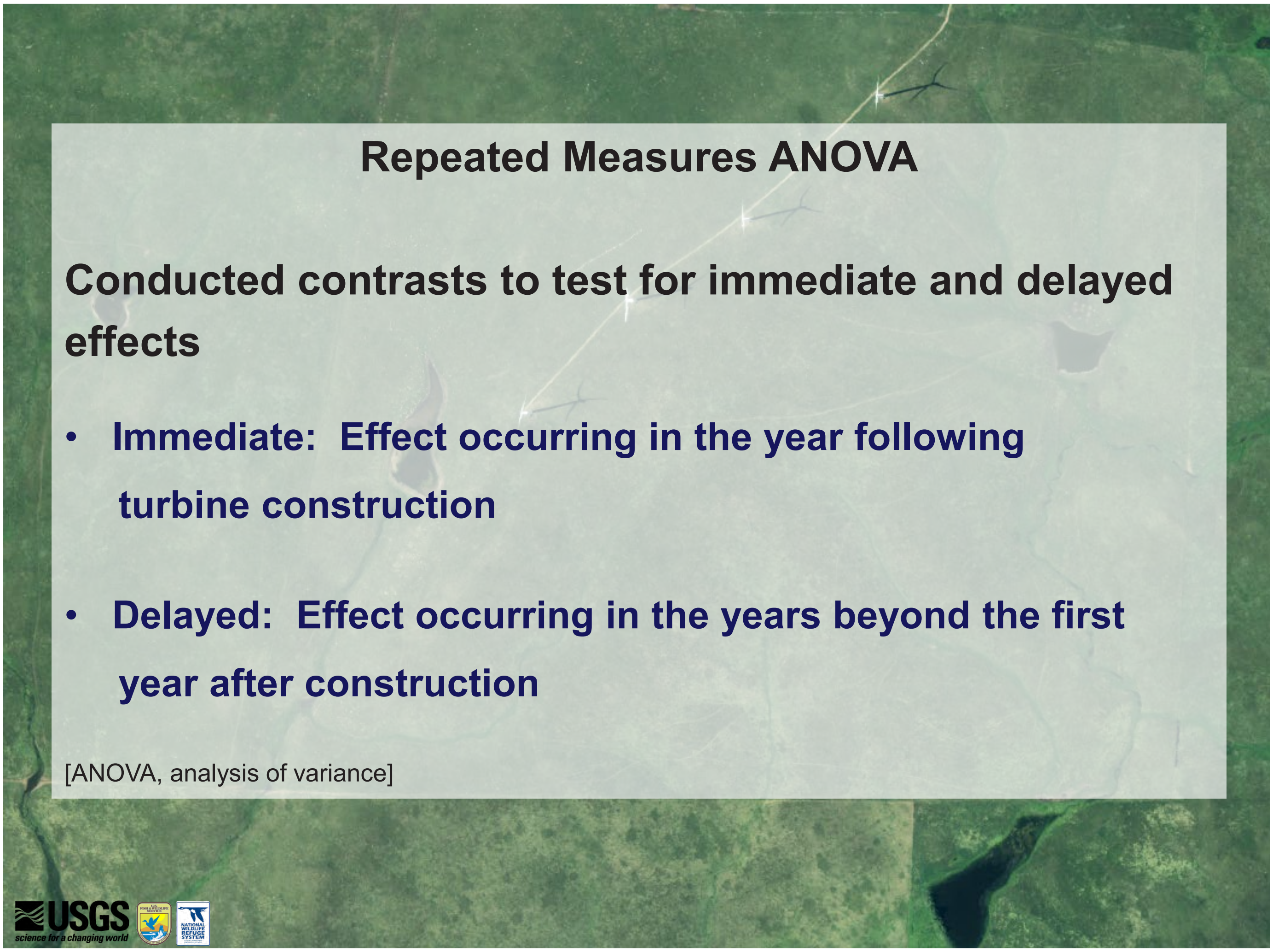
The gridded system also allowed for the mapping of bird locations to determine distances of individual birds from the turbines.



Major habitat types were delineated, such as prairie-dog towns and wetlands. For some grassland bird species, these areas were not considered breeding habitat, and they were subtracted from the total area deemed as breeding habitat for the particular species under analysis.



The density of breeding-bird pairs per 100 hectares was determined for each species by dividing the number of observed pairs by the hectares of breeding habitat. Pair density for each site overall was computed, as well as pair density by distance from turbine in four distance categories: 0–100, 100–200, 200–300, and greater than 300 meters. The maximum of two breeding-season survey densities for each combination of species, site, and year was used to reflect peak density of breeding-bird pairs.



To statistically test for effects of wind facilities, repeated measures analysis of variance (ANOVA) with contrasts were conducted to test for immediate and delayed effects. The mathematical definition of an immediate effect was defined as a difference in the change in density of breeding-bird pairs from the pretreatment year to1-year posttreatment between turbine and reference sites. The mathematical definition of a delayed effect was defined as a difference in the change in density of breeding-bird pairs from the pretreatment year to the 2–5-year posttreatment average between turbine and reference sites.

Immediate turbine effects

$$(\text{Density}_{\text{turbine, 1 yr-post}} - \text{Density}_{\text{turbine, pre}})$$

$$-\ (\text{Density}_{\text{reference, 1 yr-post}} - \text{Density}_{\text{reference, pre}})$$

$$\Delta \quad \text{Difference in change in density}$$

[yr, year; post, posttreatment; pre, pretreatment]

To test for an immediate effect, the change in pair density from the pretreatment year to 1-year posttreatment was computed for turbine and reference sites. This change in pair density was then compared between turbine and reference sites.

Delayed turbine effects

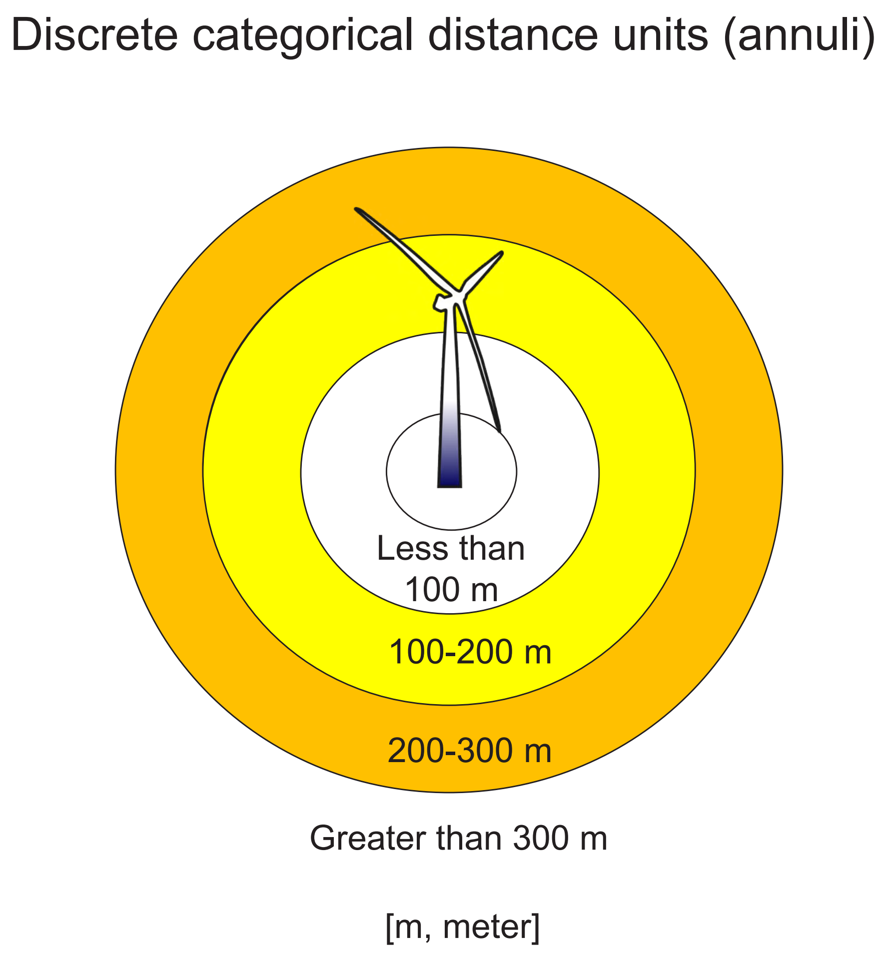
$$\left(\text{Density}_{\text{turbine, 2-5 yr-post}} - \text{Density}_{\text{turbine, pre}}\right)$$

$$- \left(\text{Density}_{\text{reference, 2-5 yr-post}} - \text{Density}_{\text{reference, pre}}\right)$$

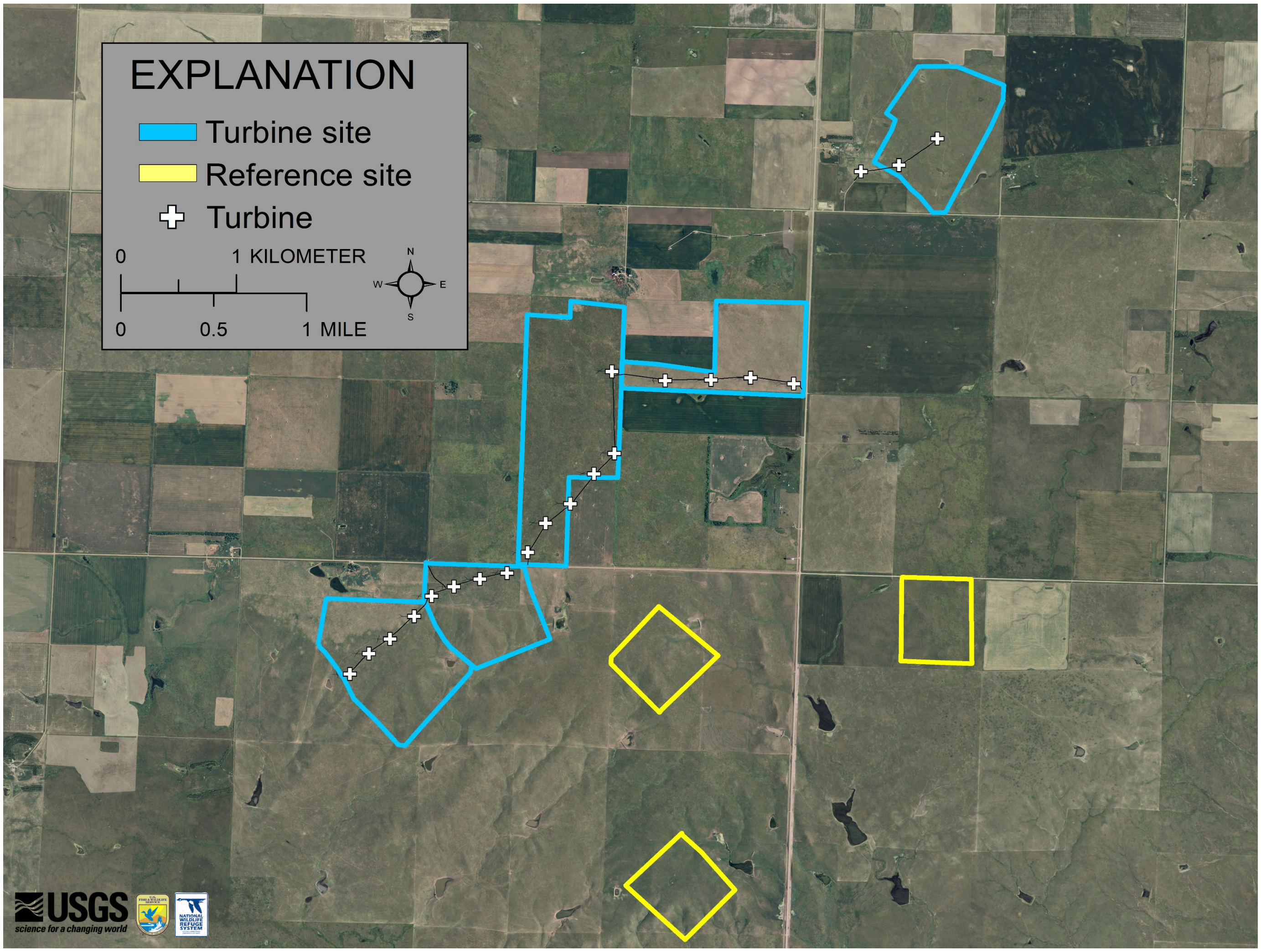
$$\Delta \text{ Difference in Change in Density}$$

[yr, year; post, posttreatment; -, minus; pre, pretreatment]

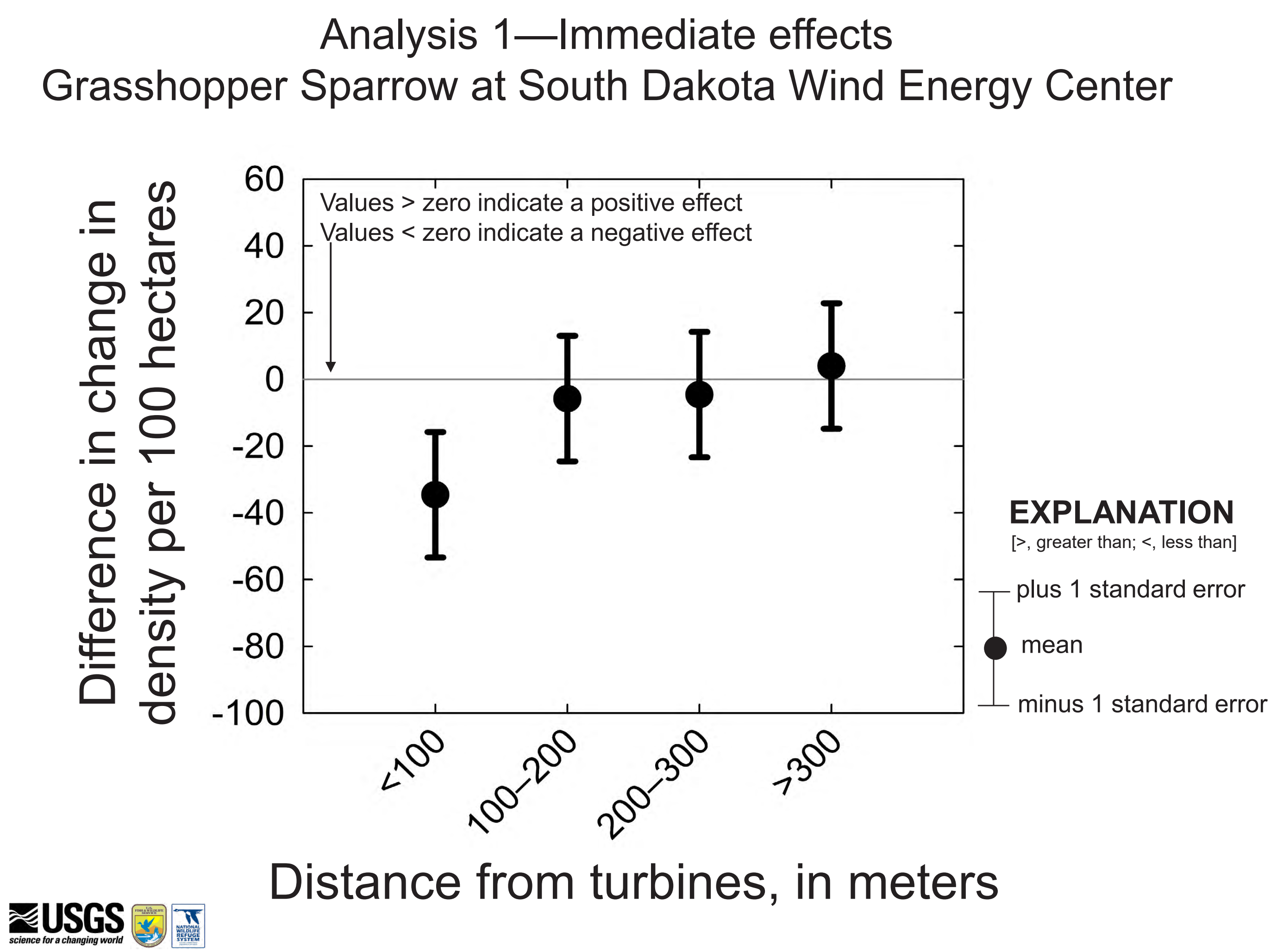
To test for a delayed effect, the change in pair density from the pretreatment year to the 2–5-year posttreatment average was computed for turbine and references sites. This change in pair density was then compared between turbine and reference sites.



Differences in change in pair density from pretreatment to posttreatment between turbine and reference sites were determined by discrete distance categories from turbine (that is, 0–100, 100–200, 200–300, and greater than 300 meters). Note that the greater than 300 meters is not represented in the image because the outer limit varied depending on wind facility.



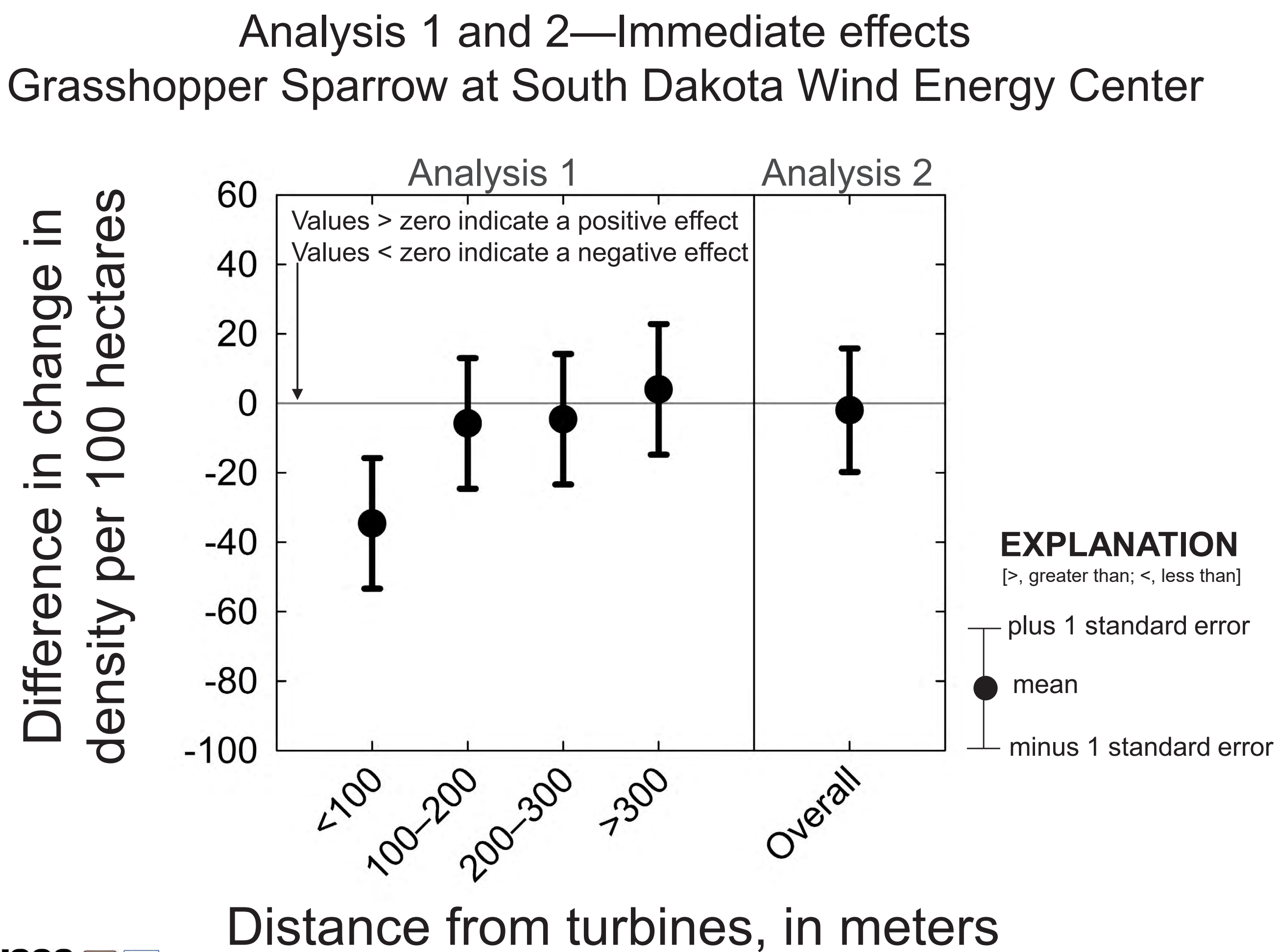
Pretreatment data on both reference and turbine sites are required for the before-after-control-impact approach. When calculating percent displacement, two important factors are changes in pair density on reference sites from the pre- to the posttreatment years that were assumed to reflect annual variation in population and changes in pair density on turbine sites from the pre- to the posttreatment years. A negative difference between these two factors (change in density on turbine sites minus change in density on reference sites) indicates displacement, and a positive difference represents attraction. One would expect comparable change in density at the turbine sites if turbines were not present. Changes observed on the turbine sites above that seen in the reference sites are assumed to represent attraction or displacement to wind turbines. More detailed information on how percent displacement was calculated is provided in the "Avian-Impact Offset Method" section.



Behavioral displacement of birds was analyzed for two time periods (immediate and delayed) by two categories (distance band and overall). The following pages will use the results for grasshopper sparrow to illustrate these analyses and time periods. Results for the analysis by distance band and the immediate time period—defined as 1-year posttreatment—at the South Dakota Wind Energy Center are shown in this image. In this analysis, the change in density by distance band was calculated between the pretreatment year and 1-year posttreatment.

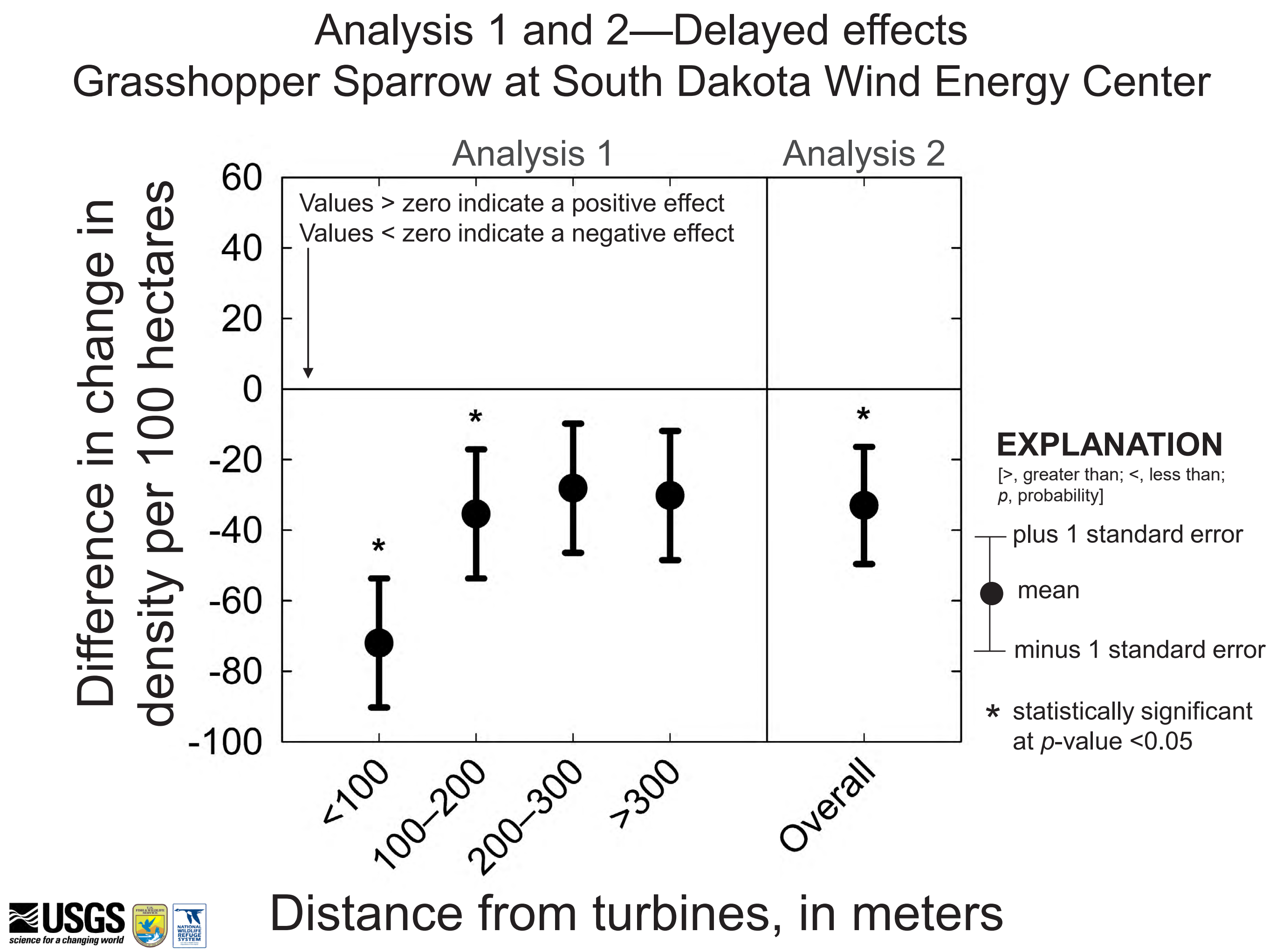
The difference in the change in pair density was then computed between the reference sites and each distance band and tested to determine whether these differences were statistically different from zero (p-value less than 0.05). These differences are the values plotted in the graph on this page. Negative values indicate displacement, whereas positive values indicate attraction. Error bars represent the standard errors.

The largest difference occurred in the distance band nearest to turbines. This difference is not statistically significant, but it may be biologically important because it indicates a potential change in density of 35 fewer grasshopper sparrow pairs per 100 hectares within 100 meters of the turbines than on the reference sites.

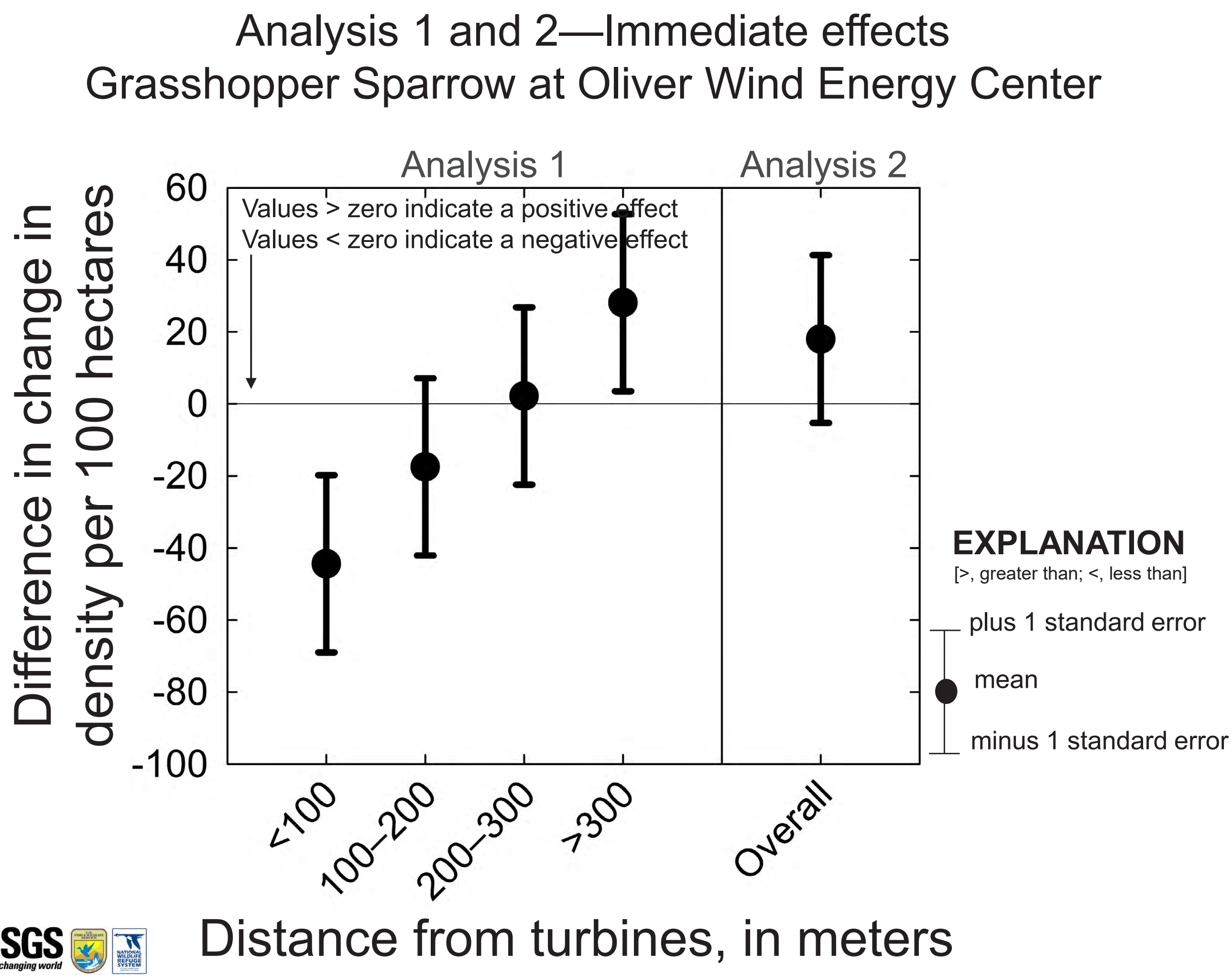


The second analysis assessed overall effects of wind facilities on the change in pair density from pretreatment to posttreatment. This analysis tested if the average density for the first posttreatment year minus the average density for the pretreatment year was equal between reference and turbine sites. For grasshopper sparrow pairs, the overall change in density was not statistically different between reference and turbine sites.

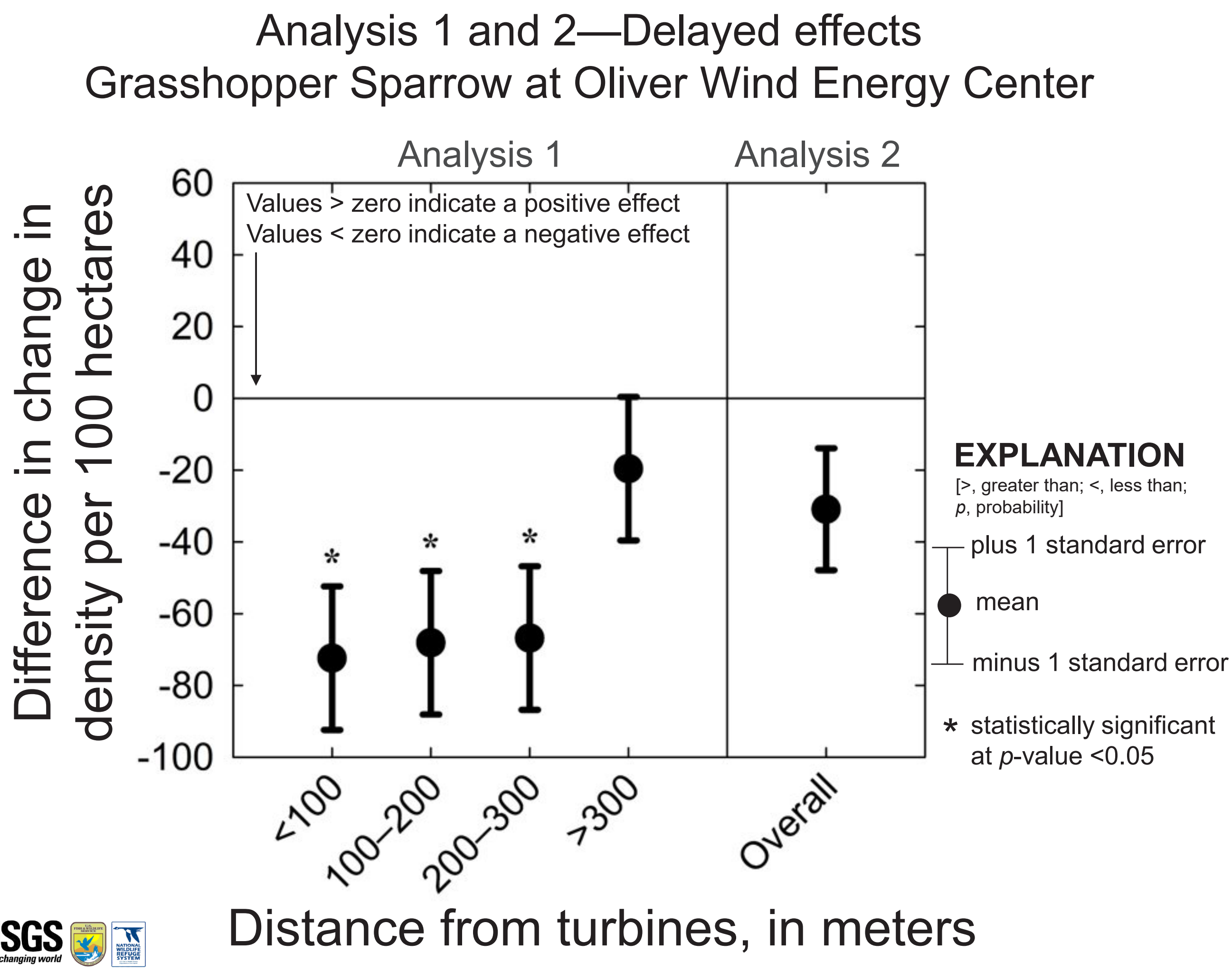
To summarize, grasshopper sparrows exhibited no statistically significant displacement either by distance category or overall during the first posttreatment year at the South Dakota Wind Energy Center.



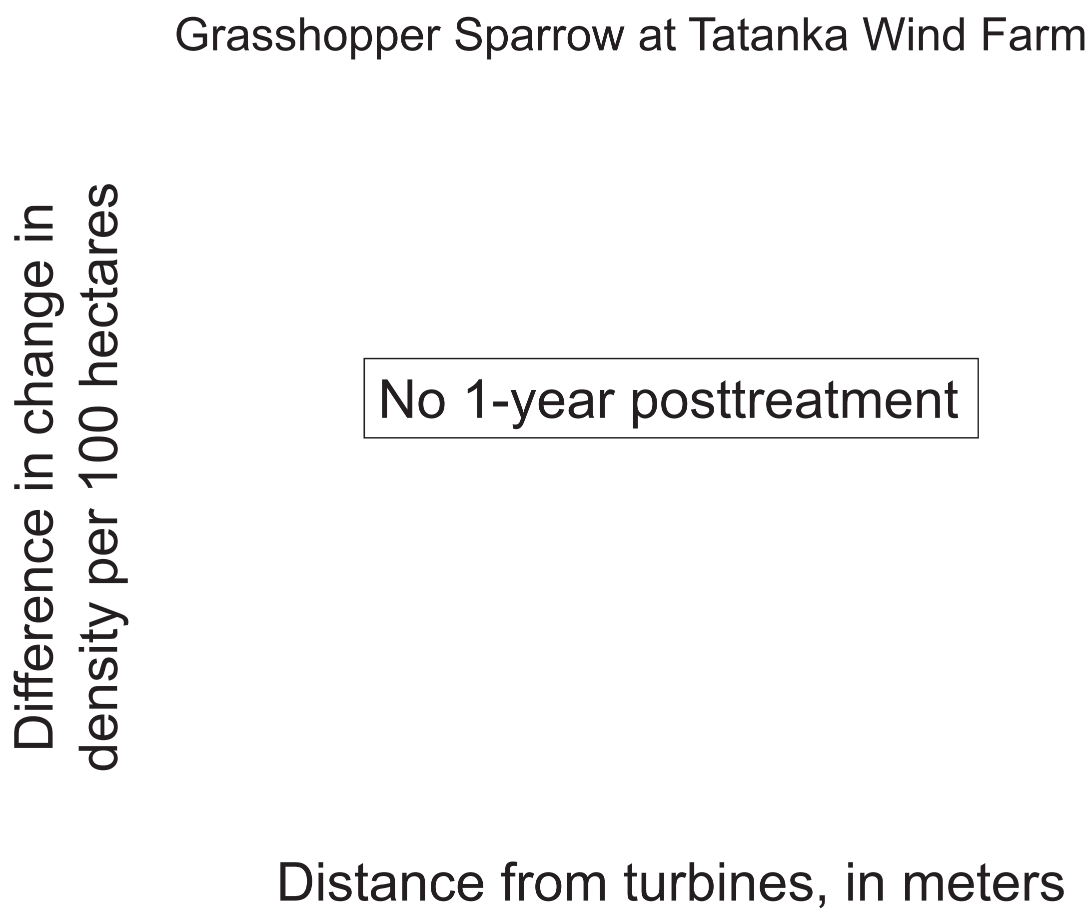
The second time period, the delayed or 2–5-year posttreatment, was analyzed for the presence of a delayed effect. Results for analysis 1 (by distance band) and analysis 2 (overall effect) are shown in the image. At the South Dakota Wind Energy Center during the 2–5-year posttreatment period, grasshopper sparrows exhibited significant displacement within 200 meters and overall.



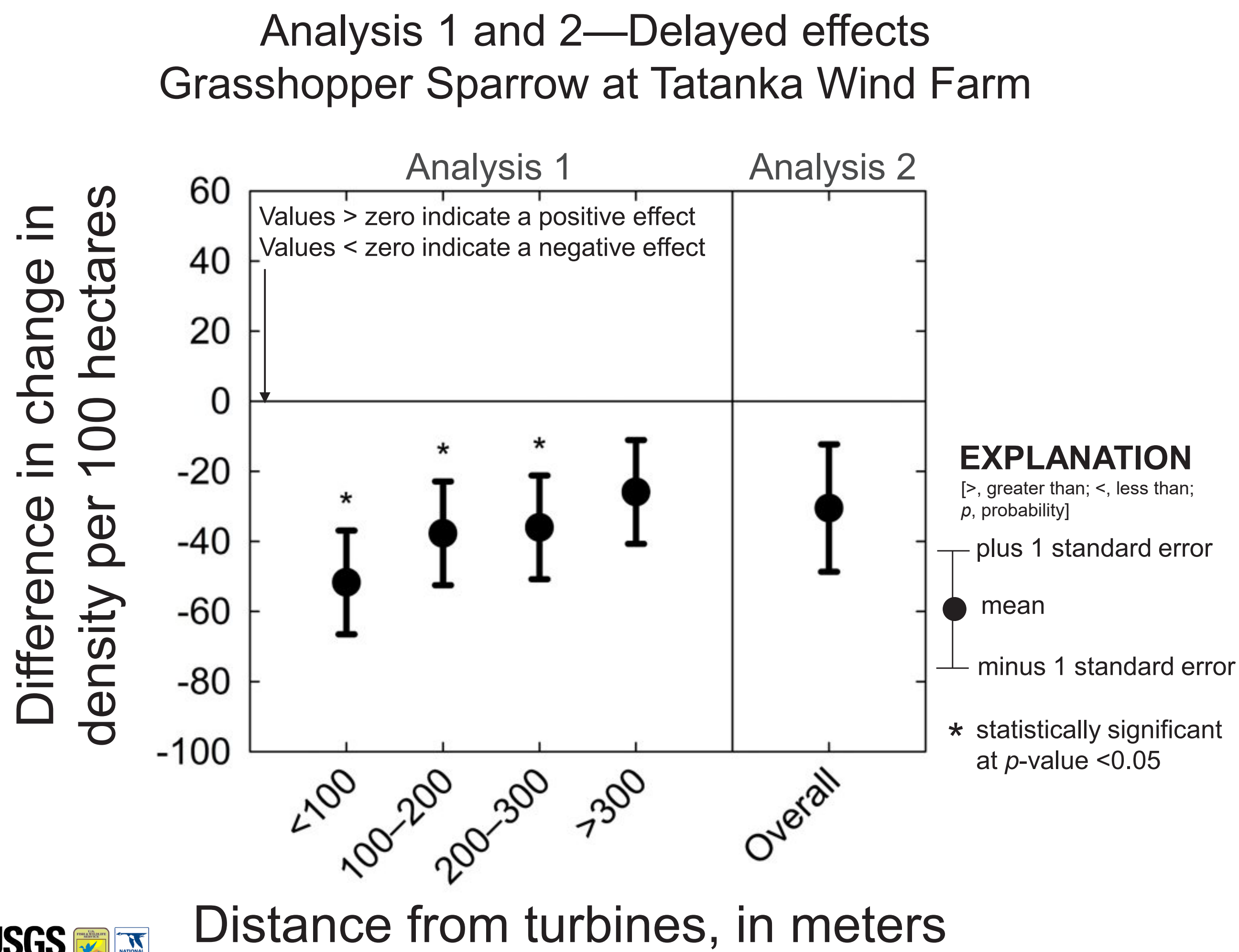
Results of analyses 1 and 2 for the 1-year immediate posttreatment time period at the second wind facility, the Oliver Wind Energy Center. For grasshopper sparrows, there were no statistically significant differences by distance category or overall. However, similar to analyses at the South Dakota Wind Energy Center, differences in change in pair density tended to be negative within 200 meters of the turbines compared to reference sites. At greater than 300 meters distance, and overall, differences in change in pair density tended to be positive compared to reference sites, which may indicate that birds are not being displaced entirely off the study area but are being displaced onsite to areas farther from turbines.



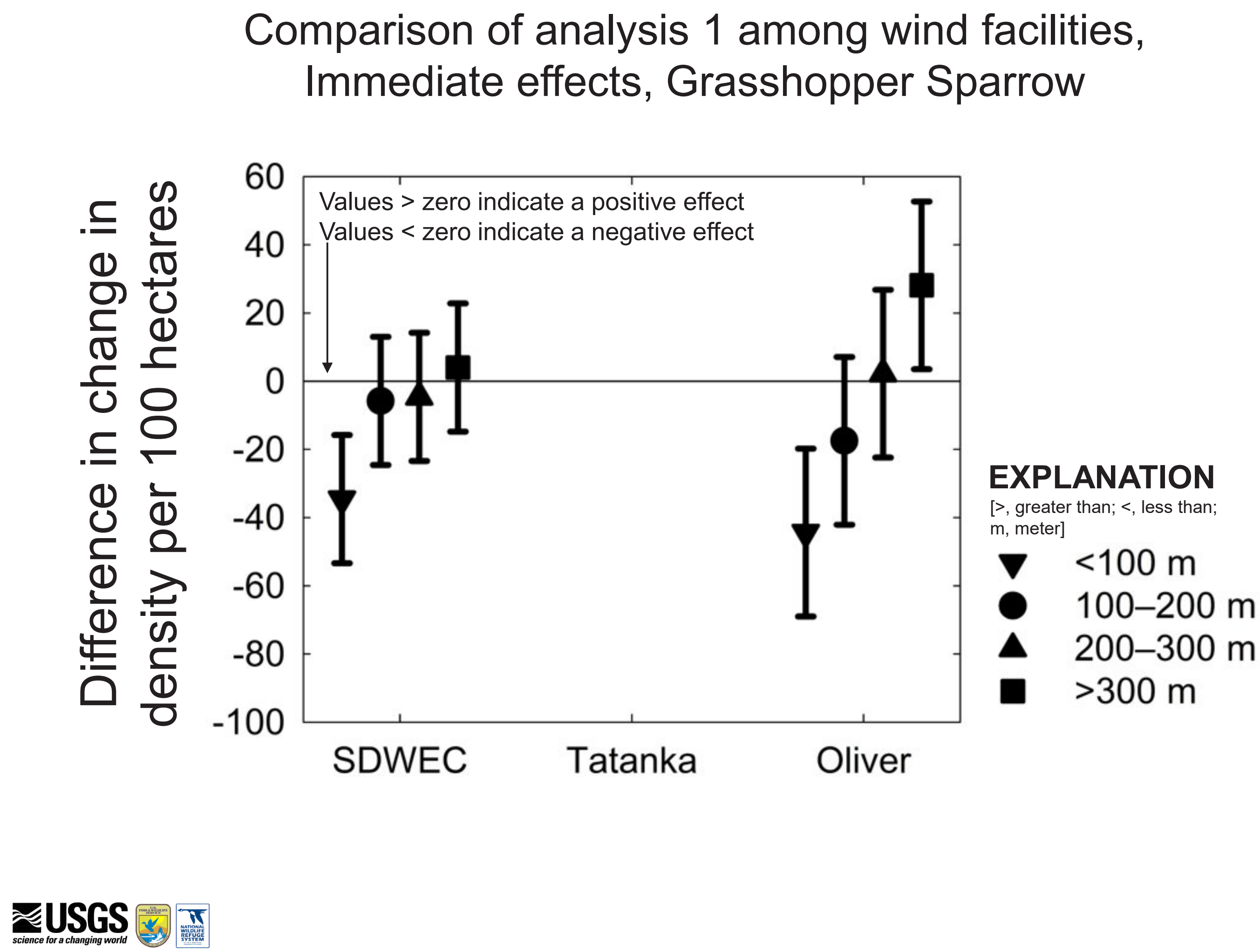
Grasshopper sparrows showed 2–5-year delayed turbine effects within 300 meters of turbines at the Oliver Wind Energy Center, with no significant overall effect.



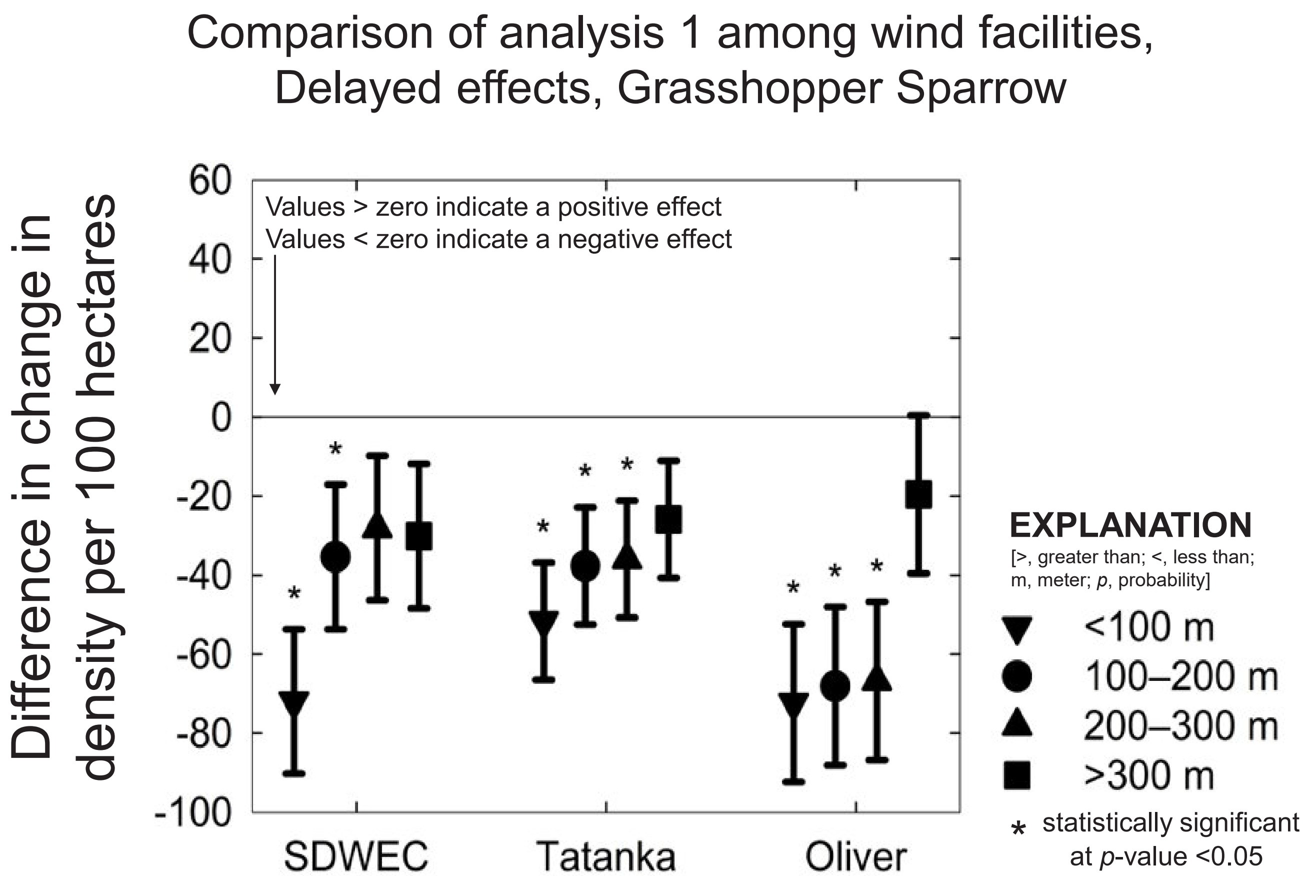
The Tatanka Wind Farm was not accessible during the 1-year immediate posttreatment, so there are no tests of immediate effects for this study area.



As at the Oliver Wind Energy Center during the 2–5-year delayed time period, grasshopper sparrows on the Tatanka Wind Farm exhibited delayed effects within 300 meters of turbines with no significant overall effect.



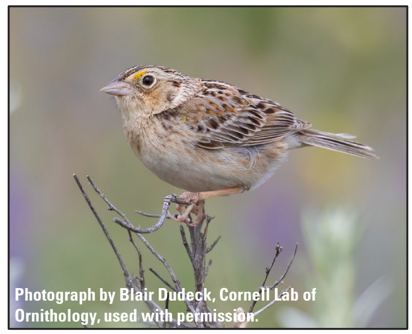
Results for analysis 1, 1-year posttreatment immediate effects, for all wind facilities, allowing for visual comparison among wind facilities. SDWEC is South Dakota Wind Energy Center.



Results for analysis 1, 2–5-year posttreatment delayed effects, for all wind facilities, allowing for visual comparison among wind facilities. SDWEC is South Dakota Wind Energy Center.

Conclusion for Grasshopper Sparrow

No significant immediate displacement; however, potential negative effects within 100 meters (m) of turbines may be biologically important


Photograph by Blair Dudeck, Cornell Lab of Ornithology, used with permission.

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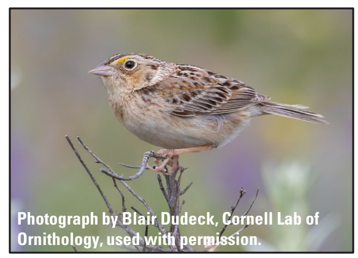
In conclusion, although no statistically significant immediate displacement effects were apparent, the potentially large negative turbine effects within 100 meters of turbines may be biologically important.

Conclusion for Grasshopper Sparrow

No significant immediate displacement; however, potential negative effects within 100 meters (m) of turbines may be biologically important

Significant negative delayed effects were observed within 200 m of turbines and usually extended out to 300 m


Photograph by Blair Dudeck, Cornell Lab of Ornithology, used with permission.

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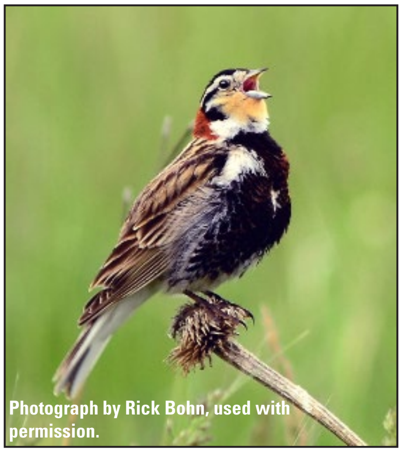
Significant negative delayed effects were observed within 200 meters of turbines and usually extended out to 300 meters.

Detailed results by species, study area, analysis, and time period are provided for all focal species in appendix 2.

The rest of this section will present a summary of the results.

Detailed results by species, study area, analysis, and time period are provided for all focal species in appendix 2. The rest of this section will present a summary of the results.



Photograph by Rick Bohn, used with permission.

Chestnut-collared Longspur
Calcarius ornatus

Photograph by Rick Bohn, used with permission.

Clay-colored Sparrow
Spizella pallida

Photograph by Rick Bohn, used with permission.

Upland Sandpiper
Bartramia longicauda

[SDWEC, South Dakota Wind Energy Center; m, meters; N/A, not applicable; >, greater than; Oliver, Oliver Wind Energy Center; Tatanka, Tatanka Wind Farm]

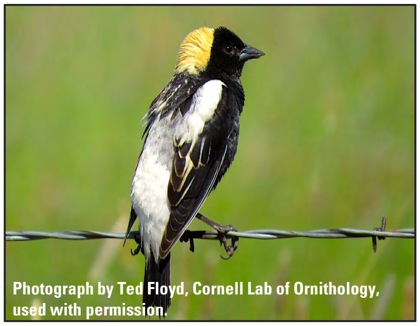
	Chestnut-collared Longspur	Clay-colored Sparrow	Upland Sandpiper
SDWEC:	Delayed within 300 m	N/A	Delayed >300 m
Oliver:	N/A	Delayed >300 m	Sustained within 100 m
Tatanka:	N/A	Delayed within 200 m	No effect

These statistically significant results for three grassland bird species indicate a preponderance of evidence for behavioral displacement. Not all species occurred at all wind facilities, as indicated by the notation "N/A" (not applicable). But where species did occur, displacement largely occurred. In cases where immediate and delayed effects occurred within the same analysis level, time period, and wind facility, the situation is termed "sustained displacement."

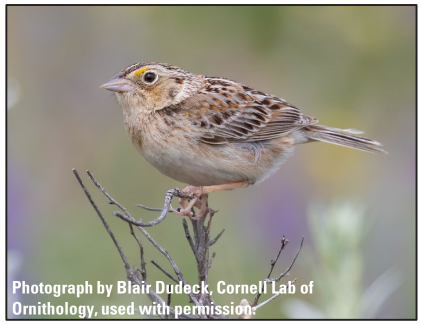
The chestnut-colored longspur only occurred at the South Dakota Wind Energy Center, where it exhibited significant displacement during the delayed time period in all distance bands except greater than 300 meters, indicating that the species may have been displaced off of the study area. The species also exhibited displacement overall.

The clay-colored sparrow exhibited delayed displacement at the Oliver Wind Energy Center and the Tatanka Wind Farm, although the range bands in which displacement occurred varied.

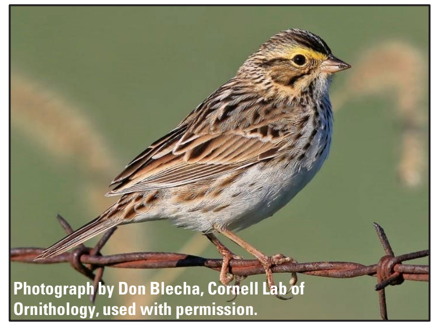
The upland sandpiper exhibited delayed effects at the South Dakota Wind Energy Center, sustained effects within 100 meters at the Oliver Wind Energy Center, and no effects at the Tatanka Wind Farm.


Photograph by Ted Floyd, Cornell Lab of Ornithology, used with permission.

Bobolink
Dolichonyx oryzivorus


Photograph by Blair Dudeck, Cornell Lab of Ornithology, used with permission.

Grasshopper Sparrow
Ammodramus savannarum


Photograph by Don Blecha, Cornell Lab of Ornithology, used with permission.

Savannah Sparrow
Passerculus sandwichensis

[SDWEC, South Dakota Wind Energy Center; m, meter; N/A, not applicable; Oliver, Oliver Wind Energy Center; Tatanka, Tatanka Wind Farm]

SDWEC:	No effect	Delayed within 200 m	N/A
Oliver:	Immediate, attraction 200–300 m; Delayed within 200 m	Delayed within 300 m	Sustained 100–300 m
Tatanka:	Delayed all distance categories	Delayed within 300 m	Delayed within 300 m

The bobolink exhibited no displacement or attraction effects of wind turbines at the South Dakota Wind Energy Center. At the Oliver Wind Energy Center, the species exhibited attraction within the 200–300 meters band during the immediate time period, indicating that birds were perhaps moving from areas near turbines to areas farther from turbines. During the delayed time period, bobolinks exhibited displacement within 200 meters. At the Tatanka Wind Farm during the delayed time period, bobolinks exhibited displacement within all distance bands and overall, indicating that perhaps the species was moving off of the study area. Results for the grasshopper sparrow were described in the immediately preceding pages. The Savannah sparrow did not occur within 100 meters at the Oliver Wind Energy Center during any survey years, so displacement obviously could not be evaluated within that band. Savannah sparrows exhibited sustained displacement from 100 to 300 meters at Oliver Wind Energy Center and delayed displacement within 300 meters at the Tatanka Wind Farm.

[SDWEC, South Dakota Wind Energy Center; N/A, not applicable; >, greater than; m, meter; Oliver, Oliver Wind Energy Center; Tatanka, Tatanka Wind Farm]

	Vesper Sparrow *Pooecetes gramineus*	Western Meadowlark *Sturnella neglecta*
SDWEC:	N/A	Sustained within 100 m; Delayed >200 m
Oliver:	No effect	No effect
Tatanka:	No effect	No effect

The vesper sparrow was the only species to show neither displacement nor attraction, so this species exhibited no effects of wind turbines. The western meadowlark is interesting because this species showed displacement at only one wind facility, where it exhibited sustained displacement within 100 meters and delayed displacement beyond 200 meters.


Photograph by Davey Walters, Cornell Lab of Ornithology, used with permission.

Killdeer
Charadrius vociferus

[SDWEC, South Dakota Wind Energy Center; m, meters; Oliver, Oliver Wind Energy Center; Tatanka, Tatanka Wind Farm]

SDWEC:	Immediate, attraction within 100 m
Oliver:	Immediate, attraction within 100 m
Tatanka:	No effect

The generalist species, the killdeer, was the only species to show consistent attraction. There were significant, positive immediate effects (attraction) observed within 100 meters of turbines at the South Dakota Water Energy Center and the Oliver Wind Energy Center. A delayed effect was not detected at any of the three wind facilities.

Number of significant findings ($p<0.05$) of displacement by distance (meters)

[<, less than; >, greater than; *p*, probability]

<100	100–200	200–300	>300
11	9	8	4

Number of possible contrasts per distance category is 36

Displacement of these grassland bird species was more prevalent near turbines than farther away, with most of the significant cases occurring within 300 meters (table 1). Displacement was detected at all three wind facilities within all distance categories and for 7 of 9 species evaluated (that is, 32 out of a total 144 contrasts indicated significant displacement).

The number of significant findings are out of a possible 36 contrasts in each distance category (tables 2 and 3 in Shaffer and Buhl, 2016). There are 36 contrasts because there are (2 time periods x 6 species at the South Dakota Wind Energy Center) + (1 time period x 8 species at the Tatanka Wind Farm) + (2 time periods x 8 species at the Oliver Wind Energy Center). By year posttreatment, there are 14 contrasts within each distance category 1-year posttreatment plus 22 contrasts within each distance category 2–5-year posttreatment.

Table 1. Significant displacements and attractions for nine grassland bird species.

[<, less than; WEME, western meadowlark; SDWEC, South Dakota Wind Energy Center; UPSA, upland sandpiper; OL, Oliver Wind Energy Center; SAVS, Savannah sparrow; GRSP, grasshopper sparrow; TAT, Tatanka Wind Farm; BOBO, bobolink; CCLO, chestnut-collared longspur; CCSP, clay-colored sparrow; >, greater than; KILL, killdeer; VESP, vesper sparrow]

Time period	Distance	Species (wind facility)[1]
	Displacements	
1-year posttreatment	<100 meters	WEME (SDWEC), UPSA (OL)
1-year posttreatment	100–200 meters	SAVS (OL)
1-year posttreatment	200–300 meters	SAVS (OL)
2–5-year posttreatment	<100 meters	GRSP (OL, TAT, SDWEC), WEME (SDWEC), BOBO (OL, TAT), CCLO (SDWEC), CCSP (TAT), UPSA (OL)
2–5-year posttreatment	100–200 meters	GRSP (OL, TAT, SDWEC), BOBO (OL, TAT), CCLO (SDWEC), CCSP (TAT), SAVS (TAT)
2–5-year posttreatment	200–300 meters	GRSP (OL, TAT), WEME (SDWEC), BOBO (TAT), CCLO (SDWEC), SAVS (TAT, OL)
2–5-year posttreatment	>300 meters	WEME (SDWEC), BOBO (TAT), CCSP (OL), UPSA (SDWEC)
	Attractions	
1-year posttreatment	200–300 meters	BOBO (OL)
1-year posttreatment	<100 meters	KILL (OL, SDWEC)

[1]There is no significant displacement for KILL or VESP.

Displacement by distance (meters [m])

Less than 100 m: displacement observed for 77 percent (%) of 31 contrasts

100–200 m: displacement observed for 81% of 31 contrasts

200–300 m: displacement observed for 87% of 31 contrasts

For eight bird species, the number of negative contrasts was tallied, indicating displacement (including times that were not significant). Because killdeer is a generalist species and a shorebird, this species was not included in further analyses (thus reducing the number of contrasts to 31). Even though statistical significance could not always be detected, this consistent finding of negative contrasts indicates that displacement is likely occurring within 300 meters of the turbines.

Displacement occurred for seven species

- Seven of nine bird species exhibited displacement within 300 meters.
- Statistically significant displacement did vary across wind facilities, species, distances, and time periods.
- However, effects were consistently negative for seven species.
- Displacement was detected 1-year posttreatment, and this displacement effect persisted at least 5 years.

When interpreting the delayed effects, recall that the 2–5-year effects are being compared to pretreatment numbers. Therefore, these delayed effects represent a cumulative effect after the turbines have been in place for 2–5 years. For species such as the grasshopper sparrow, western meadowlark, bobolink, and chestnut-collared longspur, the effects were usually greater in the 2–5-year delayed time period than in the 1-year immediate time period, indicating that effects of the turbines are continuing to accumulate with time.


Photograph by Paul Hueber, Cornell Lab of Ornithology, used with permission.


Photograph by Jay McGowan, Cornell Lab of Ornithology, used with permission.


Photograph by Dorian Anderson, Cornell Lab of Ornithology, used with permission.

Northern Pintail
Anas acuta

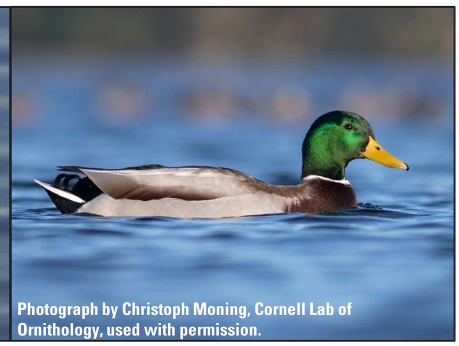
Blue-winged Teal
Spatula discors

Northern Shoveler
Spatula clypeata

Gadwall
Mareca strepera

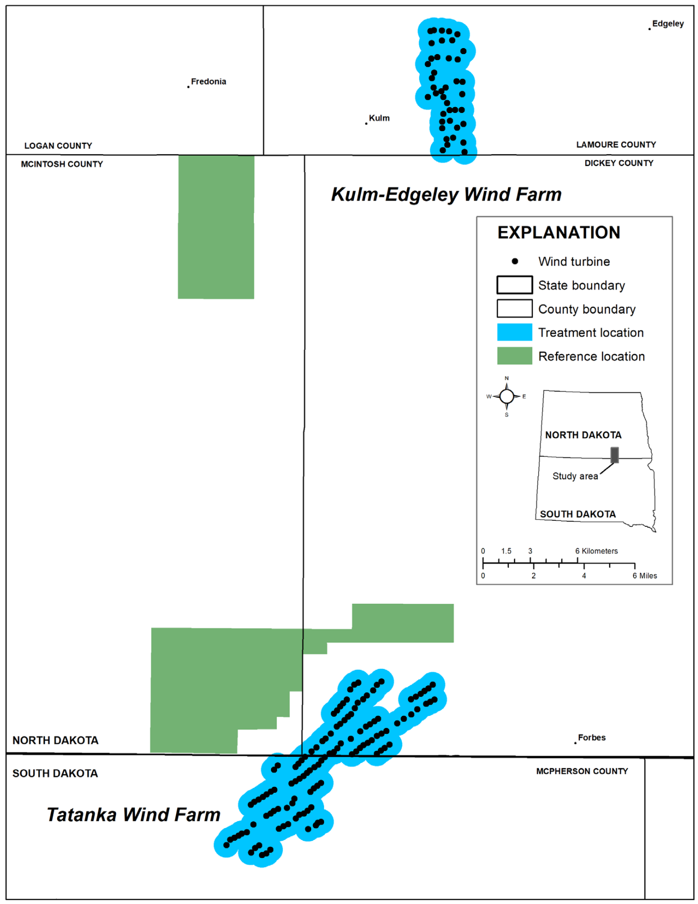
Mallard
Anas platyrhynchos


Photograph courtesy of Alan Wilson, licensed under the Creative Commons Attribution-3.0 license.


Photograph by Christoph Moning, Cornell Lab of Ornithology, used with permission.

The waterfowl research was a collaboration between the U.S. Fish and Wildlife Service and Ducks Unlimited. Loesch and others (2013) investigated the impact of wind facilities on these five species of dabbling ducks, the young of which are produced in large numbers in the Prairie Pothole Region. The objective of Loesch and others (2013) was to determine if there were differences in the density of breeding duck pairs in areas with and without wind-energy facilities.

Waterfowl wind study sites in North Dakota and South Dakota



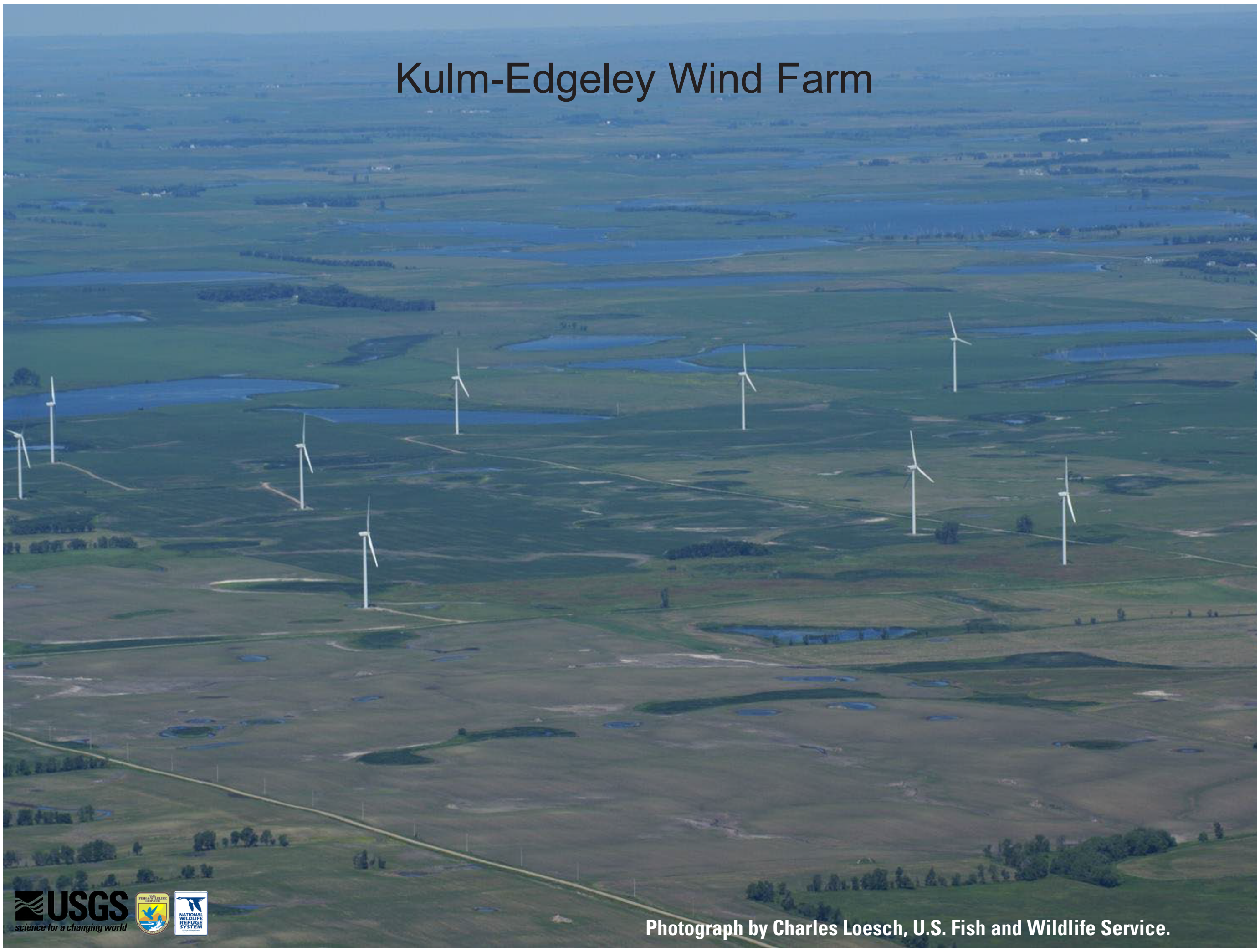
Kulm-Edgeley Wind Farm

41 turbines

Tatanka Wind Farm

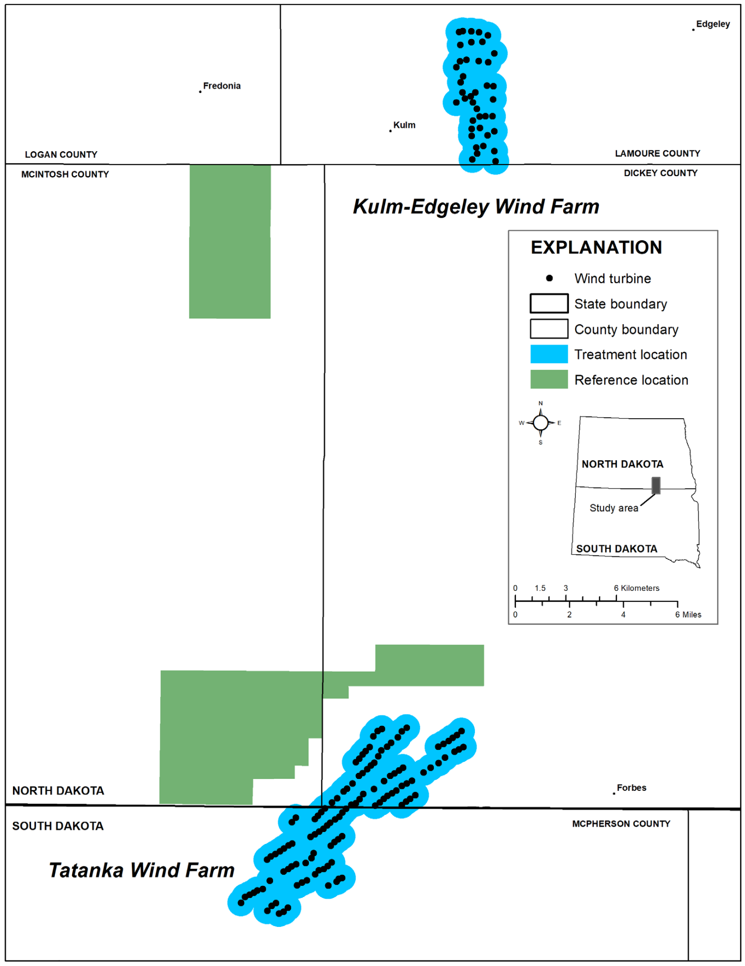
120 turbines

The waterfowl research occurred at two wind facilities: NextEra Energy's Kulm-Edgeley Wind Farm in North Dakota, which had 41 turbines, and Acciona's Tatanka Wind Farm, with 120 turbines that straddled the border of North Dakota and South Dakota. The map image is modified from Loesch and others (2013) and used with permission.



Photograph showing an aerial view of a portion of NextEra Energy's Kulm-Edgeley Wind Farm in North Dakota. This site was dominated by agriculture.

Photograph showing an aerial view of a portion of the Tatanka Wind Farm straddling the North Dakota and South Dakota State line. This site was dominated by grassland.



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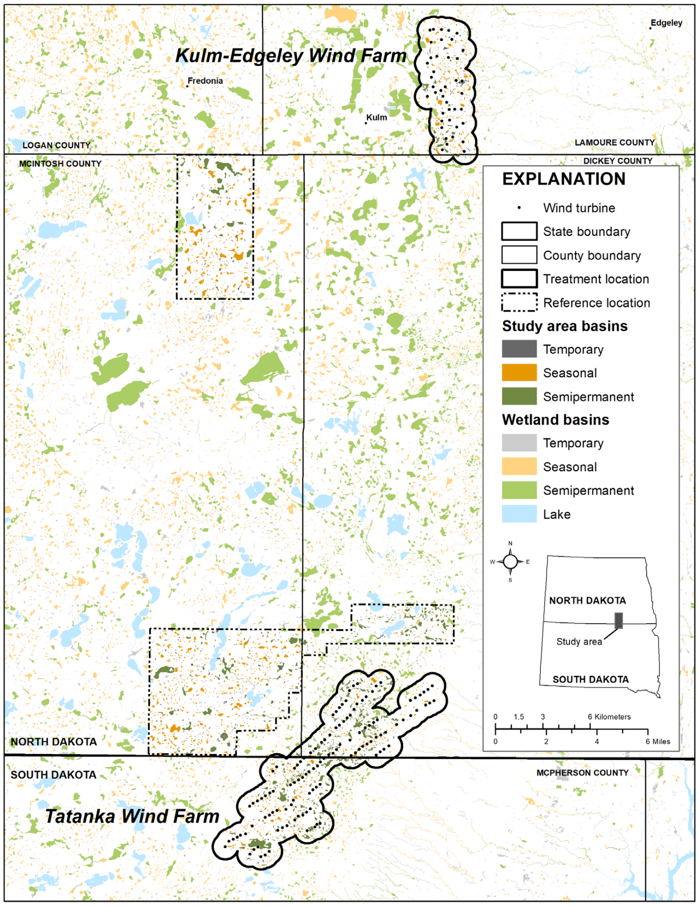
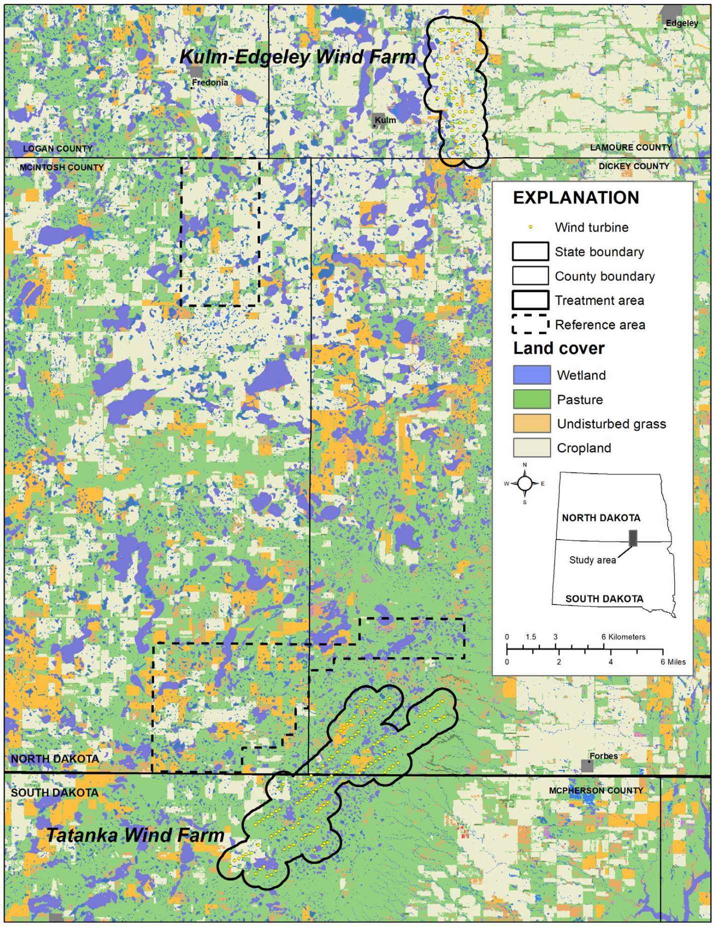
Loesch and others (2013) applied a concurrent-year, paired-reference site approach. To gather data on breeding-duck pairs on wind sites, Loesch and others (2013) applied an 800-meter buffer around wind turbines because it represents one-half the radius of a circular home range for a mallard hen, which would ensure overlap of breeding territories with nearby wind turbines.



Paired Reference Sites

Similar number and area of the three surveyed wetland classes

Paired reference sites were placed within 2.5 to 25 kilometers of nearest turbines to minimize potential for weather-related variation. To control the possibility of differences in wetland and landscape characteristics among sites, paired sites contained a similar number and areal extent of wetlands for each of the three wetland classes surveyed (temporary, seasonal, and semipermanent). The map image is modified from Loesch and others (2013) and used with permission.

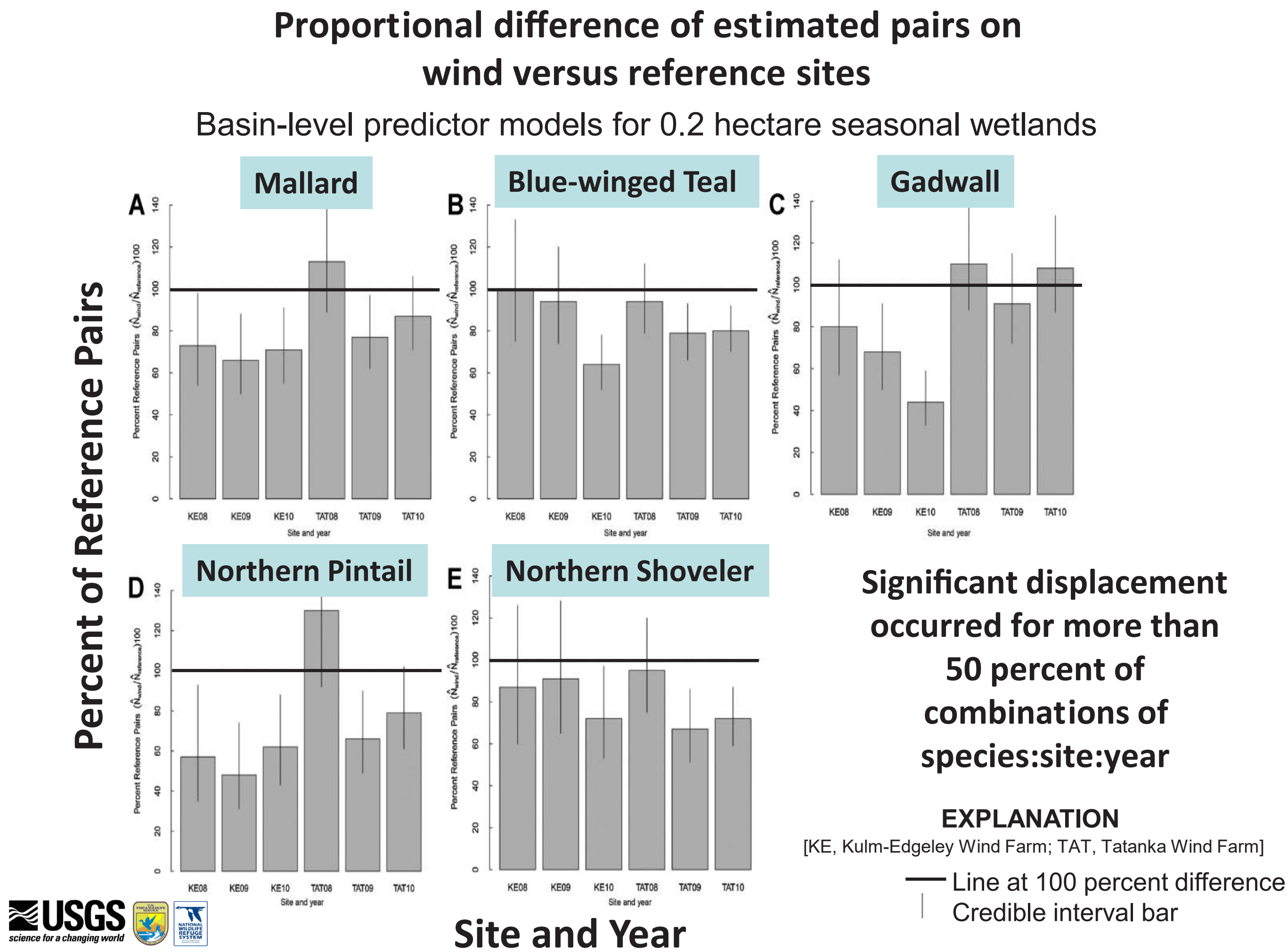


Similar in wetland density and the proportion of cropland to perennial cover

Paired reference sites were placed so that they were embedded in larger landscapes with a similar wetland density and proportion of cropland and perennial cover.

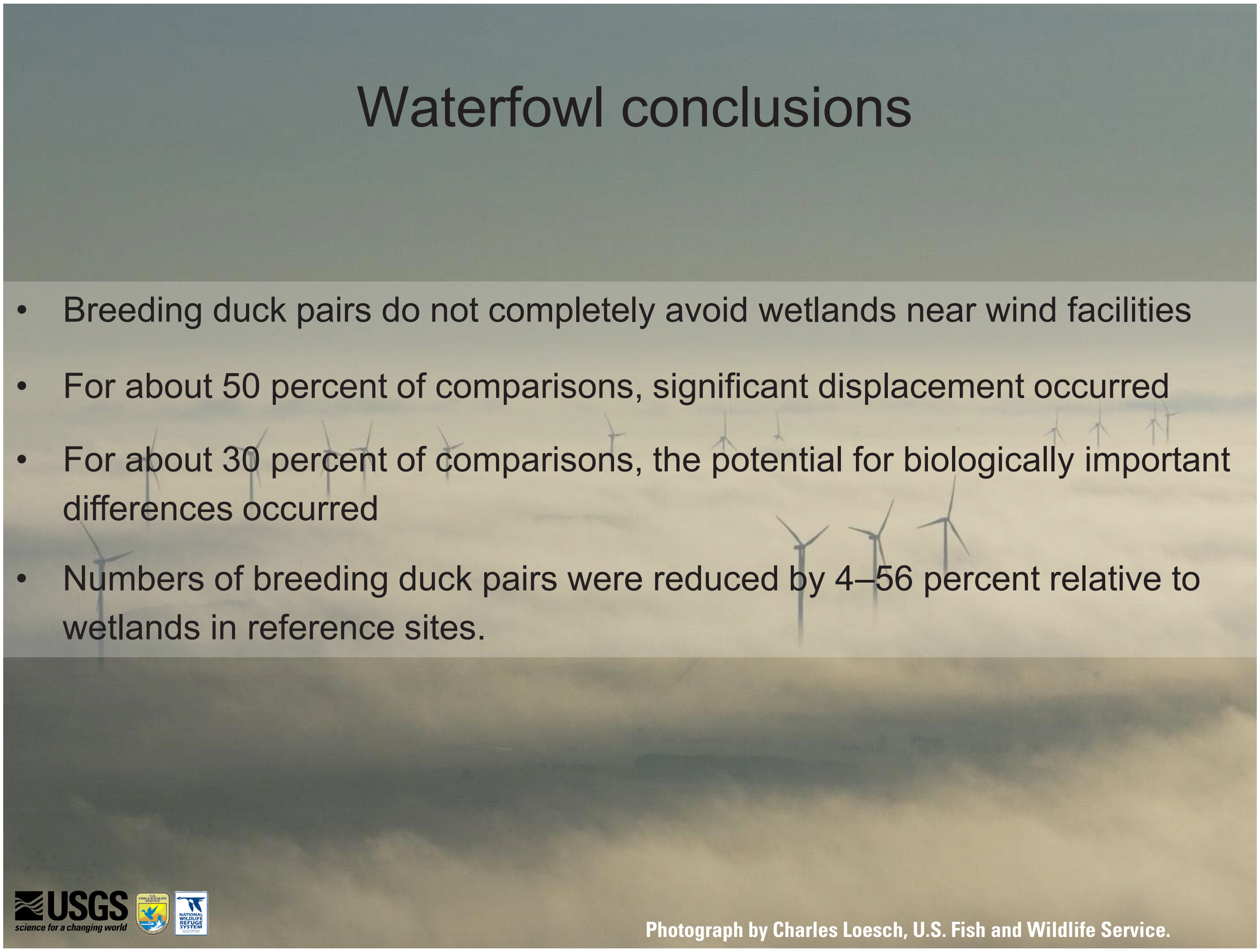
Photograph by U.S. Fish and Wildlife Service.

The waterfowl displacement research was conducted for 3 years by six observers annually. Waterfowl were surveyed in spring during two time periods (May 1–15 and May 21–June 12). A total of 5,217 wetland basins (3,475 surface hectares) were surveyed. Because waterfowl assemble into various social groupings that are affected by sex ratios, breeding phenology, and daily activities, social groups of the five target species were counted using established survey protocols. Wetland characteristics of percent full, vegetative cover class, and vegetation height were recorded.



The breeding duck pair data were used to run predictive models for each of the three years, two sites, and five species combinations. Seasonal wetlands were chosen because they were the most numerous wetland class in the study and because breeding duck pairs use seasonal wetlands in higher proportions than other wetland classes. The median size of seasonal wetlands in the study area was 0.2 hectare, so this value was used in the prediction models. The graphs are from figure 3 of Loesch and others (2013).

The graphs display the percent difference of the pair estimates on wind versus reference sites. Estimates of duck pairs below 100 percent difference indicate potential displacement. Lack of overlap of the credible interval bars with the horizontal line indicate significant displacement. For slightly more than 50 percent (16 of 30) of comparisons, differences were significantly lower. For 10 of the 14 nonsignificant comparisons, the estimates of duck pairs for wind sites tended to be lower than for paired reference sites, indicating the potential for biologically important differences.



Similar to grassland bird species, waterfowl species were determined to experience significant displacement owing to wind facilities.

Section 2 Summary

The before-after-control-impact and concurrent-year, paired-reference site designs were described.

Study methods, such as avian surveys, were described.

Detailed results were shown for one grassland bird species, illustrating the analyses by distance band and overall and for the two time periods (immediate and delayed). Detailed results for all species are available in Appendix 2.

Summarized results were provided, showing magnitude and persistence of displacement. Seven of 9 grassland bird species exhibited displacement, and average displacement increased over time. For waterfowl, displacement varied by species, year, and wind facility.

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After completing Section 2, take a moment to reflect on the contents.

Section 3—Avian-Impact Offset Method

Section 3

Section 3 explains the Avian-Impact Offset Method (AIOM) as developed in Shaffer and others (2019).

The Avian-Impact Offset Method quantifies displacement of birds by anthropogenic disturbances. Although wind infrastructure is used as the model to explain the method, the method is also applicable to offset other disturbances, such as solar, oil, gas, and road infrastructure. The method ultimately calculates the amount of grassland or wetland needed to support displaced breeding-bird pairs, from which the fiscal cost to mitigate the loss of otherwise suitable breeding habitat can be determined.

Avian-Impact Offset Method

4 Impact Metrics

Impact Distance	Linear distance for which energy infrastructure influences bird behavior
Impact Area	Buffer zone; that is, the spatial extent of habitat affected
Pre-Impact Density	Number of birds per hectare; measured prior to impact
Percent Displacement	Percent of birds displaced due to energy infrastructure

1 Offset Metric

Offset Density	Number of birds per hectare on offset habitat

Five metrics are required in the Avian-Impact Offset Method: four from the impact (or turbine) site and one from the offset site (that is, the mitigation site).

Impact distance.—The linear distance for which infrastructure influences bird behavior (that is, the maximum distance from the infrastructure at which displacement has been shown). This distance can be estimated from scientific knowledge of bird behavior (for example, Loesch and others, 2013; Shaffer and Buhl, 2016) or from field-based research aimed at obtaining this knowledge.

Impact area.—A function of impact distance that indicates the spatial extent of habitat affected by development and within which some birds are assumed to be displaced. For waterfowl, the impact area is the number of wetlands or area of wetlands (measured using any land-area metric, such as hectares or acres) circumscribed by the impact distance. For grassland birds, the impact area is the entire expanse of grassland habitat circumscribed by the impact distance and can be measured using any land-area metric. The units for the impact area must match the units used for the pre-impact density.

Pre-impact density.—A biological metric of density of breeding-bird pairs within the impact site but before the impact occurs. It is calculated as the number of bird pairs relative to the amount of habitat in the impact site (for example, pairs per wetland for waterfowl, pairs per hectare for land-based birds). Pre-impact density can be estimated using a variety of sources, including field-based surveys or published sources of avian density within the relevant habitat and geographic location. It is important that the area units within the density match the units used for impact area. For example, for waterfowl, if the impact area is measured in number of wetlands, the density must then be measured as pairs per wetland. For grassland birds, if the impact area is measured in hectares, then the density must be measured as pairs per hectare. For situations in which published sources for pre-impact density are not available, users of the avian-impact offset method may need to conduct field-based surveys for their target species, habitat, and geographic location, or use well-defined assumptions based on existing information.

Percent displacement.—The percentage of bird pairs within the impact site that is reduced as the result of energy development or other sources of anthropogenic disturbance relative to the number of bird pairs that would be present in the absence of the disturbance. Estimates of percent displacement for several avian species are currently available for energy-related disturbances, including roads (for example, Pearce-Higgins and others, 2009, 2012; Garvin and others, 2011; Thompson and others, 2015; Sansom and others, 2016; Shaffer and others, 2019). For situations in which published sources for percent displacement are not available, users of the avian-impact offset method may need to conduct field-based surveys for their target species, habitat, and geographic location, or use well-defined assumptions based on existing information.

Offset density.—The biological metric of density of breeding-bird pairs at potential offset sites that is necessary to ensure comparable biological value at the offset site. Offset density can be estimated using a variety of sources, including field-based surveys or published sources of avian density within the relevant habitat and geographic location.

Estimating percent displacement

Reported in Shaffer and others (2019)

- Included the eight grassland species, excluded generalist species
- Computed percent displacement by
  - distance categories out to 300 meters
  - time periods
  - individual wind facility, and then averaged across wind facilities
- Final estimates are applicable for North Dakota, South Dakota, and eastern Montana

One of the key metrics in using the Avian-Impact Offset Method is determining percent displacement. Because it requires the most complex math, Section 3 will start with explaining how an average percent displacement was calculated using the data from Shaffer and Buhl (2016). To estimate the percent displacement, the densities of breeding-bird pairs were taken from the analysis presented in Shaffer and Buhl (2016) for 8 of the 9 species that are grassland-obligate bird species; killdeer was excluded because it is a generalist. For each wind facility, the densities for these eight species were summed to get a total pair density.

Percent displacement was computed separately by distance categories out to 300 meters from a wind turbine and by the 1-year, 2-year, 3-year, and 5-year time periods (that is, years after turbine construction, or posttreatment). Note that no data were collected 4 years after turbine construction. Displacement was computed separately for each wind facility, and then the average was calculated to get an estimate of the average percent displacement for each time period and distance combination.

Estimating percent displacement

Predicted avian densities

(ANOVA models from Shaffer and Buhl, 2016)

- Reference sites, before and after turbine construction
- Treatment sites, before and after turbine construction

[ANOVA, analysis of variance]

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Step 1: Calculate predicted pair density. The total pair density of the focal grassland-specialist species was calculated by summing the densities (presented as number of breeding-bird pairs per 100 hectares) predicted from the analysis of variance models in Shaffer and Buhl (2016) for reference and turbine sites before and after turbine construction (that is, pre- and posttreatment).

Calculations for percent displacement

1-year after construction, South Dakota Wind Energy Center

Step 1: Sum predicted density per 100 ha across species				
Time period	**less than 100 m**	**100–200 m**	**200–300 m**	**Reference**
Pre	232.64	193.34	231.99	213.84
1-yr post	83.97	86.56	113.40	138.68

[ha, hectare; <,less than; m, meter; pre, pretreatment; yr, year; post, posttreatment]

This image shows results from the South Dakota Wind Energy Center during 1-year posttreatment at all three distance categories within 300 meters of the wind turbines. Note that percent displacement for birds was computed for each time period by distance combination for each wind facility.

Step 1: The pair densities (presented as number of breeding-bird pairs per 100 hectares) predicted from the analysis of variance models in Shaffer and Buhl (2016) for the analyzed grassland-obligate species (all species analyzed except for killdeer) were summed to get a total density of the focal species. A variance-covariance matrix was computed for these sums by assuming species were independent and by summing the species variance.

Calculations for percent displacement

1-year after construction, South Dakota Wind Energy Center

Step 1: Sum predicted density per 100 ha across species				
Time period	**<100 m**	**100–200 m**	**200–300 m**	**Reference**
Pre	232.64	193.34	231.99	213.84
1-yr post	83.97	86.56	113.40	138.68
Step 2: Compute expected density for turbine sites				
1-yr post	150.87	125.38	150.45	

$$\frac{138.68}{213.84} \times 232.64 = 150.87$$

[ha, hectare; <,less than; m, meter; pre, pretreatment; yr, year; post, posttreatment]

Step 2: Any change in pair density from the pre- to posttreatment years in the reference sites was assumed to reflect normal annual variation in the bird population, with comparable changes expected in the turbine sites if turbines were not present. Any change above the expected change was ascribed to a displacement effect (that is, this difference was assumed to be the number of breeding-bird pairs per 100 hectares displaced by the wind facility). The second step in estimating displacement rate was to compute an expected density by distance category for each year posttreatment based on the percent change from pre- to posttreatment for the reference sites. Specifically, the expected density was computed as the percent change for the reference sites (that is, the ratio of the posttreatment density to the pretreatment density) multiplied by the pretreatment density on the turbine sites. Values in red were used in Step 2 to compute the expected pair density for the category of less than 100 meters: (138.68/213.84) x 232.64 = 150.87.

A variance of each expected density was estimated by computing the variance of the ratio of reference posttreatment density to reference pretreatment density using the formula for the variance of the ratio of dependent variables (Stuart and Ord, 1994). The variance of the expected density was computed using the formula for the variance of the product of two independent variables (Goodman 1960).

Step 3. Estimating percent displacement

Predicted – Expected

Negative value indicates magnitude of bird pairs displaced

Step 3: Compute the difference between the predicted (step 1) and expected pair densities. This difference was assumed to be the number of bird pairs displaced by the wind facility.

Calculations for percent displacement

Step 1: Sum predicted density per 100 ha across species				
Time period	**<100 m**	**100–200 m**	**200–300 m**	**Reference**
Pre	232.64	193.34	231.99	213.84
1-yr post	83.97	86.56	113.40	138.68
Step 2: Compute expected density for turbine sites				
1-yr post	150.87	125.38	150.45	
Step 3: Compute difference between predicted and expected density				
1-yr post	−66.90	−38.82	−37.05	

Number of bird pairs displaced

83.97 – 150.87 = −66.90

[ha, hectare; <,less than; m, meter; pre, pretreatment; yr, year; post, posttreatment]

Step 3: The difference between the predicted (step 1) and expected pair densities. Values in red were used in Step 3 to compute the difference between predicted and expected pair density for the category of less than 100 meters: 83.97 – 150.87 = −66.90.

This difference was assumed to be the number of breeding-bird pairs per 100 hectares displaced by the wind facility. The variance of this difference was computed as the sum of the variances of the predicted and expected densities; the values were assumed independent and therefore covariance was equal to zero (Stuart and Ord, 1994).

Step 4. Estimating percent displacement

([Predicted – Expected] / Expected) x 100

Step 4: Compute the percentage of bird pairs displaced by dividing the difference between the predicted and expected densities (result from step 3) by the expected density for each distance category and multiplying by 100. The variance of this differences was computed as the sum of the variances of the predicted and expected densities; the values were assumed independent and therefore covariance equal to zero (Stuart and Ord, 1994).

Calculations for percent displacement

Step 1: Sum predicted density per 100 ha across species				
Time period	**<100 m**	**100–200 m**	**200–300 m**	**Reference**
Pre	232.64	193.34	231.99	213.84
1-yr post	83.97	86.56	113.40	138.68
Step 2: Compute expected density for turbine sites				
1-yr post	150.87	125.38	150.45	
Step 3: Compute difference between predicted and expected density				
1-yr post	−66.90	−38.82	−37.05	
Step 4: Compute percent displaced				
1 -yr post	−44.34%	−30.96%	−24.63%	

$$\frac{-66.90}{150.87} \times 100 = -44.34$$

[ha, hectare; <,less than; m, meter; pre, pretreatment; yr, year; post, posttreatment]

Step 4: The percentage of bird pairs displaced was computed by dividing the difference between the predicted and expected densities (result from step 3) by the expected density for each distance category and multiplying by 100. Values in red were used in Step 4 to compute the percent displaced for the category of less than 100 meters: (–66.90/150.87) x 100 = –44.34 percent.

Average percent displacement

Average % (standard error) across 3 wind facilities				
n years	<100 m	100-200 m	200-300 m	Weighted average
1-yr post	−51.54 (15.51)	−27.05 (15.22)	−5.69 (14.05)	−17.91 (9.47)
2-yr post	−43.86 (14.44)	−42.12 (14.51)	−32.32 (13.48)	−36.86 (9.06)
3-yr post	−57.30 (9.77)	−41.38 (9.32)	−39.48 (8.74)	−42.09 (5.87)
5-yr post	−59.85 (10.03)	−58.03 (10.04)	−48.45 (9.23)	−52.91 (6.22)

[%, percent; *n*, number of; <,less than; m, meter; yr, year; post, posttreatment]

To calculate an average percent displacement of bird pairs, the percent displacement was averaged across all three wind facilities for each distance band by time-period combination. Note that there were 1-year posttreatment data only for the Oliver Wind Energy Center and the South Dakota Wind Energy Center, 2-year posttreatment data only for the Tatanka Wind Farm and the South Dakota Wind Energy Center, and no 4-year posttreatment data at any facility. Approximate 95-percent confidence intervals can be computed for each estimate as plus or minus (2 times the standard error).

The displacement rates in the table for each distance category are the average percent displacement observed *n* years after construction of turbines. These displacement rates were computed by comparing the density observed each year to an expected density based on changes from pre-treatment density rather than the previous-year density. Therefore, these rates represent cumulative effects of the wind facility rather than yearly effects. For example, the displacement rate for 2-year posttreatment is not the displacement from 1-year to 2-year posttreatment; rather, the rate is the displacement after the turbines have been in place for 2 years. The last column of the table is a weighted average of the percent displacement for the distance bands using the size of the distance band as a weight.

The displacement rate generally continued to increase with years posttreatment. The weighted average rate of displacement after the turbines had been in place for 5 years was 53 percent. This value will be used as the displacement rate in the Avian-Impact Offset Method formula for grassland birds. Based on the Shaffer and Buhl (2016) study, extrapolation beyond 5 years posttreatment is not appropriate.

Weighted average percent displacement across distance bands

Oliver Wind Energy Center

Average percent displacement (standard error) by distance category for 5-year posttreatment

Year post	<100 m	100–200 m	200–300 m	Weighted average
5	37.24 (19.98)	58.69 (21.22)	49.62 (19.56)	51.27 (13.16)

[<,less than; m, meter; yr, year; post, posttreatment]

The calculations below illustrate how to calculate the weighted average percent displacement across the three distance bands. The example uses values from the Oliver Wind Energy Center for 5-year posttreatment. Values were 37.24 percent displacement for 0–100 meters (m), 58.69 percent for 100–200 m, and 49.62 percent for 200–300 m. The weighted average of the three distance categories in the fifth-year posttreatment was 51.27 percent.

To calculate a weighted average, the weight for each distance band needs to be computed. To calculate the area of a circle, use the following equation:

$$Area = \pi r^2 \qquad (1)$$

where

π is 3.141, and

r is the radius of the circle.

Using this equation, the calculation for the area of a 100-m circle (W_1) would be 3.141 x 100 x 100 = 31,410 m. The calculation for the area of a 200-m annulus (the 200-m circle with the 100-m circle subtracted; W_2) would be (3.141 x 200 x 200) - (31,410) = 94.230 m. The calculation for the area of a 300-m annulus (the 300-m circle with the 200-m circle subtracted; W_3) would be (3.141 x 300 x 300) – (125,640) = 157,050 m.

The weighted average for two or more distance bands can be computed with the following equation:

$$Weighted\ Average = \frac{\sum W_i X_i}{\sum W_i} \qquad (2)$$

where

W_i is the weight for distance band i, and

X_i is the percent displacement for distance band i.

The following example uses the estimates of displacement for the Oliver Wind Energy Center, 5-years posttreatment (from appendix S1, table S3 in Shaffer and others, 2019). The calculations for computing the weighted average for two and three distance bands (for example, 0–100 m and 100–200 m) are illustrated below.

Weighted average displacement rate for two distance bands.

<100 m: X_1 = 37.24

100–200 m: X_2 = 58.69

((31,410 x 37.24) + (94,230 x 58.69)) / (31,410 + 94,230)

= (1,169,708 + 5,530,359) / 125,640

= 53 percent

Weighted average displacement rate for all three distance bands.

200–300 m: X_3 = 49.62

((31,410 x 37.24) + (94,230 x 58.69) + (157,050 x 49.62)) / (31,410 + 94,230 + 157,050)

= (1,169,708 + 5,530,359 + 7,792,821) / 282,690

= 51 percent

Average percent displacement by individual wind facility

Appendix S2, Table S3 of Shaffer and others (2019)

There may be situations where the average percent displacement by individual wind facility is desired, rather than an average among facilities. Values by individual wind facility are presented in appendix S1, table S3 of Shaffer and others (2019) by distance category and year posttreatment.

Average percent displacement for waterfowl

Species	Total number of pairs	Average change (percent)	Standard error
Blue-winged Teal	2,632	−15.17	5.43
Mallard	1,541	−19.00	6.84
Gadwall	1,251	−16.50	10.28
Northern Pintail	768	−26.33	12.02
Northern Shoveler	734	−19.33	4.79

Average percent displacement for each of the five waterfowl species was derived from values reported in table 1 of Shaffer and others (2019), which showed the percent difference of predicted breeding duck pair abundance between estimates for the median seasonal wetland size at NextEra Energy’s Kulm-Edgeley Wind Farm and Acciona’s Tatanka Wind Farm in North Dakota and South Dakota, relative to estimates for the reference sites without wind development (see Loesch and others, 2013). Standard errors are approximate. Values are from the turbine sites.

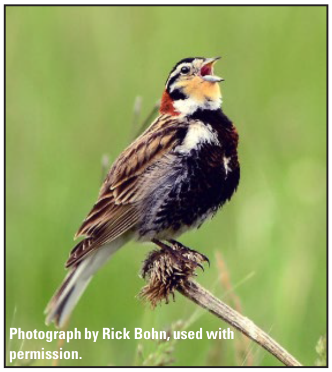
Average percent displacement for waterfowl

The overall average percent displacement for the five species of waterfowl is 18 percent.

This value was computed as a weighted average of the percent change using the total number of pairs within the turbine sites for each species as a weight.

The weighted average percent displacement for waterfowl across two wind facilities is 18 percent. This value was computed as a weighted average of the percent change using the total number of pairs within the turbine sites for each species as a weight.

Conclusions from displacement research

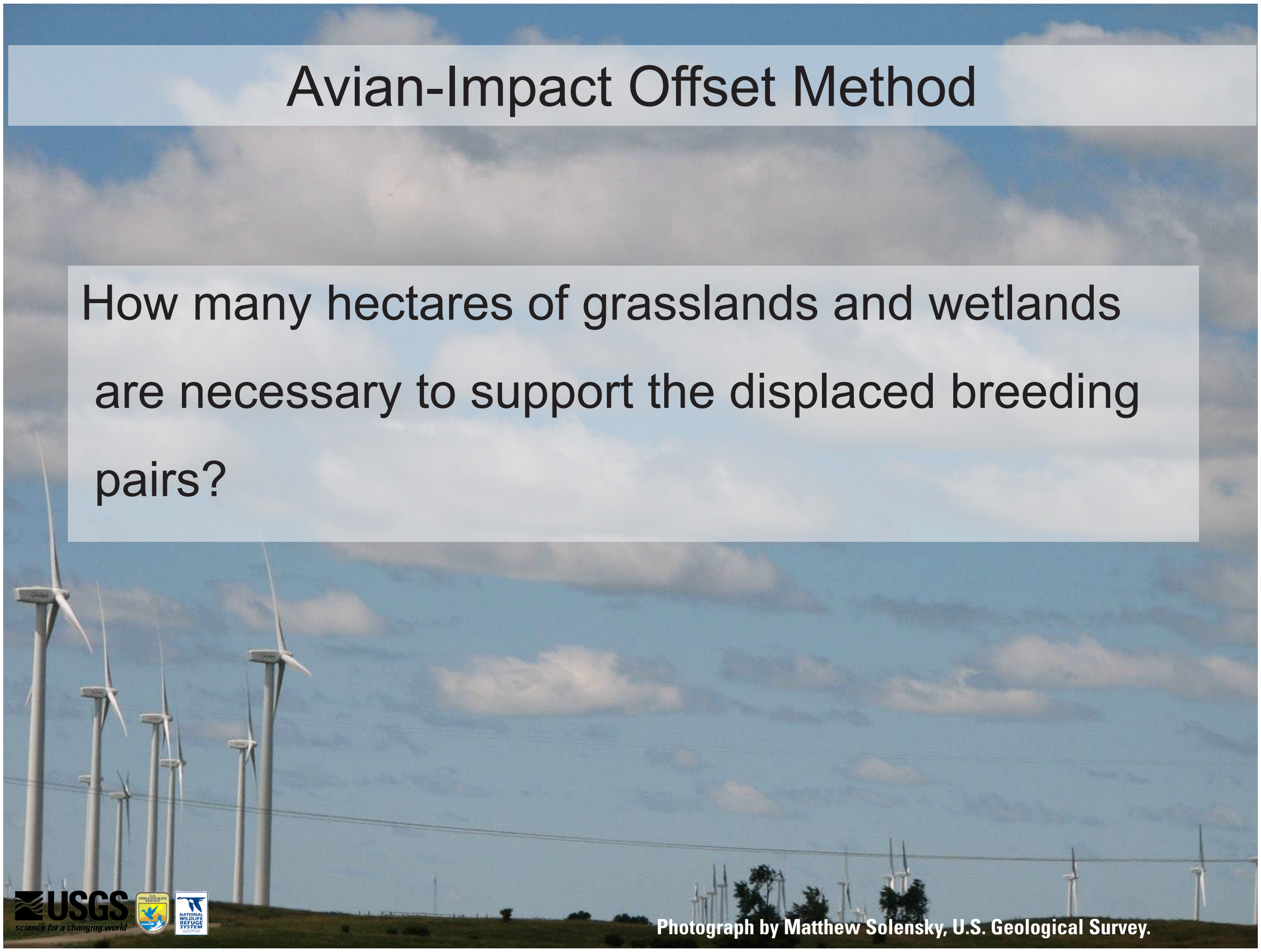

Photograph by Rick Bohn, used with permission.

Average 53 percent displacement of breeding pairs (5 years after construction)


Photograph by Paul Hueber, Cornell Lab of Ornithology, used with permission.

Average 18 percent displacement of breeding pairs

To summarize, the average displacement for grassland bird pairs by 5 years posttreatment (that is, after turbine construction) was 53 percent, whereas average displacement for waterfowl was 18 percent (Shaffer and others, 2019). These are the displacement rates that will be used in the Avian-Impact Offset Method formula, which will be discussed in the rest of this section.



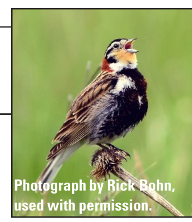
Thus far, this section has discussed calculations relating solely to determining percent displacement of birds. Percent displacement is 1 of 5 metrics needed to populate the Avian-Impact Offset Method. The rest of this section will illustrate how to incorporate percent displacement and the other four metrics into the method, remembering that the overall objective is to calculate the hectares of grasslands or wetlands needed to support the displaced breeding pairs (that is, how many hectares would be needed to offset the loss of suitable breeding habitat).

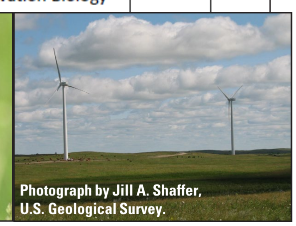
Avian-Impact Offset Method

Metrics in worksheet form

Shaffer, J. A., C. R. Loesch, and D. A. Buhl. 2019. Estimating offsets for avian displacement effects of anthropogenic impacts. Ecological Applications 29(8):e1983. 10.1002.eap.1983. Supporting Information.

Appendix S1. Table S3. Example 2. Calculation sheet developed to use the avian-impact offset method to estimate offsets for displaced breeding grassland bird pairs using hypothetical 6-turbine wind facility example.					Row 1
					2
Instructions:					3
1. Fill in Metric (i.e., numeric value for the parameter), Units, and Source column for rows 10-14.					4
2. If density is measured as number pairs per hectare, Impact Area should be measured in hectares. If density is measured as number pairs per wetland, Impact Area should be measured as number of wetlands.					5
3. Enter Percent Displacement as a number between 1 and 100.					6
4. The units for the Offset Area will be the area units from the Offset Density, e.g., if Offset Density is measured as pairs/ha then Offset Area will be ha and if Offset Density is measured as pairs/wetland then Offset Area is number of wetlands.					7
					8
Parameter	Metric	Units	Source	Formula	9
Impact Distance	300	m	Shaffer and Buhl (2016)		10
Impact Area	112	ha	Derived from GIS		11
Pre-Impact Density	1.9	pairs/ha	Shaffer and Buhl (2016)		12
Percent Displacement	53	percent	This paper		13
Offset Density	1.9	pairs/ha	Equal Value Habitat		14
Number Pairs in Impact Site	***213***	***pairs***		***B15 = B11*B12***	15
Number Pairs Displaced	***113***	***pairs***		***B16 = B15*(B13/100)***	16
Offset Area	***59***	***ha***		***B17 = B16/B14***	17
Column A	B	C	D	E	
Shaffer, J. A., and D. A. Buhl. 2016. Effects of wind-energy facilities on grassland bird distributions. Conservation Biology 30:59-71.					

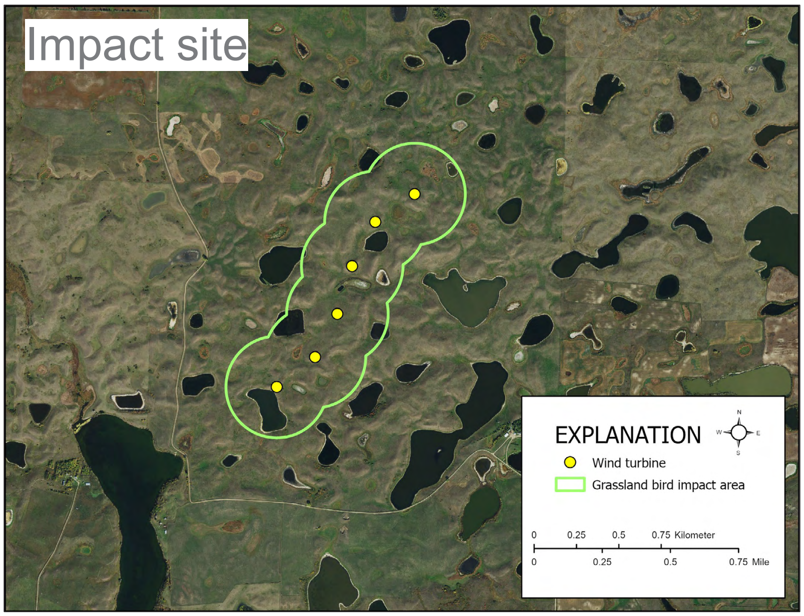

Photograph by Rick Bohn, used with permission.


Photograph by Jill A. Shaffer, U.S. Geological Survey.

A series of Excel worksheets containing these metrics and illustrating real-world examples are available in appendix S1 of Shaffer and others (2019). The image on this page is appendix S1, table S3, example 2, which is the example for grassland birds and wind turbines. This image is used with permission (image not altered). The next few images will show how to apply the Avian-Impact Offset Method to example for grassland birds and wind turbines.

Computation of area needed to support displaced pairs of grassland birds

Example of a 6-turbine wind facility in the Prairie Pothole Region



Impact Distance = 300 m

Impact Area (a)

= 112 ha (277 ac)

Pre-Impact Density (d_1)

= 1.9 pairs per ha

Percent Displacement (r)

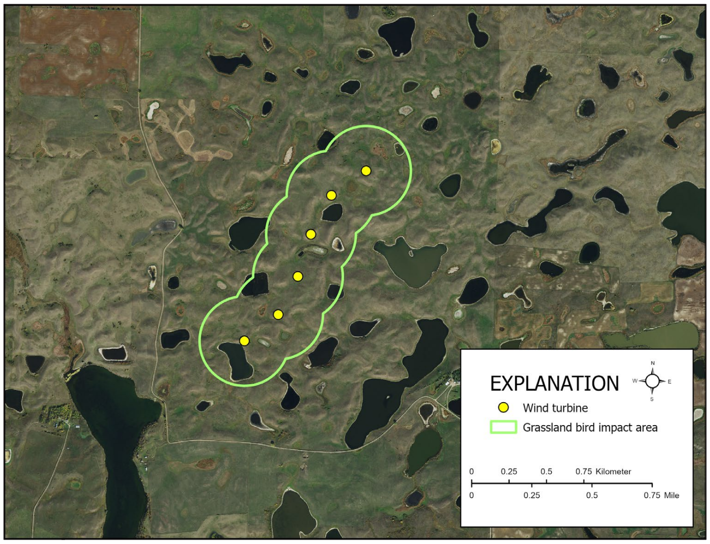
= 53%

To illustrate how to estimate compensatory area for grassland birds, an example will be used based on a hypothetical six-turbine wind facility placed within a typical prairie pothole landscape. An impact distance of 300 meters was used to calculate the zone of influence because Shaffer and Buhl (2016) reported that 87 percent of significant displacement effects were within 300 meters of turbines. Based on this impact distance, the impact area within the buffer zone around the turbines is about 112 hectares, the calculation of which can be obtained using a geographic information system (Environmental Systems Research Institute, 2018). Note that this value reflects the acreage of breeding habitat for grassland birds; thus, wetland acreage and nonbreeding habitats within the buffer would be removed.

The value of 1.9 pairs per hectare as the pre-impact density was obtained from the analysis of variance estimates for grassland birds in Shaffer and Buhl (2016), and the average value for percent displacement of 53 percent for grassland birds was obtained from Shaffer and others (2019).

Abbreviation explanations for image: [m, meter; ha, hectare; ac, acre; %, percent]

Computation of area needed to support displaced pairs of grassland birds



Step 1

Calculate number of breeding pairs within impact area

p = no. pairs within 300-m buffer zone

$= a \times d_1$

112 ha x 1.9 pairs per ha = 213 pairs

Impact Area (a) = 112 ha, or 277 ac

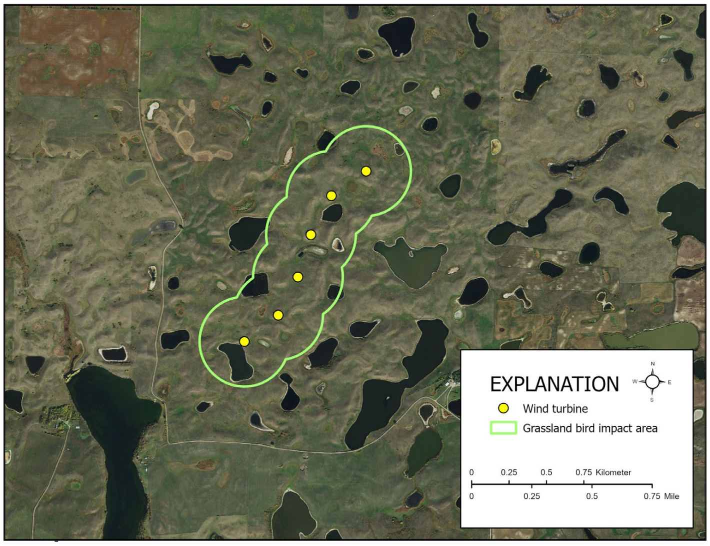
Pre-Impact Density (d_1) = 1.9 pairs per ha

Percent Displacement (r) = 53%

Step 1: Calculate the number of breeding pairs within the area impacted by energy infrastructure using impact area multiplied by pre-impact density ($a \times d_1$). In this example, 112 hectares x 1.9 pairs per hectare equals 213 breeding pairs of grassland birds (of the eight focal species) within the impact area.

Abbreviation explanations for image: [no., number; m, meter; ha, hectare; ac, acre; %, percent]

Computation of area needed to support displaced pairs of grassland birds



Step 2

Calculate number of breeding pairs displaced

No. pairs displaced = p x r

213 pairs x 0.53 =

113 pairs

Impact Area (a) = 112 ha, or 277 ac

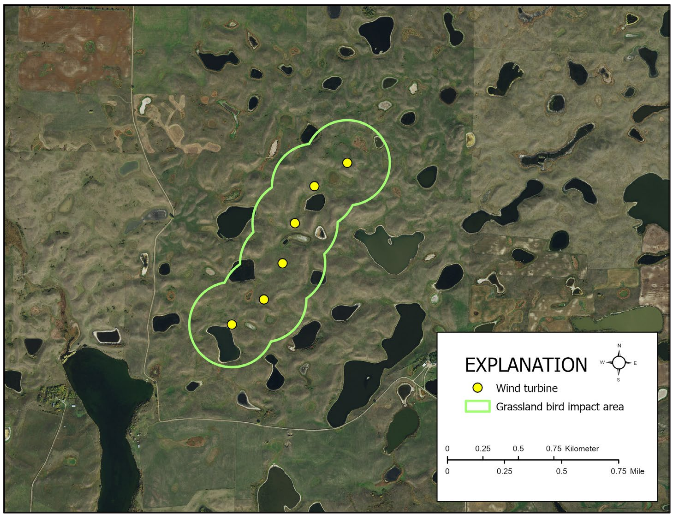
Pre-Impact Density (d_1) = 1.9 pairs per ha

Percent Displacement (r) = 53%

Step 2: Calculate the number of displaced pairs in the impact area using pairs multiplied by percent displacement (*p* x *r*), which would be 213 pairs x 53 percent equals 113 breeding pairs.

Abbreviation explanations for image: [no., number; m, meter; ha, hectare; ac, acre; %, percent]

Computation of area needed to support displaced pairs of grassland birds



Step 3

Calculate amount of habitat needed to offset the displaced breeding pairs

No. pairs displaced / Offset Density

113 pairs / 1.9 pairs per ha = 59 ha (146 ac)

Pre-Impact Density (d_1) = 1.9 pairs per ha = Offset Density (d_2) = 1.9 pairs per ha

Impact Site and Offset Site have Equivalent Biological Value

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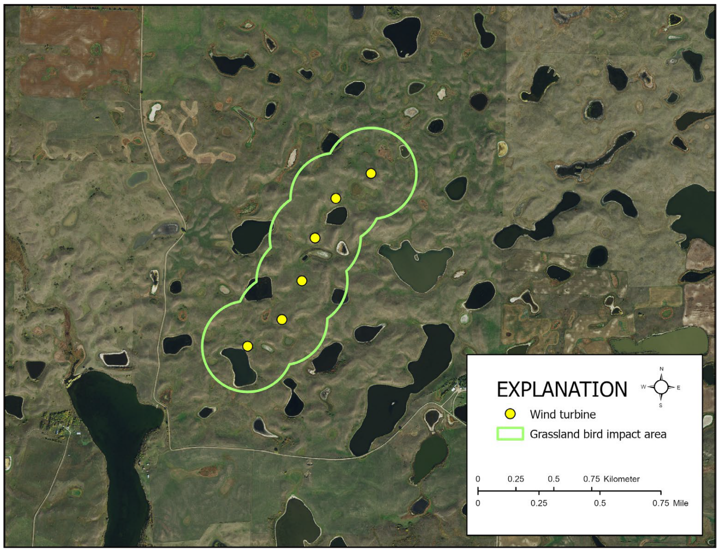
Step 3: Calculate the amount of habitat needed to offset the displaced breeding pairs. On this image, there is the assumption that the offset density is equal to pre-impact density at 1.9 pairs per hectare, making the amount of habitat needed to compensate for the displaced pairs to be 59 hectares. The assumption of equal densities would apply in situations in which the offset site and the impact site are of the same ecosystem type in the same geographical location, under the same land use, and embedded in the same landscape matrix of land uses. For the example on this image, the sites are mixed-grass prairie in the Prairie Pothole Region that are grazed and that are embedded in a wetland-grassland complex characteristic of a prairie pothole landscape. Thus, this example assumes that the offset site and the impacted site have equivalent biological value.

Abbreviation explanations for image: [no., number; ha, hectare; ac, acre]

Computation of area needed to support displaced pairs of grassland birds



Simplification where
Impact Density = Offset Density

Area needed to support displaced pairs

$$= p \times r / d$$

$$= a \times \cancel{d} \times r / \cancel{d}$$

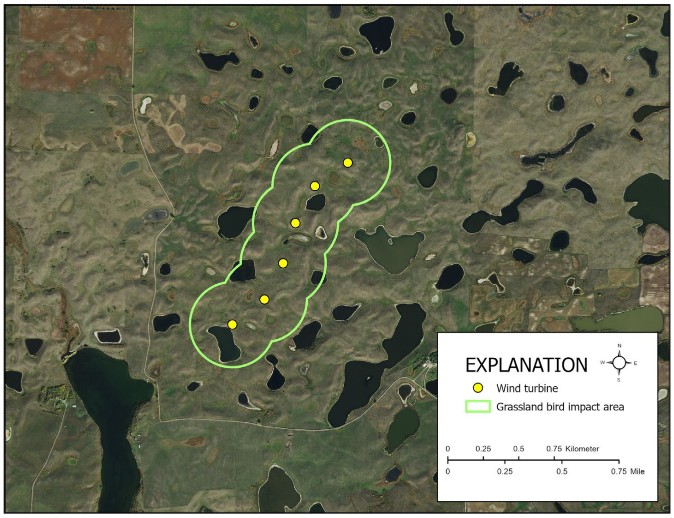
$$= a \times r$$

112 ha x 0.53 = 59 ha (146 ac)

Steps 1, 2, and 3 can be shortened in the situation where the offset site and the impact site have equivalent biological value, otherwise stated as the offset density is equal to pre-impact density. The equation simply becomes area (*a*) x displacement rate (*r*), or 112 hectares x 0.53 (that is, 53 percent). Thus, 59 hectares would be needed to compensate for the displacement of the 113 grassland birds used in this example.

Abbreviation explanations for image: [p, number of pairs within 300-meter buffer zone; r, percent displacement; d, pre-impact density; a, impact area; ha, hectare; ac, acre]

Computation of area needed to support displaced pairs of grassland birds



Where Pre-Impact Density ≠ Offset Density

No. pairs displaced / Offset Density

113 pairs / 1.5 pairs per ha = 75 ha (185 ac)

Pre-Impact Density (d_1) = 1.9 pairs / ha ≠ Offset Density (d_2) = 1.5 pairs per ha

Impact Site and Offset Site are NOT of Equivalent Biological Value

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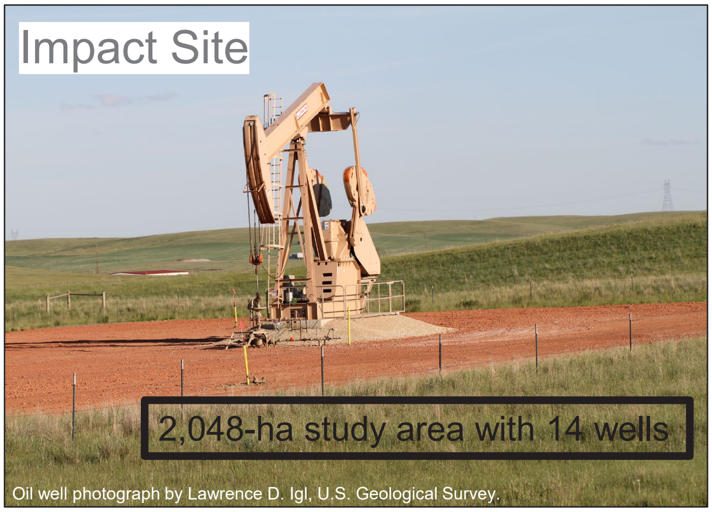
Step 3: Under the assumption that the biological value of the offset site is not equal to the biological value of the impact site (for example, a situation in which the only available offset habitat was a different habitat, such as a restored grassland), one would need to determine density of breeding-bird pairs for the restored grassland. For demonstrative purposes of this example, the offset density is determined to be a hypothetical 1.5 pairs per hectare. The amount of habitat needed to support the displaced bird pairs would then be 75 hectares of restored grassland. Offset density can be estimated using a variety of sources, including field-based surveys or published sources of avian density within the relevant habitat and geographic location.

Abbreviation explanations for image: [≠, not equal to; no., number; ha, hectare; ac, acre]

Computation of area needed to support displaced pairs of grassland birds—Oil/Gas example



Impact Distance, Wells = 350 m

Impact Distance, Roads = 150 m

Impact Area (a)

= 942 ha (2,328 ac)

Pre-Impact Density (d_1)

= 3.182 pairs per ha

Percent Displacement (r)

= 33%

Area needed to support displaced pairs = 311 hectares

For an example in applying the Avian-Impact Offset Method to oil and gas infrastructure, the values from Thompson and others (2015) are used to populate the Avian-Impact Offset Method formula. Thompson and others (2015) measured avoidance of unconventional oil wells for 10 species of grassland birds in mixed-grass prairies in northwestern North Dakota. The information needed to apply the Avian-Impact Offset Method was provided in figure 4D of their publication. The figure depicts a 2,048-hectare study area of grassland in which 14 wells are placed and associated roads buffered by their respective impact distances. The impact distance was 350 meters for oil wells and 150 meters for roads. The authors determined that 46 percent of the study area was impacted, so the impact area is 942 hectares (2,048 x 0.46). Pre-impact density was reported as 3.182 pairs per hectare (appendix A of Thompson and others, 2015). The authors cite a percent displacement of 33 percent. To simplify the calculations for illustrative purposes, the assumption was made that the offset habitat is biologically equivalent to the impact habitat so that the pre-impact density and the offset density are the same value. As a result, the estimated amount of mixed-grass prairie habitat necessary to replace the grassland bird pairs displaced by oil wells and roads in this particular scenario was 311 hectares (942 hectares x 33 percent displacement).

Abbreviation explanations for image: [m, meters; ha, hectare; ac, acre; %, percent]

Shaffer, J. A., C. R. Loesch, and D. A. Buhl. 2019. Estimating offsets for avian displacement effects of anthropogenic impacts. Ecological Applications 29(8):e1983. 10.1002.eap.1983. Supporting Information.

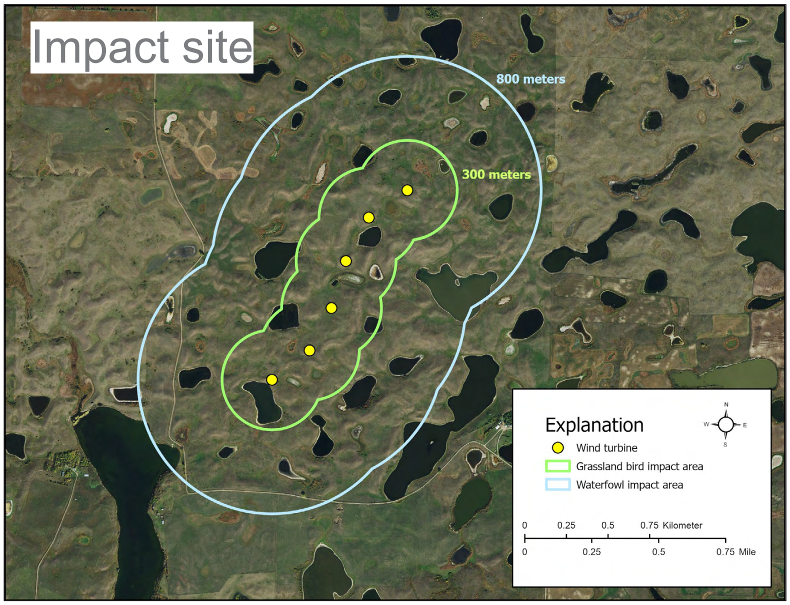
Appendix S1. Table S4. Example 3. Calculation sheet developed to use the avian-impact offset method to estimate offsets for displaced breeding grassland bird pairs using an oil-extraction infrastructure example.					Row 1
					2
Instructions:					3
1. Fill in Metric (i.e., numeric value for the parameter), Units, and Source column for rows 10-14.					4
2. If density is measured as number pairs per hectare, Impact Area should be measured in hectares. If density is measured as number pairs per wetland, Impact Area should be measured as number of wetlands.					5
3. Enter Percent Displacement as a number between 1 and 100.					6
4. The units for the Offset Area will be the area units from the Offset Density, e.g., if Offset Density is measured as pairs/ha then Offset Area will be ha and if Offset Density is measured as pairs/wetland then Offset Area is number of wetlands.					7
					8
Parameter	Metric	Units	Source	Formula	9
Impact Distance	350/150	m; wells/roads	Thompson et al. (2015)		10
Impact Area	942	ha	Thompson et al. (2015)		11
Pre-Impact Density	3.2	pairs/ha	Thompson et al. (2015)		12
Percent Displacement	33	percent	Thompson et al. (2015)		13
Offset Density	3.2	pairs/ha	Equal Value Habitat		14
Number Pairs in Impact Site	***3014***	***pairs***		***B15 = B11*B12***	15
Number Pairs Displaced	***995***	***pairs***		***B16 = B15*(B13/100)***	16
Offset Area	***311***	***ha***		***B17 = B16/B14***	17
Column A	B	C	D	E	
Thompson, S. J., D. H. Johnson, N. D. Niemuth, and C. A. Ribic. 2015. Avoidance of unconventional oil wells and roads exacerbates habitat loss for grassland birds in the North American Great Plains. Biological Conservation 192:82-90.					

Bird photograph by Rick Bohn, used with permission.
Oil well photograph by Lawrence D. Igl, U.S. Geological Survey.

This is the table provided in appendix S1, table S4, example 3 of Shaffer and others (2019) that demonstrates how to populate the Avian-Impact Offset Method formula for the grassland bird and oil/gas scenario. The image is used with permission (image not altered).

Computation of area needed to support displaced pairs of waterfowl

Example of a 6-turbine wind farm in the Prairie Pothole Region



Impact Distance = 800 m

Impact Area (a)

= no. wetlands

109 wetland basins

Pre-Impact Density (d_1)

= no. pairs per wetland

1.82 duck pairs

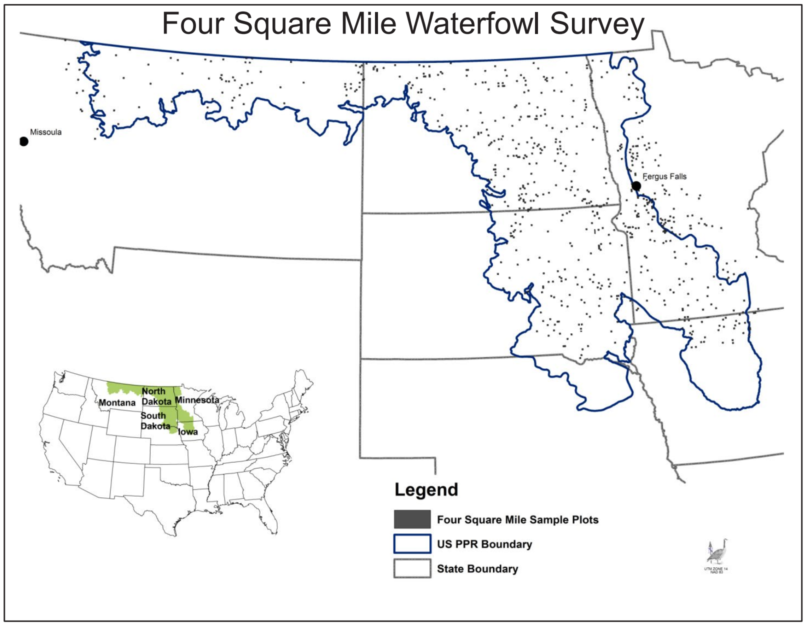
Percent Displacement (r)

= 18%

An example based on the same hypothetical six-turbine wind facility used for the grassland bird example will be used to illustrate how to estimate compensatory area for waterfowl. An 800-meter buffer is used for the impact distance. Loesch and others (2013) chose 800 meters because it is one-half the radius of an average circular home range for a mallard hen, which ensures overlap of breeding territories with nearby wind turbines. Recall that impact area is defined as the spatial extent of affected habitat. For waterfowl, the affected habitat is the number of wetland basins within 800 meters, which is 109 as determined from a geographic information system (Environmental Systems Research Institute, 2018) for the particular scenario pictured. In the geography in which this example occurs (that is, the Prairie Pothole Region of the United States), 86 percent of the 3.4 million wetland basins mapped by the U.S. Fish and Wildlife Service National Wetlands Inventory program (Wilen and Bates, 1995) are less than or equal to 0.80 hectare, and thus the National Wetlands Inventory provides a measurable unit of number or area of wetlands.

Abbreviation explanations for image: [m, meters; no., number; %, percent]

Computation of area needed to support displaced pairs of waterfowl



Step 1

Calculate number of breeding pairs within impact area

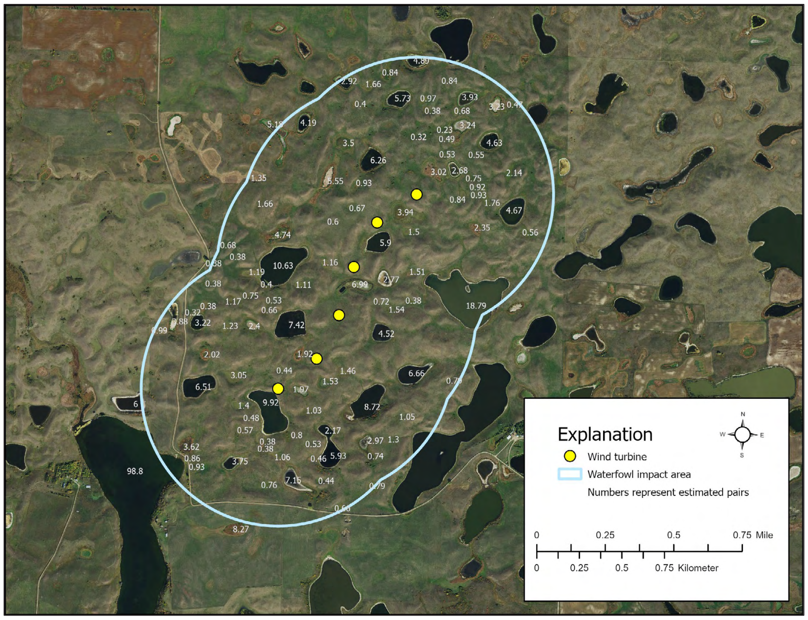
Pre-Impact Density (d_1)

d_1 = average number of breeding duck pairs per wetland within the impact area

d_1 = 1.82 duck pairs per wetland

Step 1: Determine a pre-impact density, for which the estimate of the number of duck pairs from each of the 109 wetland basins is needed. Those abundance estimates were obtained from models generated from data collected by the Four-Square-Mile Breeding Waterfowl Survey (Reynolds and others, 2006). This survey records habitat conditions and number of waterfowl pairs in the Prairie Pothole Region and is conducted by the U.S. Fish and Wildlife Service offices of the Habitat and Population Evaluation Team. The Bismarck, North Dakota, and Fergus Falls, Minnesota, offices have conducted surveys since 1987, and the Great Falls, Montana, office since 2005. Pair-prediction models have been developed for five species of dabbling ducks (blue-winged teal, gadwall, mallard, northern pintail, northern shoveler) and for four wetland classes (temporary, seasonal, semipermanent, and lake) (Reynolds and others, 2006). Pair estimates represent the estimated average number of breeding duck pairs that would be expected to occupy a target wetland during average wetland conditions (in the absence of wind-energy production). Based on the models, the average number of duck pairs per wetland in the buffer zone around the 6-turbine wind example is estimated at 1.82, and this number is the estimated pre-impact density.

Computation of area needed to support displaced pairs of waterfowl



Step 1

Calculate number of breeding pairs within impact area

p = no. pairs within 800-m buffer zone

$= a \times d_1$

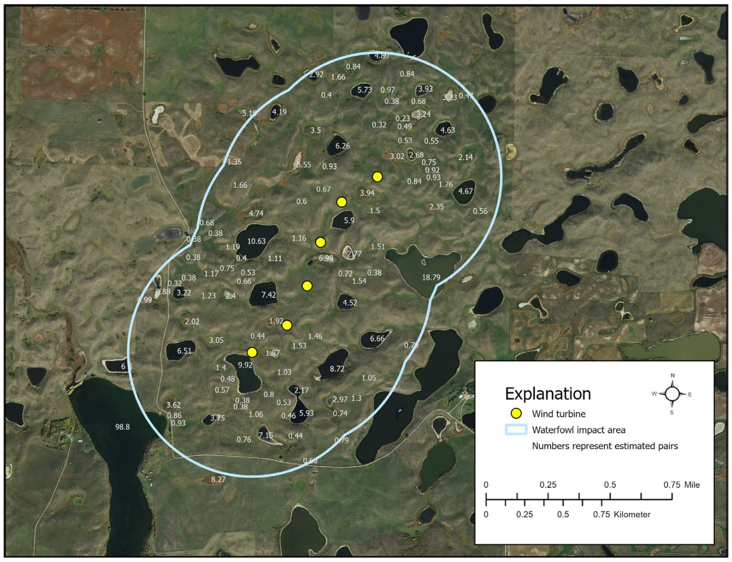
= 109 wetlands x 1.82 duck pairs per wetland

= 198 duck pairs

Step 1: Thus, the 109 wetland basins within the 800-meter radius of wind turbines would support an estimated 198 duck pairs (109 wetlands x 1.82 duck pairs per wetland).

Abbreviation explanations for image: [no., number; m, meters; a, impact area; d_1, pre-impact density]

Computation of area needed to support displaced pairs of waterfowl



Step 2

Calculate number of breeding pairs displaced

No. pairs displaced = p x r

198 pairs x 0.18 =

35.6 pairs

Impact Area (a) = 109 wetlands

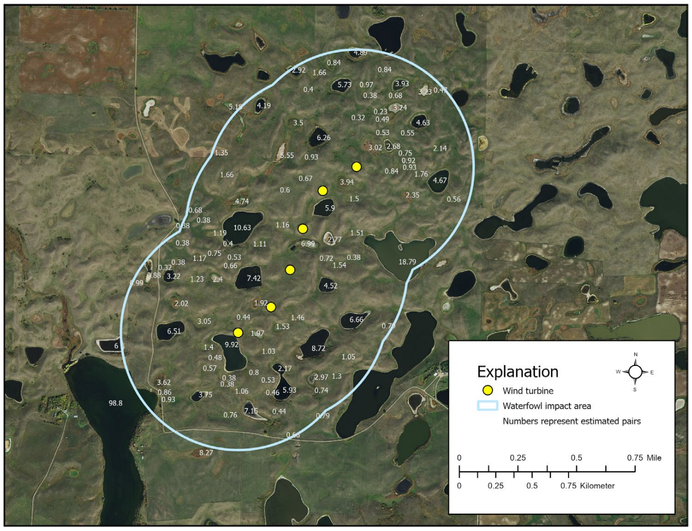
Pre-Impact Density (d_1) = 1.82 duck pairs per wetland

Percent Displacement (r) = 18%

Step 2. The number of breeding pairs displaced within an 800-meter radius of wind turbines is computed as pairs x displacement rate, or 198 breeding pairs x 18 percent = 35.6 breeding pairs displaced.

Abbreviation explanations for image: [no., number; p, number of pairs within 800-meter buffer zone; m, meters; %, percent]

Computation of area needed to support displaced pairs of waterfowl



Step 3

Calculate amount of habitat needed to offset the displaced breeding pairs

No. seasonal wetlands to restore

No. pairs displaced / Offset Density

Impact Distance = 800 m

Impact Area (a) = 109 wetlands

Pre-Impact Density (d_1) = 1.82 duck pairs per wetland

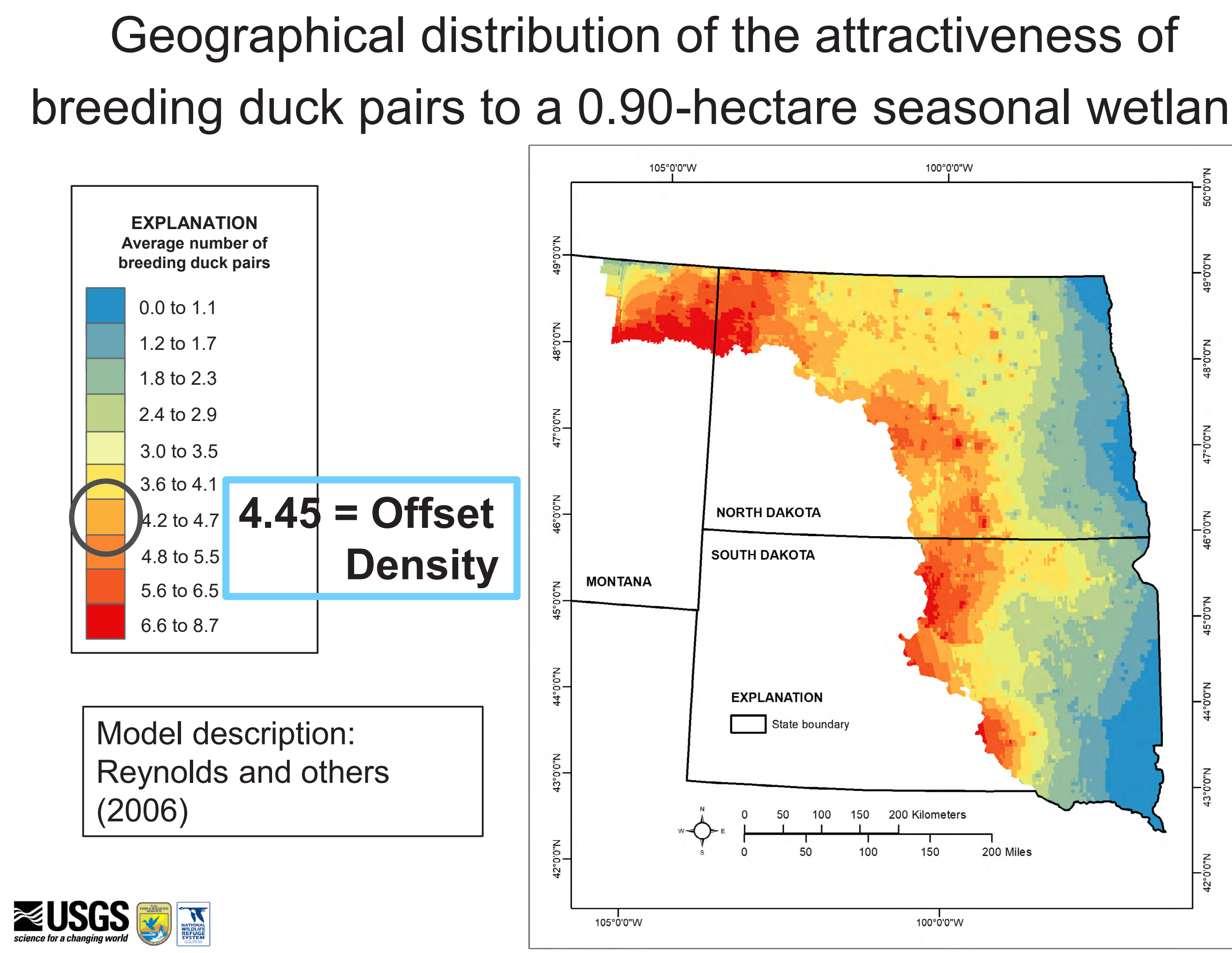
Percent Displacement (r) = 18%

35.6 pairs / 4.45 =

8 wetlands

Step 3: The next step calculates the number of hectares of seasonal wetlands to restore. The focus is on seasonal wetlands for two reasons. First, seasonal wetlands attract the highest densities of breeding pairs (Reynolds and others, 2006), and second, seasonal wetlands are the most restored wetland basin class (Loesch and others, 2012). Before this can be calculated, however, the offset density needs to be determined. The next image describes how the value of 4.45 was determined.

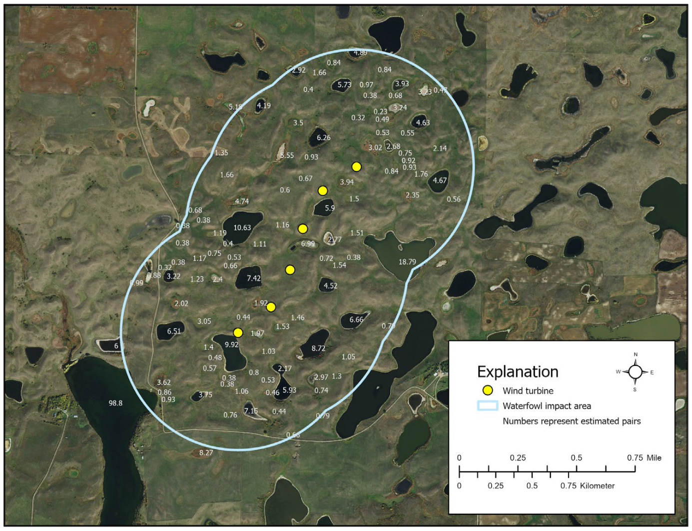
Abbreviation explanations for image: [no., number; m, meters; %, percent]



Step 3: Because of the importance of seasonal wetlands in the Prairie Pothole Region, the U.S. Fish and Wildlife Service modeled the geographic variation in the attractiveness of 0.90-hectare seasonal wetlands within the region for the five species of dabbling ducks. Application of this model allows one to make location-specific estimates of biological equivalence relative to the location of wind-energy development.

The six-turbine example occurred in a geographical location modeled to contain about 4.45 breeding duck pairs in a 0.90-hectare seasonal wetland; thus, 4.45 is the offset density in the example. The map image modified from Shaffer and others (2019) and used with permission.

Computation of area needed to support displaced pairs of waterfowl



Step 3

Calculate amount of habitat needed to offset the displaced breeding pairs

No. seasonal wetlands to restore

No. pairs displaced / Offset Density

35.6 pairs / 4.45 =

8 wetlands

Impact Distance = 800 m

Impact Area (a) = 109 wetlands

Pre-Impact Density (d_1) = 1.82 duck pairs per wetland

Percent Displacement (r) = 18%

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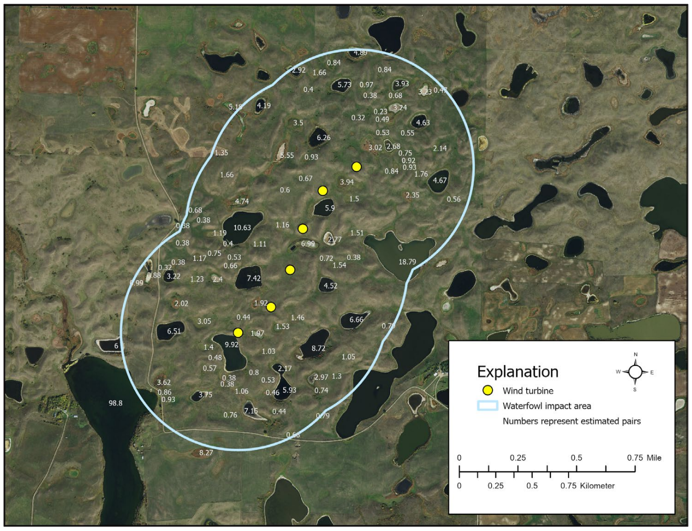
Step 3: To determine how many seasonal wetlands would need to be restored to compensate for the 35.6 duck pairs displaced within an 800-meter radius of wind turbines, the number displaced is divided by 4.45, yielding eight wetlands.

Abbreviation explanations for image: [no., number; m, meters; %, percent]

Computation of area needed to support displaced pairs of waterfowl



Step 3

Calculate amount of habitat needed to offset the displaced breeding pairs

No. hectares to restore

8 wetlands x 0.90 ha = 7.2 ha (18 ac)

Impact Distance = 800 m

Impact Area (a) = 109 wetlands

Pre-Impact Density (d_1) = 1.82 duck pairs per wetland

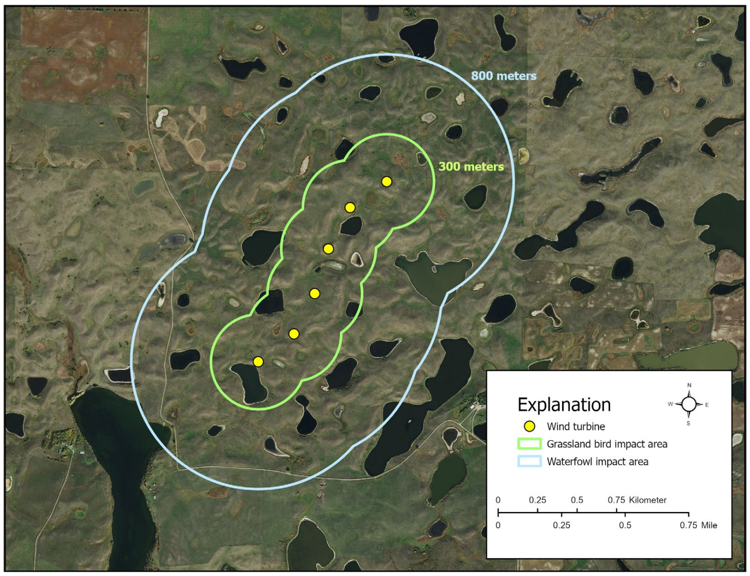
Percent Displacement (r) = 18%

Step 3: Recall that the average size and typical class of wetland restored by the Partners for Fish and Wildlife is a 0.90-hectare seasonal wetland. Multiplying 0.9 hectares by the number of wetlands provides the hectares needed to compensate for displaced birds. In the example, 7.2 hectares of seasonal wetlands would compensate for the loss of the displaced 35.6 duck pairs. Because there are higher densities of ducks on smaller than on larger wetlands (Reynolds and others, 2006; Loesch and others, 2012), the restoration of several small wetlands rather than of one large wetland will support more pairs.

Abbreviation explanations for image: [no., number; ha, hectares; ac, acres; m, meters; %, percent]

Summary of area needed to support pairs of grassland and wetland birds displaced within 300 and 800 meters of wind turbines

Example of a 6-turbine wind farm in the Prairie Pothole Region



59 hectares of grassland

7 hectares of seasonal wetlands

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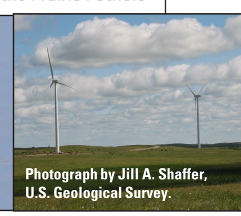
In summary, using the six-turbine string example, equivalent biological compensation for displaced grassland and waterfowl breeding pairs within 300 m and 800 m of wind turbines, respectively, would require 59 hectares of grassland to compensate for displaced grassland bird pairs and 7 hectares of seasonal wetlands to compensate for displaced waterfowl pairs.

Shaffer, J. A., C. R. Loesch, and D. A. Buhl. 2019. Estimating offsets for avian displacement effects of anthropogenic impacts. Ecological Applications 29(8):e1983. 10.1002.eap.1983. Supporting Information.

Appendix S1. Table S2. Example 1. Calculation sheet developed to use the avian-impact offset method to estimate offsets for displaced breeding waterfowl pairs using hypothetical 6-turbine wind facility example.					Row 1
					2
Instructions:					3
1. Fill in Metric (i.e., numeric value for the parameter), Units, and Source column for rows 10-14.					4
2. If density is measured as number pairs per hectare, Impact Area should be measured in hectares. If density is measured as number pairs per wetland, Impact Area should be measured as number of wetlands.					5
3. Enter Percent Displacement as a number between 1 and 100.					6
4. The units for the Offset Area will be the area units from the Offset Density, e.g., if Offset Density is measured as pairs/ha then Offset Area will be ha and if Offset Density is measured as pairs/wetland then Offset Area is number of wetlands.					7
					8
Parameter	Metric	Units	Source	Formula	9
Impact Distance	0.8	km	Loesch et al. (2013)		10
Impact Area	109	wetlands	Derived from GIS		11
Pre-Impact Density	1.82	pairs/wetland	Reynolds et al. (2006)		12
Percent Displacement	18	percent	This paper		13
Offset Density	4.5	pairs/wetland	Loesch et al. (2012)		14
Number Pairs in Impact Site	***198***	***pairs***		*B15 = B11*B12*	15
Number Pairs Displaced	***36***	***pairs***		*B16 = B15*(B13/100)*	16
Offset Area	***8***	***wetlands***		*B17 = B16/B14*	17
Column A	B	C	D	E	
Loesch, C. R., R. E. Reynolds, and L. T. Hansen. 2012. An assessment of re-directing breeding waterfowl conservation relative to predictions of climate change. Journal of Fish and Wildlife Management 3:1-22.					
Loesch, C. R., J. A. Walker, R. E. Reynolds, J. S. Gleason, N. D. Niemuth, S. E. Stephens, and M. A. Erickson. 2013. Effect of wind energy development on breeding duck densities in the Prairie Pothole Region. Journal of Wildlife Management					
Reynolds, R. E., T. L. Shaffer, C. R. Loesch, and R. R. Cox, Jr. 2006. The farm bill and duck production in the Prairie Pothole Region: increasing the benefits. Wildlife Society Bulletin 34:963-974.					

Photograph by Paul Hueber, Cornell Lab of Ornithology, used with permission.



Photograph by Jill A. Shaffer, U.S. Geological Survey.

This is the table provided in appendix S1, table S2, example 1 of Shaffer and others (2019) that demonstrates how to populate the Avian-Impact Offset Method formula for the waterfowl and wind scenario. The image is used with permission (image not altered).

Shaffer, J. A., C. R. Loesch, and D. A. Buhl. 2019. Estimating offsets for avian displacement effects of anthropogenic impacts. Ecological Applications 29(8):e1983. 10.1002.eap.1983. Supporting Information.

Appendix S1. Table S1. Calculation sheet developed to use the avian-impact offset method to estimate offsets for displaced breeding bird pairs.					Row 1
					2
Instructions:					3
1. Fill in Metric (i.e., numeric value for the parameter), Units, and Source column for rows 10-14.					4
2. If density is measured as number pairs per hectare, Impact Area should be measured in hectares. If density is measured as number pairs per wetland, Impact Area should be measured as number of wetlands.					5
3. Enter Percent Displacement as a number between 1 and 100.					6
4. The units for the Offset Area will be the area units from the Offset Density, e.g., if Offset Density is measured as pairs/ha then Offset Area will be ha and if Offset Density is measured as pairs/wetland then Offset Area is number of wetlands.					7
					8
Parameter	Metric	Units	Source	Formula	9
Impact Distance					10
Impact Area					11
Pre-Impact Density					12
Percent Displacement		percent			13
Offset Density					14
Number Pairs in Impact Site		***pairs***		***B15 = B11*B12***	15
Number Pairs Displaced		***pairs***		***B16 = B15*(B13/100)***	16
Offset Area				***B17 = B16/B14***	17
Column A	B	C	D	E	

Finally, there is a blank worksheet in appendix S1, table S1 of Shaffer and others (2019) for practitioners to populate the required metrics of the Avian-Impact Offset Method formula for their own specific example. The image is used with permission (image not altered).

Section 3 Summary

The Avian-Impact Offset Method (AIOM) is a formula that calculates the displacement impact of anthropogenic disturbances on grassland bird and waterfowl pairs by determining the number of hectares of grasslands and wetlands that would be necessary to support those displaced pairs.

The AIOM is applicable for disturbances including solar, oil, gas, and road infrastructure.

The AIOM consists of four Impact Metrics and one Offset Metric.

Calculations for determining average percent displacement were illustrated for two studies.

Demonstrations of the AIOM for four scenarios were provided, using examples for grassland birds and wind and oil infrastructure, including cases in which the biological value of offset habitat is equal to the impacted habitat and when biological value is not equal, and for waterfowl and wind infrastructure.

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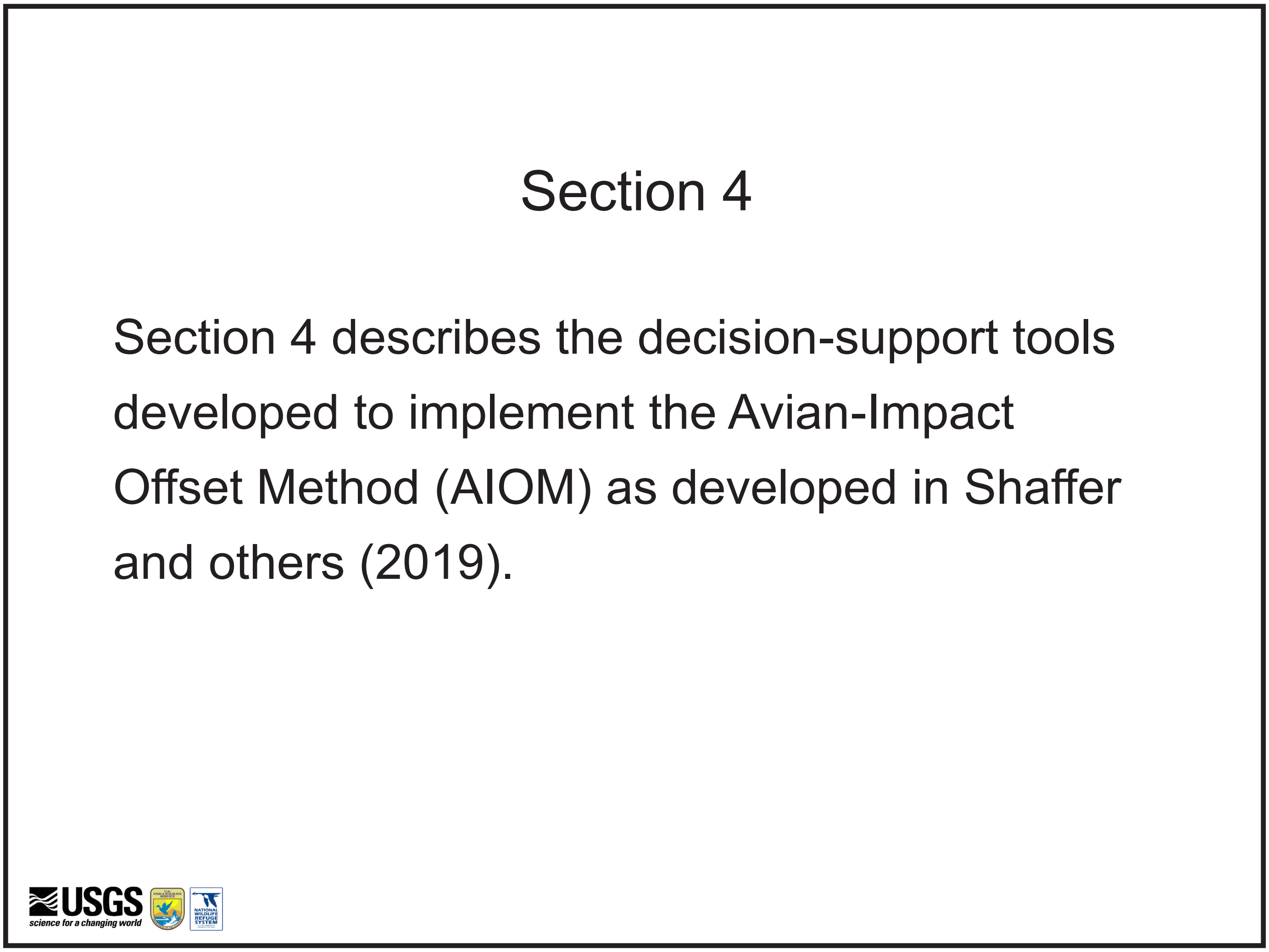
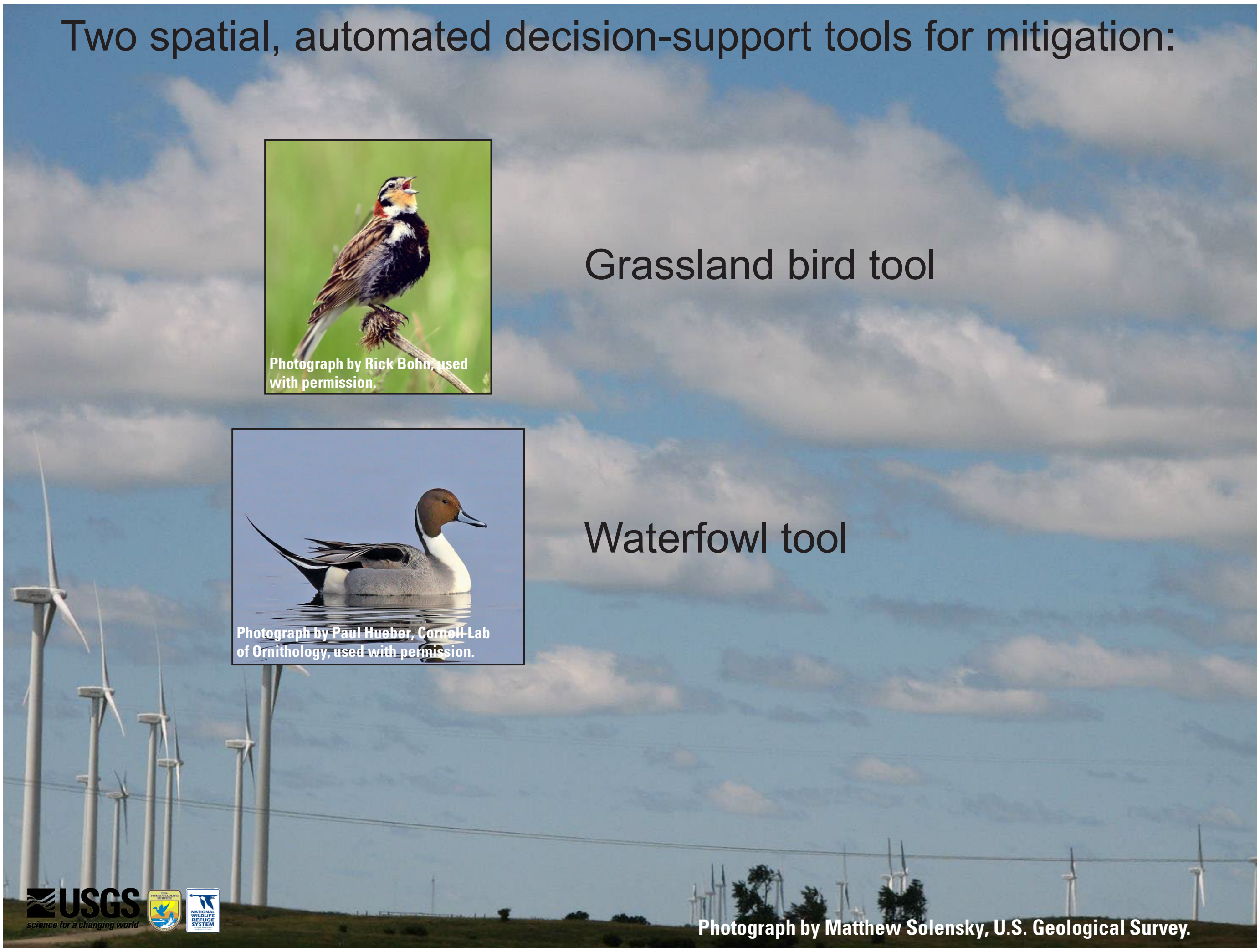
After completing Section 3, take a moment to reflect on the contents.

Section 4—Decision-Support Tools



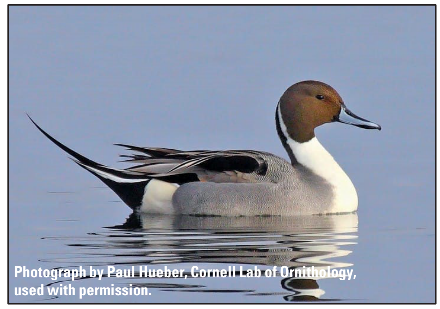
This section describes the decision-support tools developed to implement the Avian-Impact Offset Method.



There are two decision-support tools. One tool was developed with biological inputs specific for grassland birds, whereas the second tool was developed with biological inputs specific for waterfowl.

Decision-support tools

Application 1: Automating the AIOM



The AIOM tools provide an automated calculation of biological value similar to the AIOM and the ability to visualize the Impact Area.

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There are three primary applications of each tool. One application is to provide an automated calculation of biological value similar to the Avian-Impact Offset Method (AIOM) and the ability to visualize the impact area.

Decision-support tools

Application 2: Finding suitable offset sites for grassland birds after development

After development: Useful for evaluating a pool of potential offset sites to identify the site predicted to have the most similar biological value to the impact site

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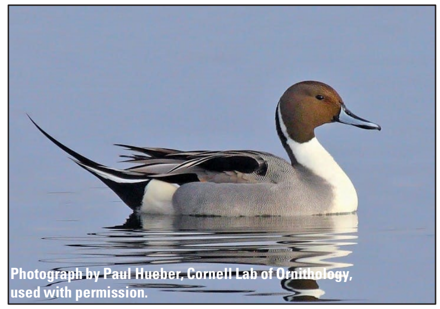
The second application is designed for the situation after infrastructure development siting has occurred and an offset site(s) needs to be located. The decision-support tools can evaluate a pool of potential offset sites to identify the site(s) predicted to have the most similar biological value to the impact site. For grassland birds, that means identifying the site where the estimated average probability of occurrence is most equal to that of the impact site. For waterfowl, that means identifying the number of pairs displaced, the acres of seasonal wetland necessary to provide habitat for the displaced pairs, and the number of 0.90-hectare (2.2-acres) seasonal wetlands in the associated county that need to be restored to provide habitat for the displaced pairs.

Decision-support tools

Application 3: Estimating impact of potential developments


Photograph by Rick Bohn, used with permission.


Photograph by Paul Hueber, Cornell Lab of Ornithology, used with permission.

Prior to development: Evaluates a pool of sites being considered for development by estimating and comparing the biological value that would be impacted if development were to occur.

The third application of the decision-support tools is designed to evaluate a pool of sites being considered for infrastructure development to estimate the biological value that would be impacted (lost) if development were to occur on that site. Using wind facilities as an example, a developer could conduct an evaluation prior to the siting of a wind facility by running simulations at multiple locations to identify project-level impacts. A developer also could conduct this evaluation after the siting of a wind facility, but before finalization of individual turbine locations, and run simulations to evaluate the impact of individual siting decisions. By comparing the development impact among multiple sites or among individual locations, a developer could choose to develop the site that will have minimal impact to biological value, and thus, the site that will incur the lowest mitigation cost.

Decision-support tools

ArcMap 10.6.1 and ArcPro 2.7.4

Install the AIOM ArcToolBox and supporting geodatabases.

Refer to Instruction Guide (see Appendix 3).

[AIOM, Avian Impact Offset Method]

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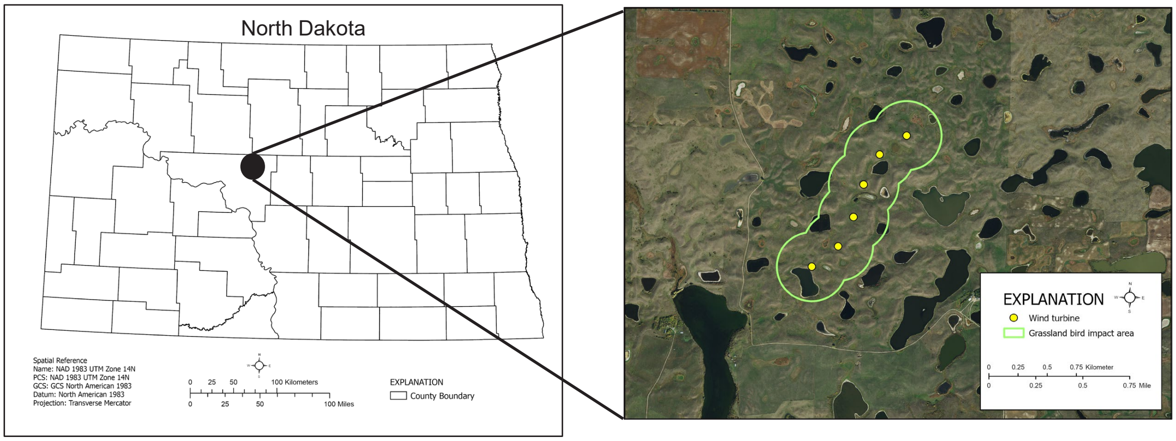
Section 4 describes the decision-support tools for use with ArcMap version 10.6.1 and ArcPro version 2.7.4. These tools likely will not work with ArcMap versions earlier than this. To describe the process of applying the Avian-Impact Offset Method to the decision-support tools, that same hypothetical six-turbine wind facility used in the “Avian-Impact Offset Method” section will be used. Accompanying instructions are available in appendix 3.

Decision-support tools

Inputs of spatial data



Obtain spatial layers delineating specific locations of anthropogenic infrastructure.

An aerial image of the impact location may be helpful for visualization (the image shows a hypothetical location).

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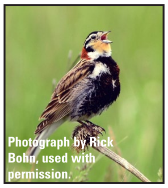
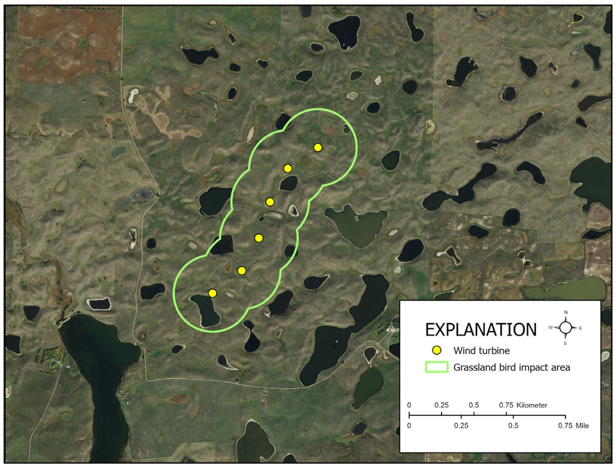
An aerial image of the impact location can be obtained as a helpful visual, but an image is not necessary for the analysis using the decision-support tools. Note that the impact location on the image is hypothetical. This imagery is from the National Agriculture Imagery Program (U.S. Department of Agriculture, 2019). What is necessary is a point, line, or polygon shapefile or feature class of the relevant infrastructure to be processed by the Avian-Impact Offset Method tools.



Grassland bird decision-support tool

Application 1: automating the AIOM



[m, meters; ha, hectare; ac, acre; %, percent]

Recall the example from Section 3, taken from Shaffer and others (2019):

Impact Distance = 300 m*

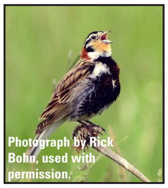
Impact Area (a) = 112 ha (277 ac)

Pre-Impact Density (d_1) = 1.9 pairs per ha

Percent Displacement (r) = 53%*

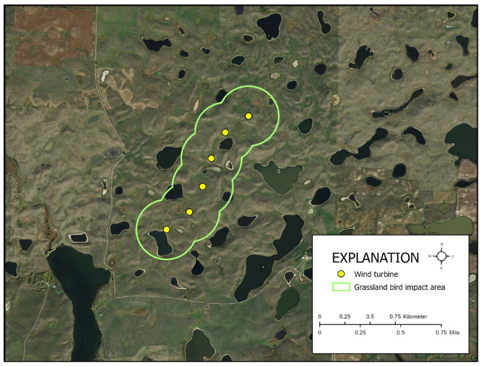
*These are the default values for the grassland bird decision-support tool.

The grassland bird tool contains a dialog box in which the spatial and biological metrics required to calculate the estimated impact can be input. Default values from Shaffer and others (2019) are used for impact distance and percent displacement unless field-derived values are available. An important detail to note is that the decision-support tool calculates final output in acres rather than hectares.

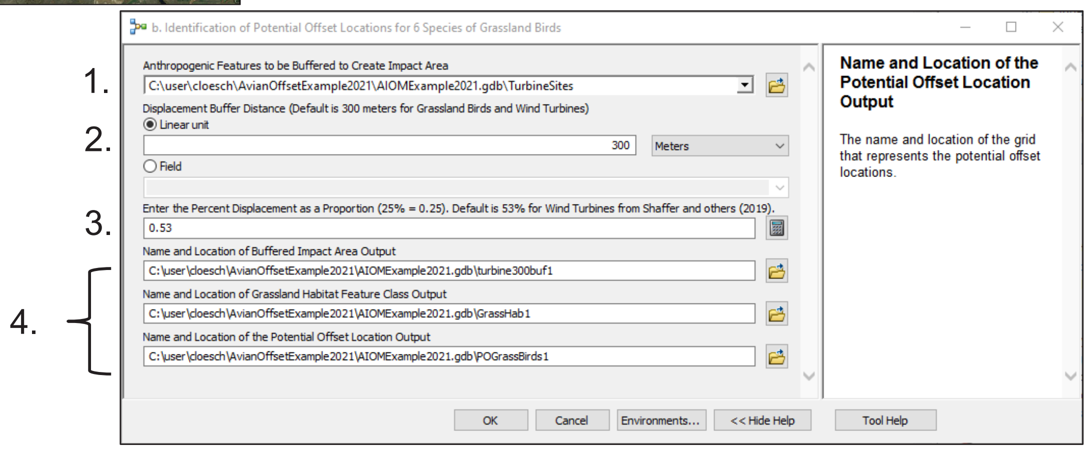


Grassland bird decision-support tool

Application 1: automating the AIOM—ArcMap

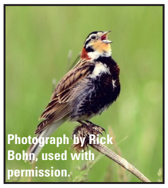


1. Input feature to be buffered—here, a point file of turbine locations
2. Input Impact Distance—default value is 300 meters.
3. Input Percent Displacement—default is 53 percent.
4. User to enter where outputs are to be stored.



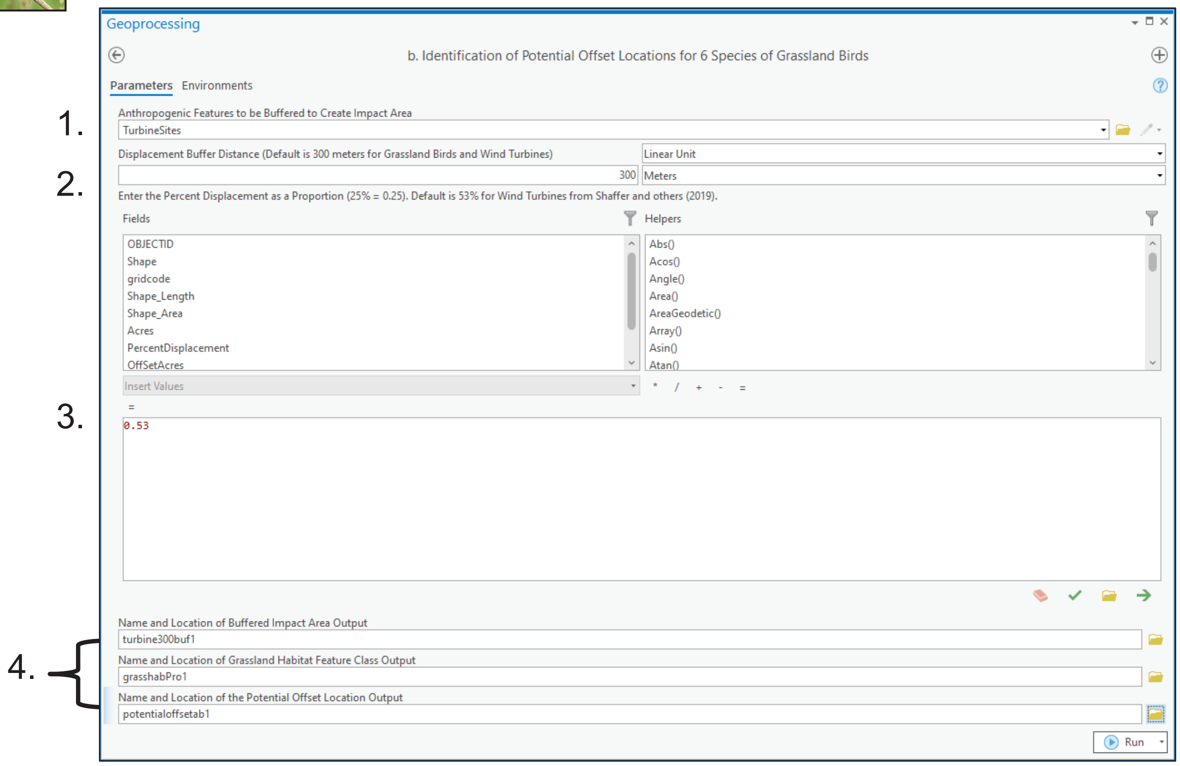
Here is a step-by-step description of how to use the grassland bird decision-support tool in ArcMap to apply the Avian-Impact Offset Method (AOIM).

1. Select a point, line, or polygon file with the locations of the anthropogenic disturbance. In this example, a point file with six turbine locations is used.
2. The impact distance uses the default value of 300 meters (the default value can be replaced with field-derived data if available, or data from other sources of published literature).
3. The input percent displacement uses the default value of 53 percent, entered as 0.53 (the default value can be replaced with field-derived data if available, or data from other sources of published literature).
4. The user enters the names of the files and locations on the computer where outputs will be stored for the buffered impact area, the grassland habitat feature class, and the potential offset location.

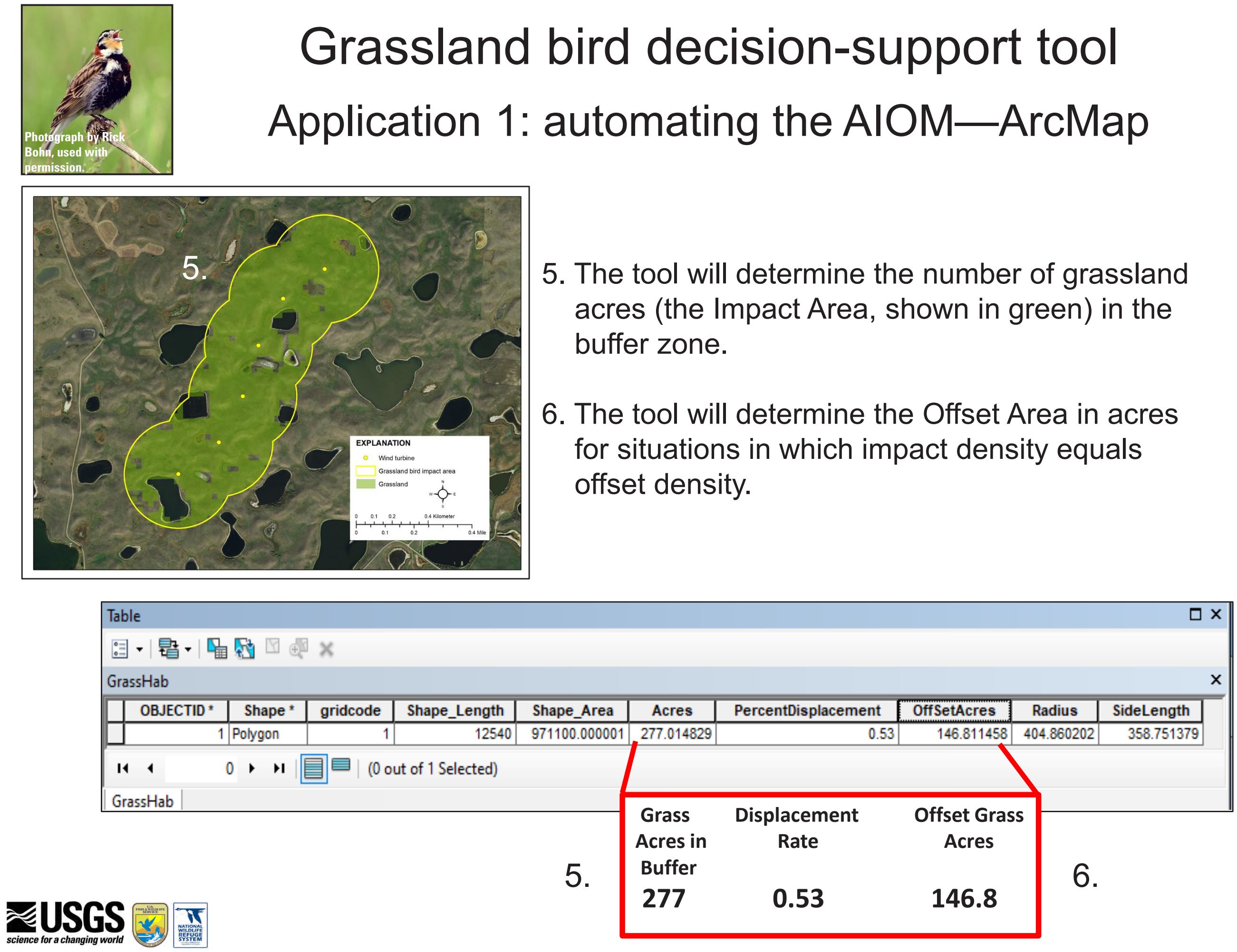


Grassland bird decision-support tool

Application 1: automating the AIOM—ArcPro



The steps for ArcPro 2.7.4 are the same as for ArcMap 10.6.1, but the dialog box looks slightly different. The numbers along the side of the dialog box correspond to the steps in the previous slide.

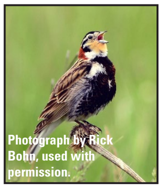


5. The decision-support tool will determine the number of grassland acres (that is, the impact area, shown in green) in the buffer zone.

Note that the tool codes grassland habitat as "1" [under OBJECTID] if the underlying habitat in the National Land Cover Dataset (Homer and others, 2020) is native prairie, hayland, pasture, or grassland enrolled in the Conservation Reserve Program, and these habitats are tabulated as impact area. All other habitats are coded as "0" and removed from the area tabulated as the impact area.

6. The tool will then determine the offset area—the number of acres that would be needed to compensate for the displaced bird pairs. Again, note that the decision-support tool uses acres rather than hectares.

Note that the tool is designed for situations where impact density equals offset density. The decision-support tool does not have fields with which to enter density values. Recall that the worksheet available in appendix S1, table S3 in Shaffer and others (2019) can be used in situations where impact density and offset density are not equal.



Grassland bird decision-support tool

Application 2: finding suitable offset sites after development

Challenge:

How to predict where on the landscape there might be patches of grassland habitat of similar biological value to the impacted site, when biological value is measured as avian density or occurrence.

Answer:

Apply the models of Niemuth and others (2017)

- These models provide relative probability of occurrence values that can be used to estimate biological value.

The next application for which the decision-support tools can be used is finding where on the landscape a suitable offset site might be located. The challenge in finding suitable offset sites for the purposes of compensatory mitigation is determining the biological value of potential candidate sites. The ideal method for determining biological value of potential candidate offset sites would be field-based avian surveys to determine actual avian species composition and density, which are time- and labor-intensive and incur cost. In situations where field-based surveys are not feasible, models that predict where certain species occur and in what numbers can serve as a substitute. The models of Niemuth and others (2017) serve such a role, for they provide relative probability of occurrence values that can be used to estimate biological value.

Where birds occur is a function of many, often interrelated, factors

Models try to account for the influence of these factors

Examples of some factors:

Species' distribution range

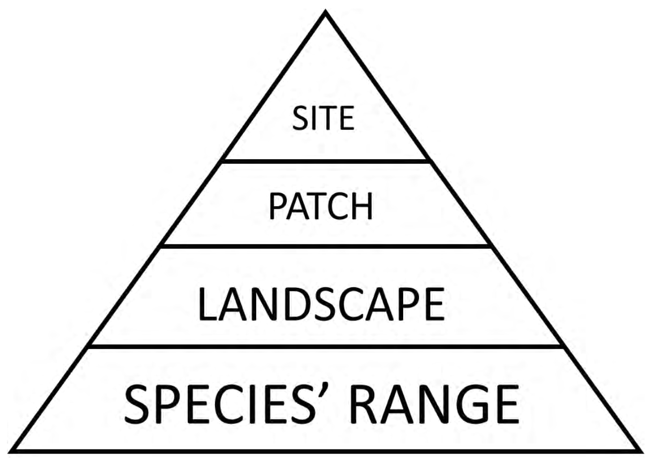
Climate, topography, elevation

Landcover and management

Observer ability

Survey timing

Hierarchical levels influencing where a bird occurs



The models of Niemuth and others (2017) were chosen for several reasons: their models are based on the same geographical area as the hypothetical example and the field research of Shaffer and Buhl (2016), and thus, there is similar overlap in the species composition between the two studies; and the models of Niemuth and others (2017) account for a number of important factors that affect why birds occur where they do.

Where a bird settles is often described by biologists as a hierarchical decision, with a bird considering a particular nesting site based on "local" factors (such as vegetation structure within the field—or patch) as well as "landscape" factors (such as how much of the surrounding countryside is developed for residential or industrial uses or for agricultural or conservation uses). Often, these local and landscape factors are affected by land-management decisions such as whether lands are planted to a row crop, such as corn (*Zea mays*), for an agricultural product or are planted to grasses to provide livestock forage or wildlife habitat. Natural features, such as the elevation, topography, and soil-profile characteristics, also influence avian habitat selection. In addition, every avian species has a distribution range within which they occur, and of course, if an area is outside that range, the species will not occur there. The models of Niemuth and others (2017) accounted for this hierarchical selection.

In addition, the climate of an area influences bird occupancy. The data on avian occurrence gathered by people is influenced by factors associated with the people doing the observing. The ability to detect birds is affected by observer ability (for example, hearing acuity), as well as by survey design (for example, the daily and seasonal timing of bird surveys). The models of Niemuth and others (2017) account for these survey and sampling issues.

Grassland bird decision-support tool

Application 2: finding suitable offset sites after development

Relative probability of occurrence (RPO) models applied to:

- Six species—Upland Sandpiper, Savannah Sparrow, Grasshopper Sparrow, Clay-colored Sparrow, Western Meadowlark, Bobolink

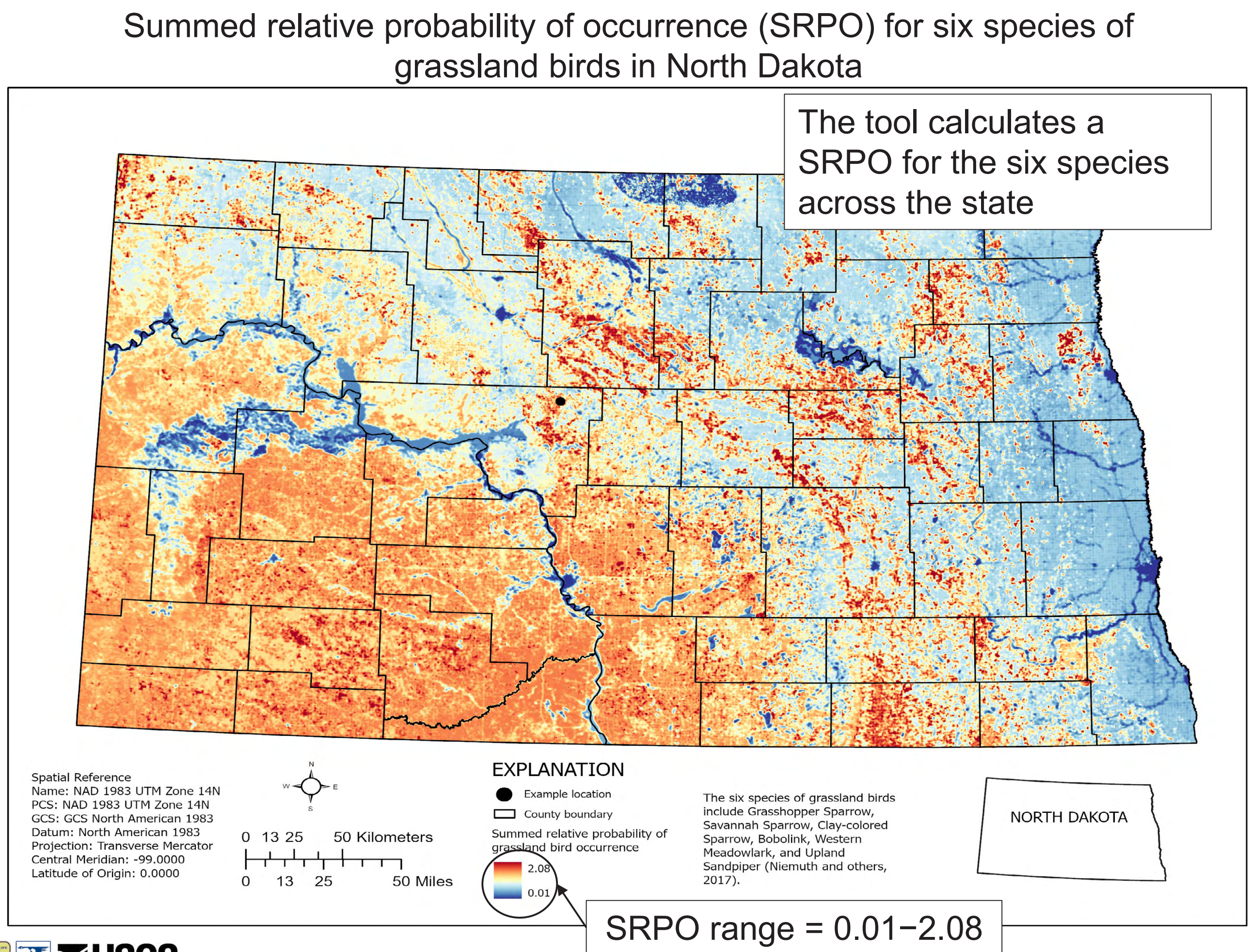
Models applied to National Land Cover Dataset (Homer and others, 2020)

Geo-processing steps in ArcMap and ArcPro:

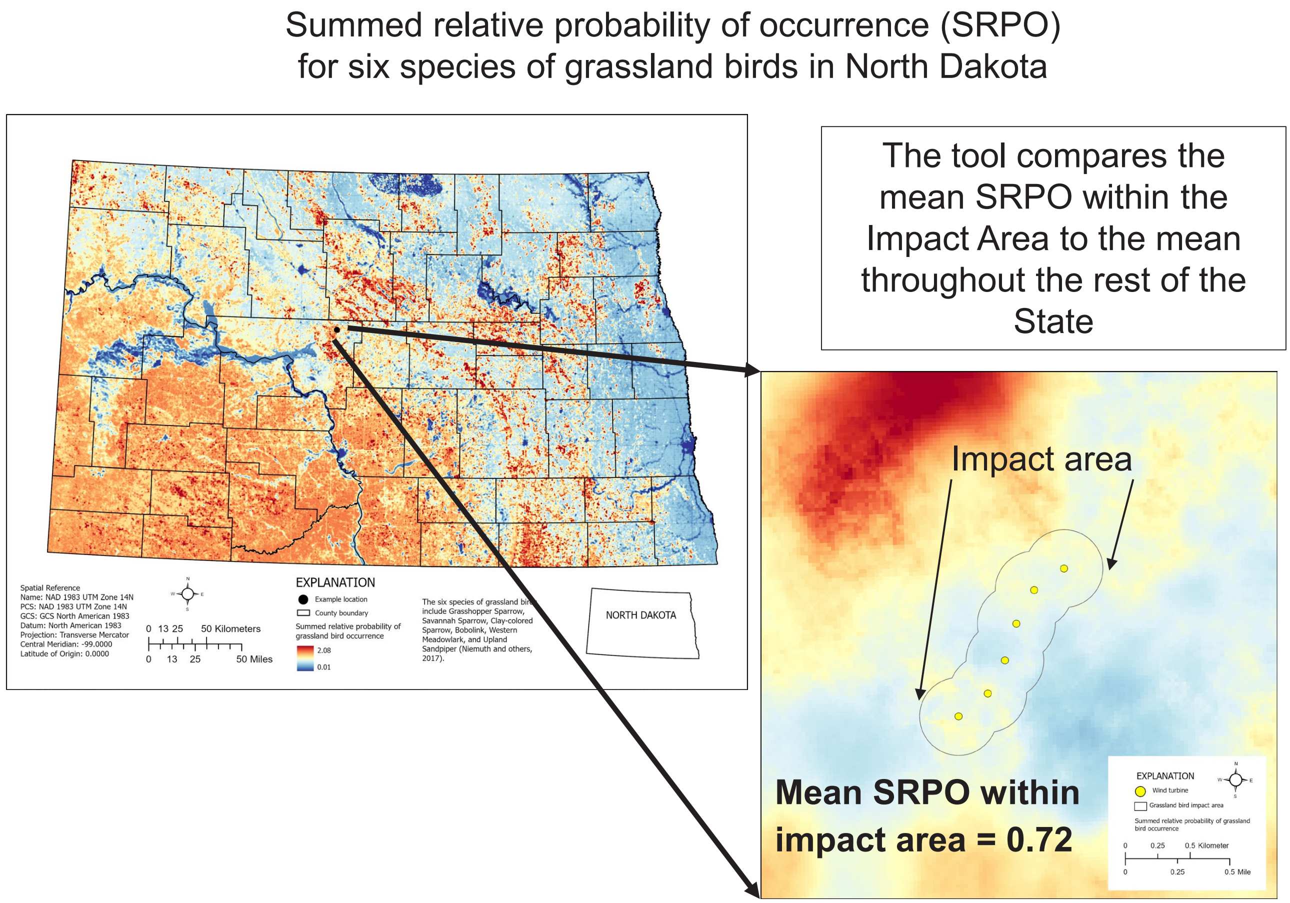
- Obtained RPO data for the six species
- Summed the RPO for North Dakota
- Calculated the mean summed RPO for the Impact Area and identified areas above and below the mean summed RPO

The models of Niemuth and others (2017) predicted the distribution and relative probability of occurrence of six of the same eight grassland-obligate species (that is, bobolink, clay-colored sparrow, grasshopper sparrow, Savannah sparrow, upland sandpiper, western meadowlark) that occurred within the Shaffer and Buhl (2016) study. Thus, the models can be used to identify geographical locations suitable for grassland offsets. Pertinent to the challenge of finding offset sites predicted to be of equal or higher biological value than impact sites, the grassland bird models can evaluate a pool of potential offset sites in proximity to the impact site to identify sites predicted to be the most equal in biological value to the impact site. One might contend that the ideal method for determining biological value of potential candidate offset sites would be field-based avian surveys to determine avian species composition and density because even if species composition is similar, density may not be similar. However, given the time and cost involved with that approach, it is less likely to be adopted than a predictive model. Moreover, predictive models have the advantage of incorporating many more years of data than is likely to be collected during one field study, and models can account for inter-annual variation in such factors as climate and species abundance. Thus, the decision-support tools were developed using predictive models.

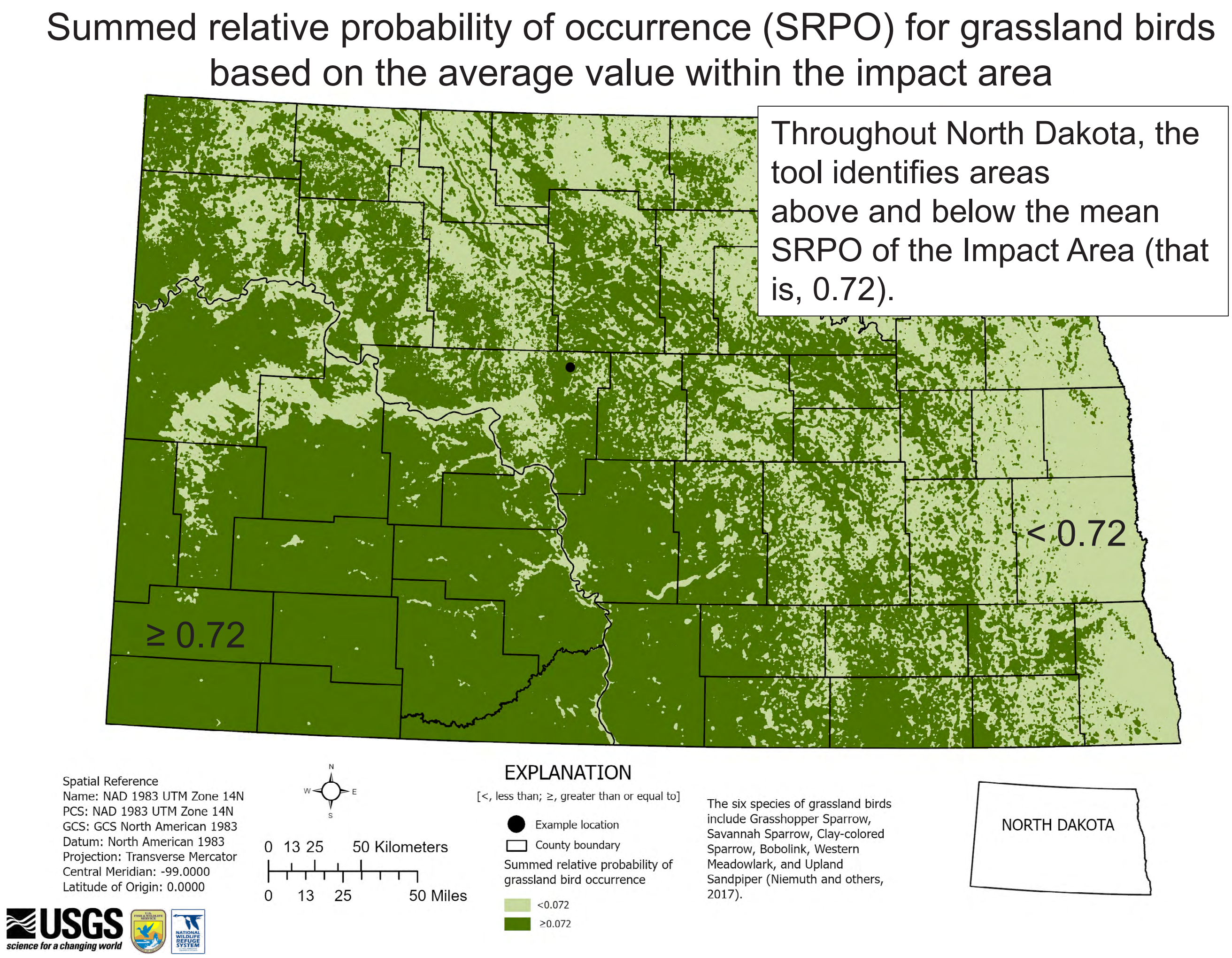
To develop a predictive model, we substituted the requirement of a pre-impact density value with an estimated summed relative probability of occurrence. Given that abundance estimates are correlated with estimates of relative probability of occurrence (table 3 in Niemuth and others, 2017), the results of the summed relative probability of occurrence models in Niemuth and others (2017) can be used as an index to grassland bird abundance.



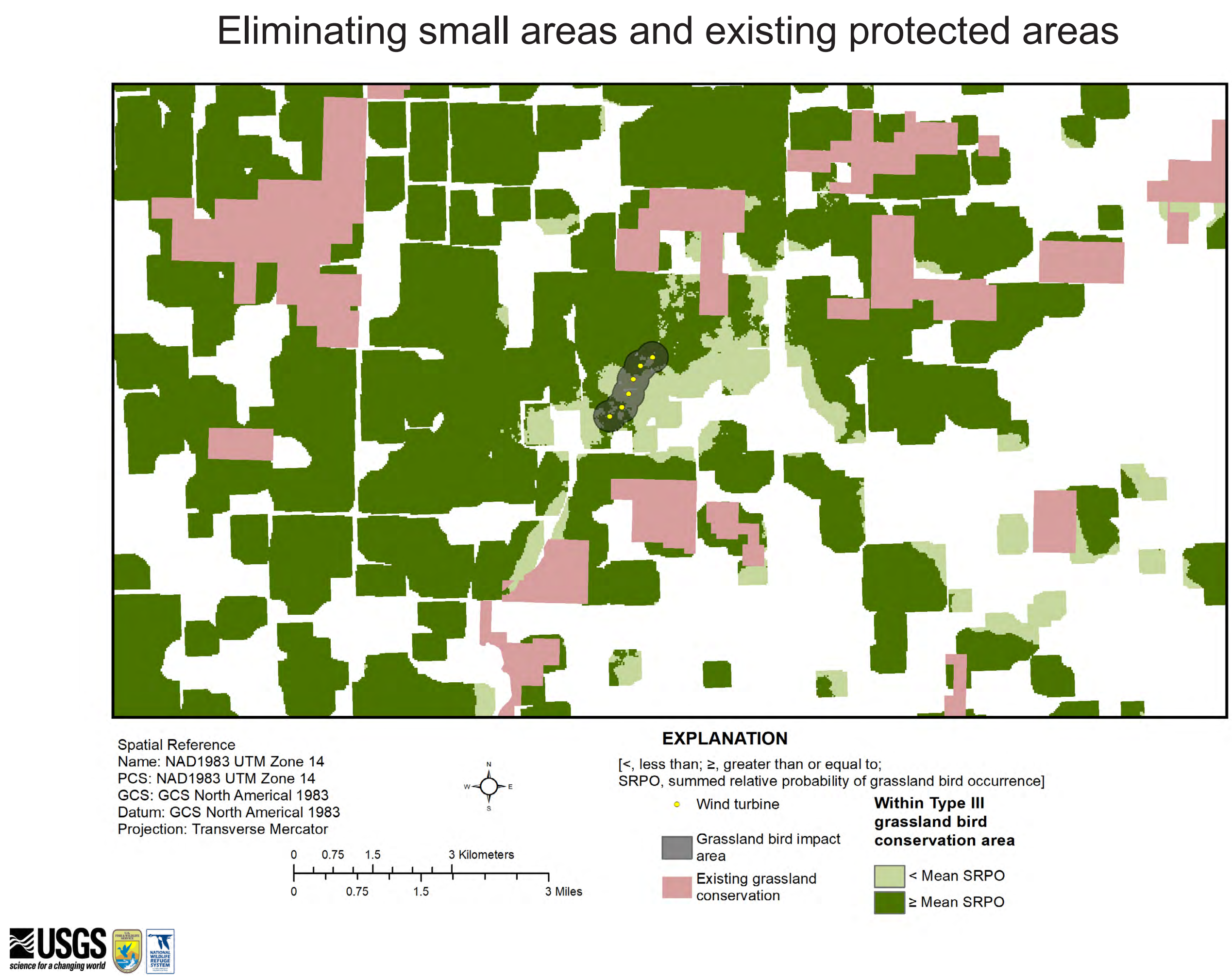
The decision-support tool estimates the biological value of the habitat for grassland birds within the geographic region of interest (this image depicts North Dakota). The decision-support tool sums the relative probability of occurrence for the six grassland bird species at the level of 30 by 30-meter pixels. The range of values of the summed relative probability of occurrence within North Dakota is 0.01 to 2.08. For illustrative purposes, the map depicts North Dakota, but the models of Niemuth and others (2017) and Fields and others (2018) were run for Montana, North Dakota, South Dakota, Nebraska, Kansas, those portions of Colorado and Wyoming east of the Rocky Mountains, and portions of Minnesota and Iowa.



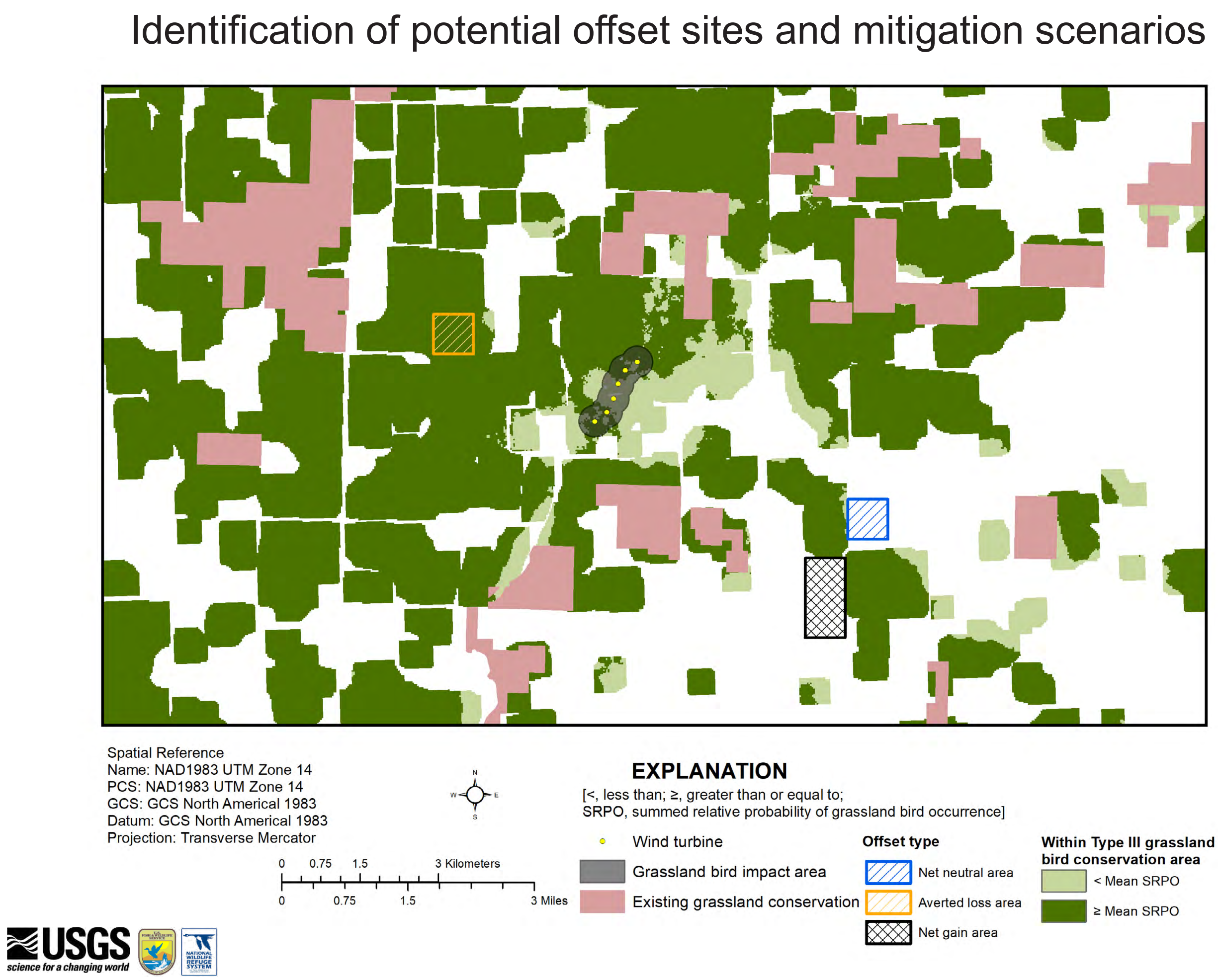
The decision-support tool estimates the biological value of the habitat for grassland birds within the impact area within the hypothetical wind facility. The mean of the cumulative cell values for the impact area is compared to the cumulative cell values in the rest of the State. The mean summed relative probability of occurrence value within the impact area (0.72) is used as a threshold for considering offset locations with comparable biological value. The map image is modified from Shaffer and others (2019) and used with permission.



A new spatial layer is created that depicts locations where the cumulative cell values of the summed relative probability of occurrence are greater than or equal to the mean value of the impact area.



Offset locations are further refined by eliminating small and fragmented parcels following the definition of Type III Grassland Bird Conservation Areas as proposed by Johnson and others (2010), as well as by eliminating habitat that is already protected. Any location that adheres to a definition of a Type III Grassland Bird Conservation Area and where the summed relative probability of occurrence is greater than the mean value within the impact area would be considered an equivalent offset location. The map image is modified from Shaffer and others (2019) and used with permission.



For the grassland bird example in which 59 hectares (146 acres) of habitat of comparable biological value is estimated to be necessary to offset behavioral impacts associated with a wind facility, any 59-hectare location where the value for the summed relative probability of occurrence of the Type III Grassland Bird Conservation Area is greater than the mean value within the impact area would be considered an equivalent offset location for averted-loss acquisition. However, different types of mitigation can be considered. The averted-loss scenario can be considered if protection of existing grassland habitat is desired; however, the outcome of this scenario is a net decrease of habitat in the overall landscape. Restoration of disturbed habitat is necessary to avoid net loss. Restoration of cropland to grassland would represent an example of a net neutral mitigation scenario. Restoration of acreage that exceeds the identified offset acreage would represent a net gain mitigation scenario. The map image is modified from Shaffer and others (2019) and used with permission.

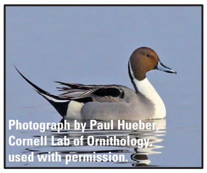
Grassland bird decision-support tool

Application 3: estimating impact of potential developments


Photograph by Rick Bohn, used with permission.

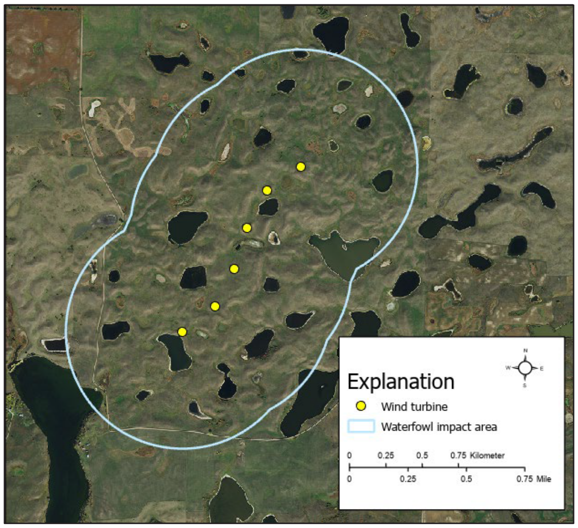
Prior to development: Evaluates a pool of sites being considered for development by estimating and comparing the biological value that would be impacted if development were to occur.

The third application of the grassland bird decision-support tool is designed to evaluate a pool of sites prior to development (that is, for areas being considered for future infrastructure development). The tool can estimate the biological value that would be impacted (lost) if development were to occur on sites of interest. By comparing the development impact among multiple sites, a developer could choose to develop the site that will have minimal impact to biological value, and thus, the site that will incur the lowest mitigation cost.



Waterfowl decision-support tool

Application 1: automating the AIOM



Recall the example from Section 3, taken from Shaffer and others (2019):

Impact Distance = 800 m*

Impact Area = 109 wetlands

Pre-Impact Density = 1.82 pairs per wetland

Percent Displacement = 18%*

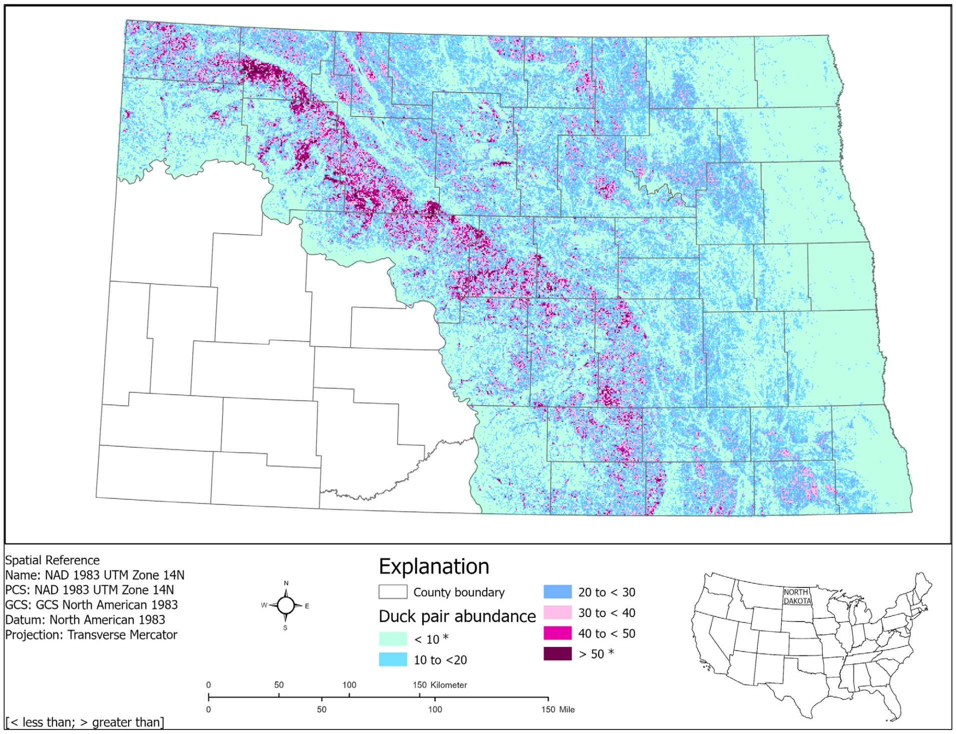
*These are the default values for the waterfowl decision-support tool.

[= equals; m, meters; %, percent]

The waterfowl decision-support tool operates in a similar fashion to the grassland bird decision-support tool in that both tools contain dialog boxes in which the spatial and biological metrics required to calculate the estimated impact can be input. Default values from Shaffer and others (2019) are used for impact distance and percent displacement unless field-derived values are available. AIOM is Avian-Impact Offset Method.

Waterfowl decision-support tool

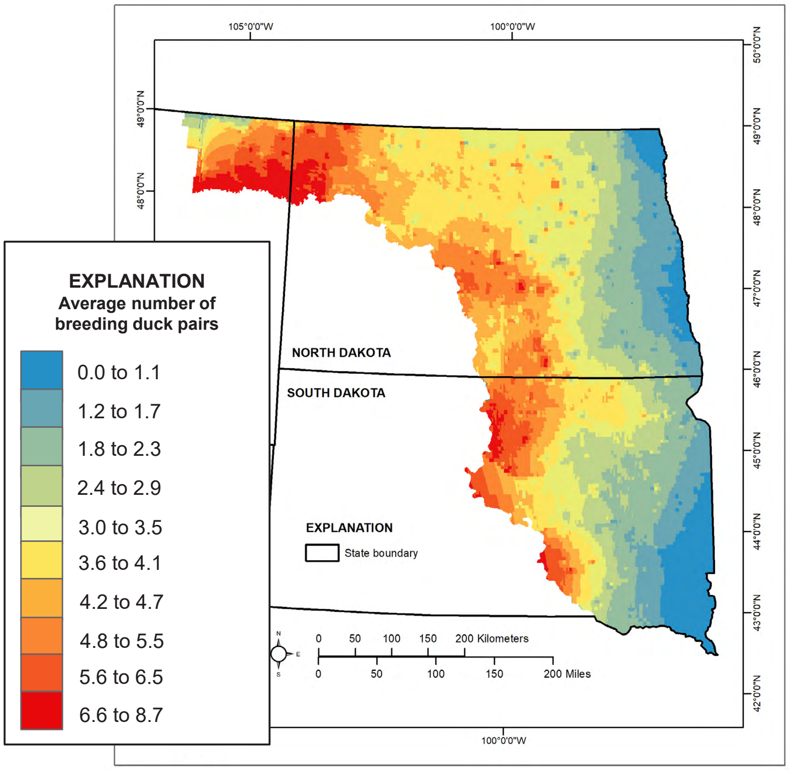
Estimating pairs associated with Pre-Impact Density



To aid in estimation of pre-impact density, the waterfowl decision-support tool draws upon the models of Reynolds and others (2006) and the process described in Loesch and others (2012) to estimate duck abundance in relation to wetland size and class relative to geographic location.

Waterfowl decision-support tool

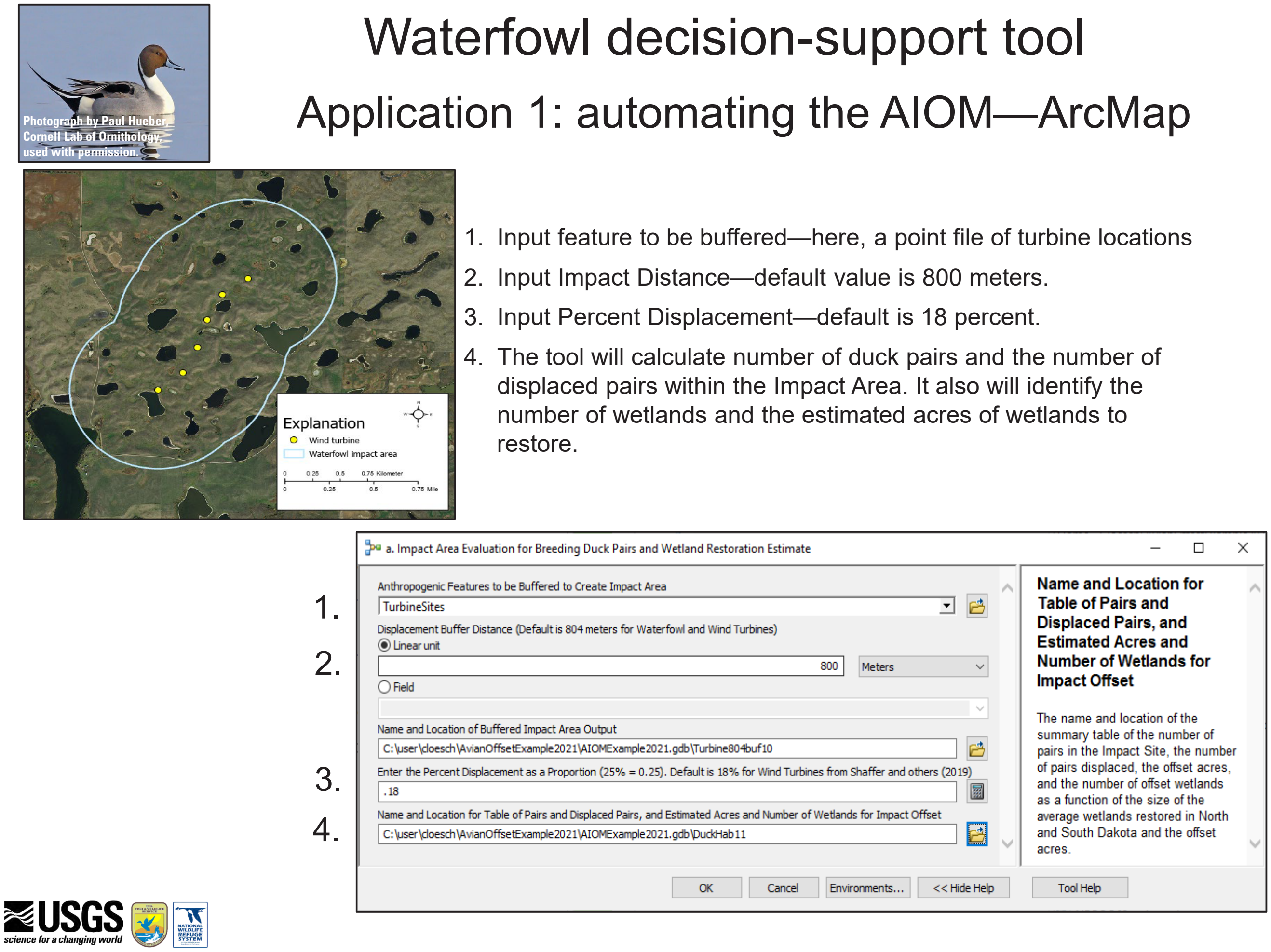
Modeling geographical variation in biological value



Geographical variation in number of breeding duck pairs in 0.90-hectare seasonal wetlands across the Prairie Pothole Region

Pair-Model description:
Reynolds and others (2006)

To aid estimation of a wetland's restoration potential relative to its geographical location, wetland size and class are held constant. The biological value of a wetland of similar size and type varies geographically across the project area. Accounting for this geographical variation is important when estimating the amount of wetland restoration needed to offset the displacement of breeding pairs, because that estimate will also vary geographically. To account for this variation, a spatial network of 780-meter cells was used to model the biological value of a 0.90-hectare seasonal wetland relative to its geographical location in North Dakota, South Dakota, and northeastern Montana. The 0.90-hectare size and the seasonal type of wetland was used for this process because that is the most common size and type of wetland restored by the U.S. Fish and Wildlife Service Partners for Fish and Wildlife in North Dakota and South Dakota (Loesch and others, 2012). The map image is modified from Shaffer and others (2019) and used with permission.



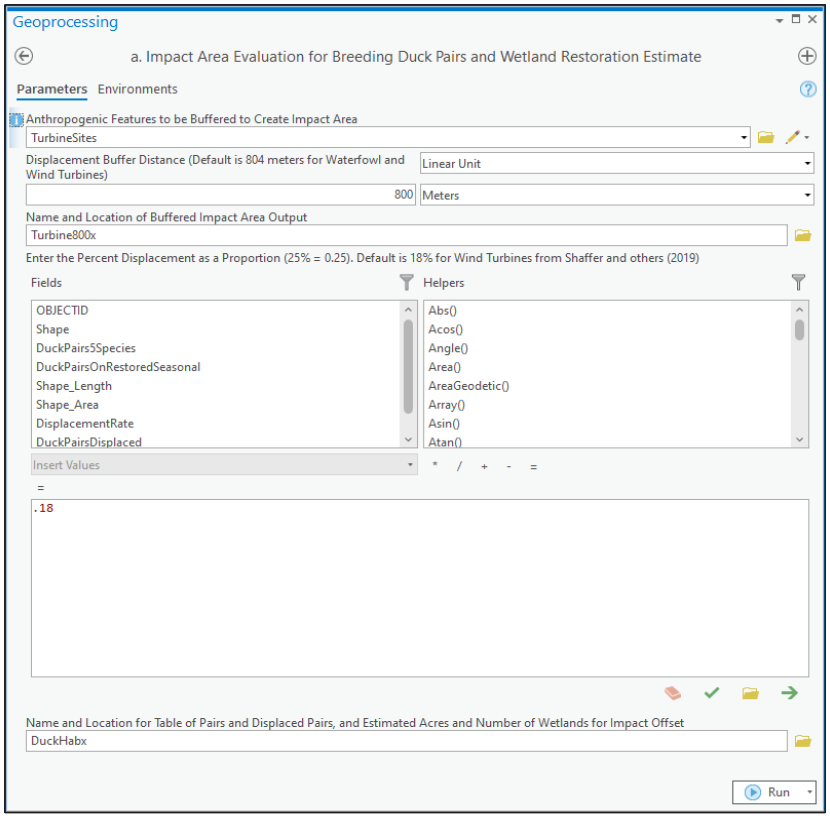
This image provides a step-by-step description of how to use the waterfowl decision-support tool in ArcMap to apply the Avian-Impact Offset Method (AIOM).

1. Select a point, line, or polygon file with the location(s) of the anthropogenic disturbance. In this example, a point file with turbine locations is used.
2. The impact distance is set to the default value of 800 meters. All default values can be replaced with user-defined values if other data are available.
3. The percent displacement is set the default value of 0.18. All default values can be replaced by user-defined values if other data are available.
4. The user enters the name of the file and location on the computer where the output table will be stored that contains the number of pairs, number of displaced pairs, number of wetlands, and estimated number of acres to restore.

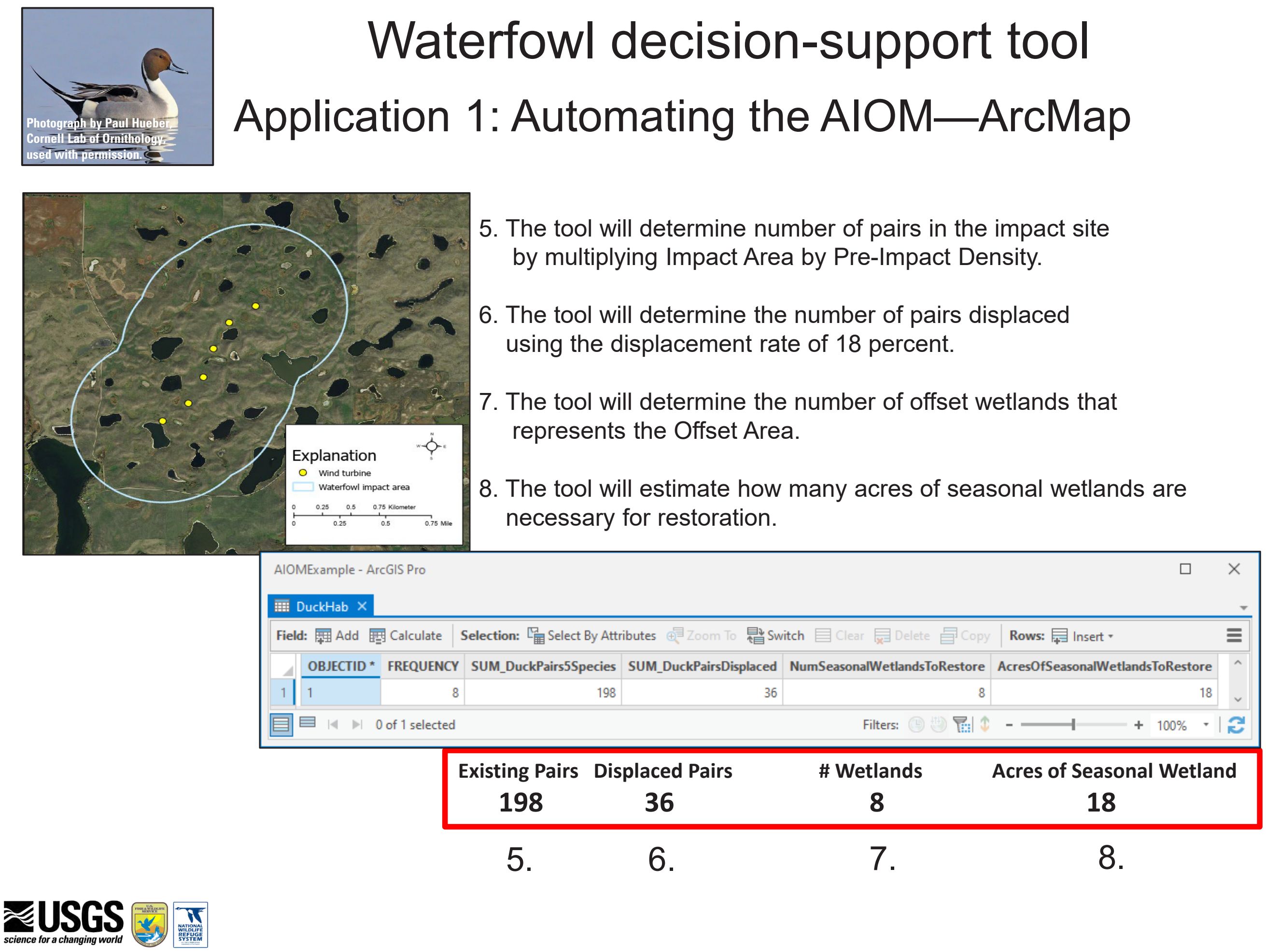
Waterfowl decision-support tool

Application 1: automating the AIOM—ArcMap

1.
2.
3.
4.



The steps for ArcPro 2.7.4 are the same as for ArcMap 10.6.1, but the dialog box looks slightly different. The numbers along the side of the dialog box correspond to the steps in the previous slide.



5. The decision-support tool will estimate the number of breeding waterfowl pairs at the impact site by multiplying the impact area by the pre-impact density.

6. The tool will determine the number of breeding duck pairs displaced by applying the default displacement rate of 18 percent (entered as 0.18).

7. The tool will determine the offset area, which is expressed as number of wetlands. To calculate the offset area, the number of displaced pairs is divided by offset density (in this case, 4.45, which is the county average [that is, the county in which the impact site is located] of the number of breeding pairs for the five duck species that are attracted to a 2.2-acre seasonal wetland).

8. To estimate how many acres of seasonal wetlands are necessary for restoration, the offset area (number of wetlands) is multiplied by 2.2 (the average size of seasonal wetlands, in acres, restored in North Dakota and South Dakota by the U.S. Fish and Wildlife Service Partners for Fish and Wildlife Program).

Waterfowl decision-support tool

Application 2: finding suitable offset sites after development

Challenge:

How to locate restorable wetlands of similar biological value to the impacted site?

Answer:

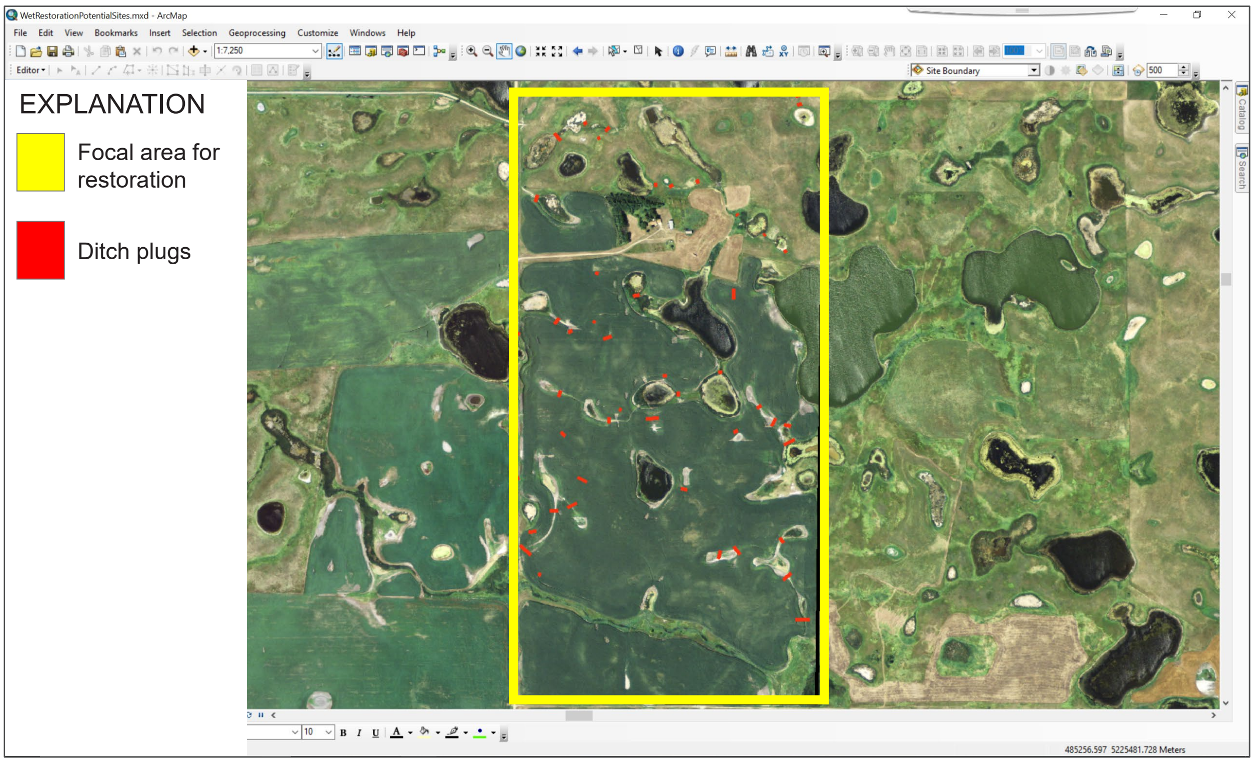
The decision-support tool and additional spatial data can be used to:

- Locate the associated number of 0.9 hectares of drained seasonal wetlands and restore them (difficult)
- Locate drained wetlands and restore them until duck pair biological benefits are equalled or exceeded (feasible)

As with the grassland bird decision-support tool, the waterfowl decision-support tool can be used to find where on the landscape a suitable offset site might be located. Currently, the geographic coverage of the waterfowl decision-support tool is the Prairie Pothole Region of Montana, North Dakota, South Dakota, Minnesota, and Iowa. To locate suitable wetland areas that can serve as mitigation offset sites, drained wetland areas are identified for restoration potential. Drained wetlands are abundant in the Prairie Pothole Region. When hydrology is restored to drained wetlands, flora and fauna usually respond and provide benefits for waterfowl comparable to wetlands that have not been previously drained.

Steps for finding candidate wetlands for restoration

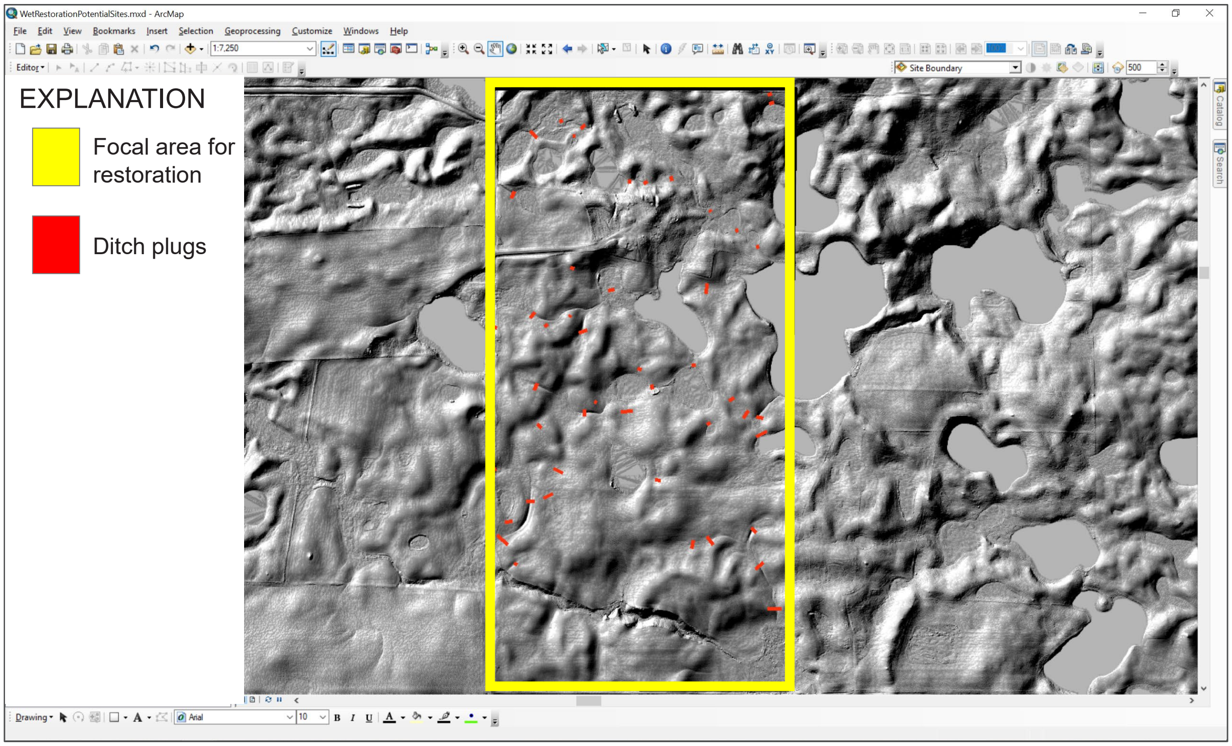
Step 1: locating drained wetlands



There are several steps necessary to identify candidate sites for wetland restoration, such as identifying areas with drained wetlands.

Steps for finding candidate wetlands for restoration

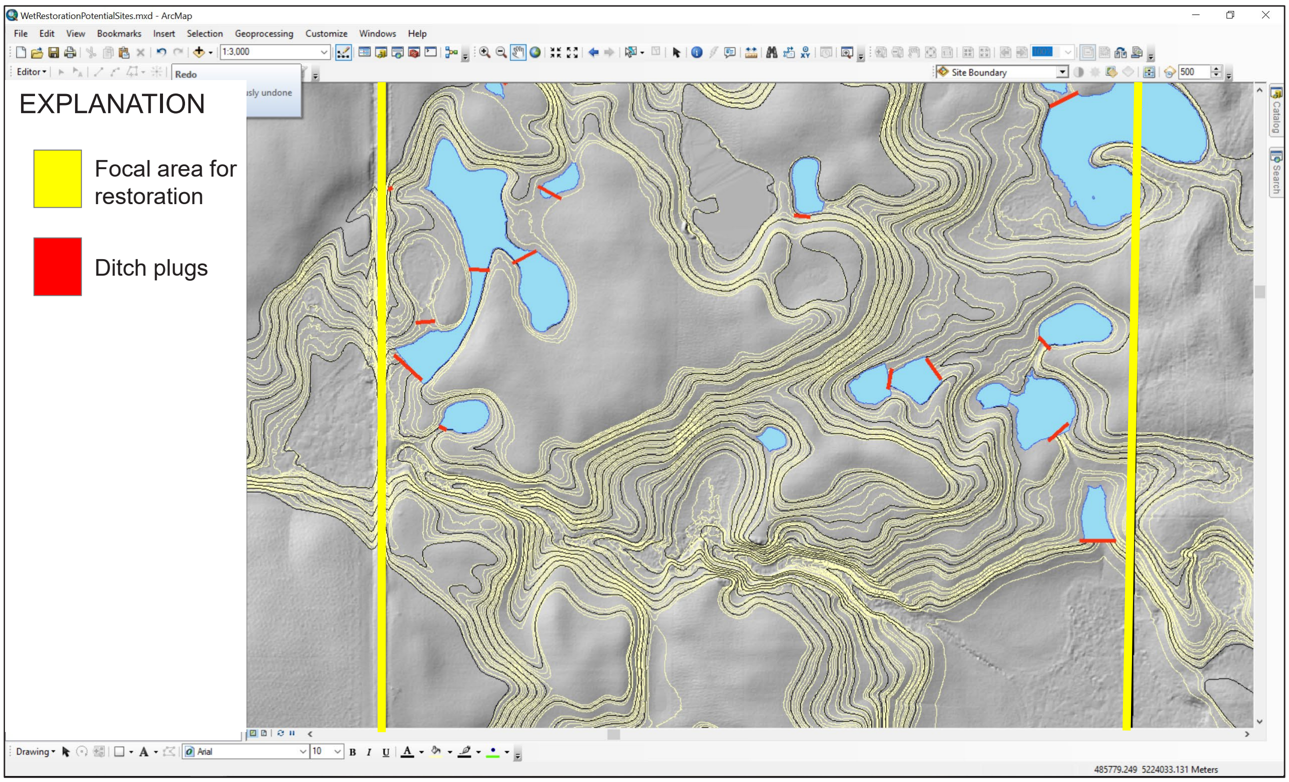
Step 2: using lidar to visualize wetland depressions



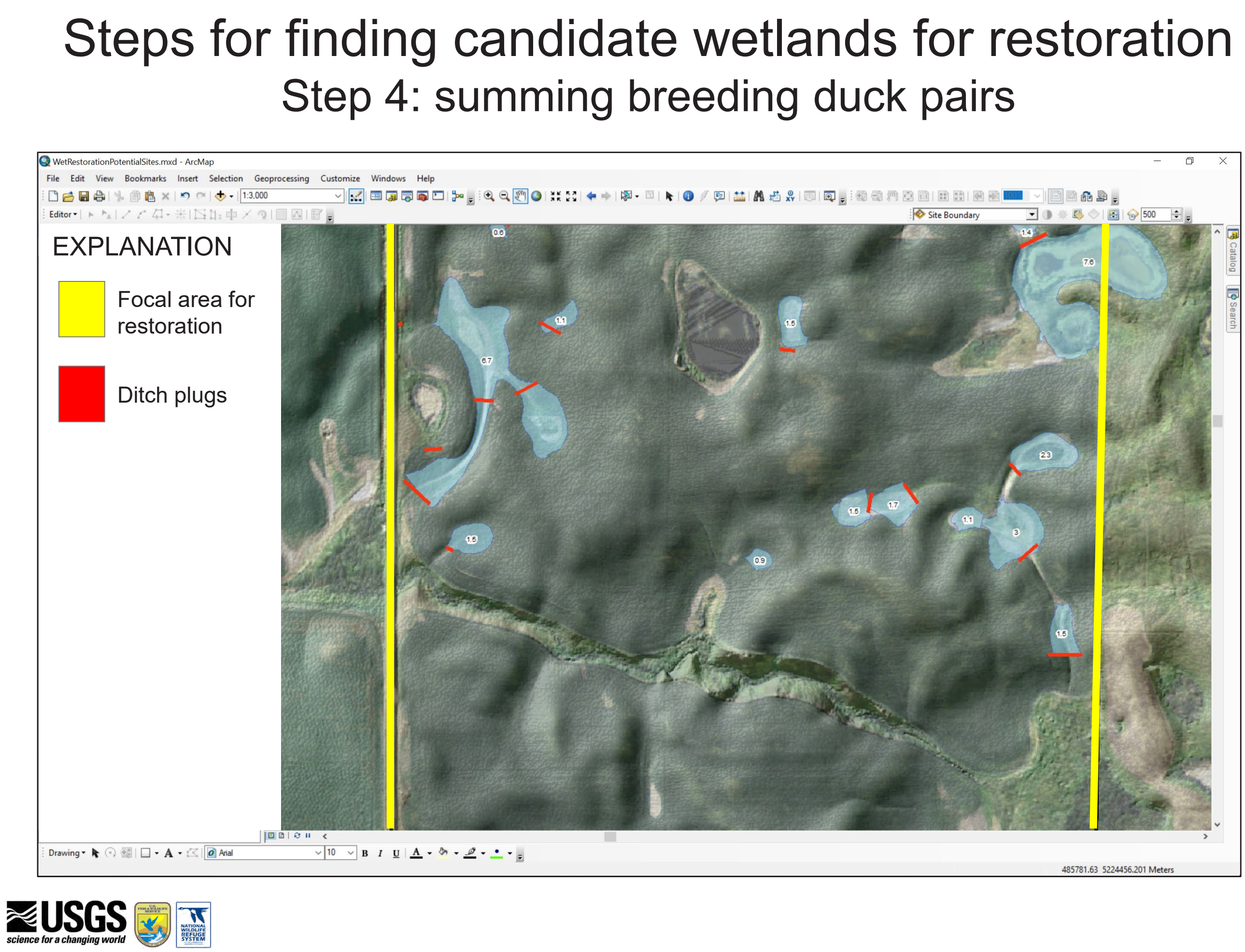
The high-resolution capability of the remote-sensing technology of light detection and ranging (lidar) is used to create terrain data that are displayed here as a shaded-relief map for greater visualization of surface features. In Step 2, lidar helps identify existing wetlands, drained wetlands and their associated drainage ditches, and locations for potential plug locations. Actual plug locations would need to be confirmed with site visits and appropriate survey equipment.

Steps for finding candidate wetlands for restoration

Step 3: using lidar to develop wetland size



In Step 3, light detection and ranging (lidar) is used to generate terrain data to develop contour and elevation information, which aids in determining wetland extent and predicting the size of wetlands after restoration. This example shows the generation of 0.3-meter (1-foot) contour lines. The light blue areas approximate the area of potential ponded water if restored to the respective contour.



The aforementioned procedures allow for the mapping and estimation of duck pairs using updated models similar to those of Reynolds and others (2006). In Step 4, the number of breeding duck pairs estimated to be compensated for from wetland restoration (numbers on the restored wetlands) can be summed until they approximate the desired offset, and those wetlands subsequently restored if net-neutral mitigation is desired.

Waterfowl decision-support tool

Application 3: estimating impact of potential developments

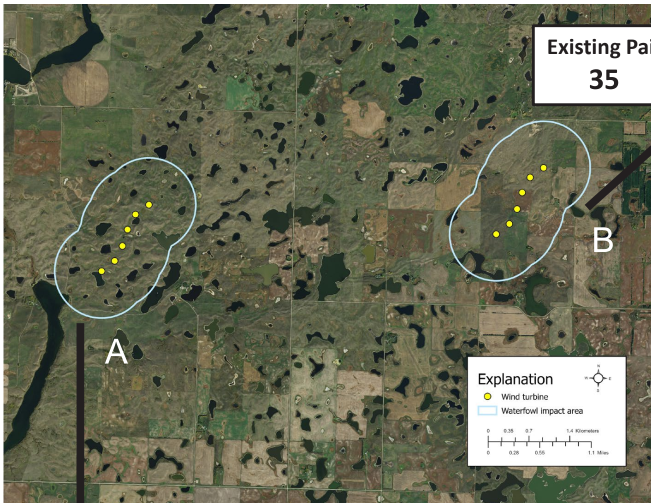
Prior to development: Evaluates a pool of sites being considered for infrastructure development by estimating and comparing the biological value that would be impacted if development were to occur.

The waterfowl decision-support tool has a third application: to evaluate a pool of sites prior to development to estimate the biological value that would be impacted (lost) if development were to occur on that site. By comparing the development impact among multiple sites, a developer could choose to develop the site that will have the minimal impact to biological value, and thus, the site that will incur the lowest mitigation cost.

Waterfowl decision-support tool

Application 3: estimating impact of potential developments

Existing Pairs	Displaced Pairs	Number Wetlands	Acres of Seasonal Wetland
35	6	1.5	3



Placing the wind facility in the landscape at site A, which has high biological value to waterfowl owing to the numerous small wetlands, would incur a higher mitigation cost in terms of number and acres of wetland restoration, than placing the wind facility in the landscape at site B, which has a lower biological value to waterfowl owing to low numbers of wetlands.

Existing Pairs	Displaced Pairs	Number Wetlands	Acres of Seasonal Wetland
198	36	8	18

USGS science for a changing world

This image provides a comparison of the mitigation cost between two potential wind sites. The placement of a wind facility at site A would incur a higher mitigation cost than the placement of a wind facility at site B. For the wind facility at site A, situated as it is in a landscape of numerous small wetlands that equate to high biological value for waterfowl, the Avian-Impact Offset Method estimates the displacement of 36 waterfowl pairs, necessitating the restoration of eight wetlands totaling 18 acres. For the wind facility at site B, situated as it is in a landscape of few small wetlands that equate to low biological value for waterfowl, the Avian-Impact Offset Method estimates the displacement of six waterfowl pairs, necessitating the restoration of only 1.5 wetlands or 3 acres of seasonal wetlands. Application 3 of the decision-support tools allows for just such comparisons to allow developers of energy infrastructure to estimate and compare mitigation costs among potential future sites.

Section 4 Summary

The grassland bird and waterfowl decision-support tools serve these functions:

- automate the Avian-Impact Offset Method for both grassland birds and waterfowl
- identify suitable offset sites after development for grassland birds
- identify the number and acres of seasonal wetlands for restoration
- estimate the impact of potential development and siting decisions

The grassland bird decision-support tool uses the models of Niemuth and others (2017) to determine grassland areas with equivalent biological value to impacted grasslands.

The waterfowl decision-support tools use the models of Reynolds and others (2006) and Loesch and others (2012) to determine number and acres of wetlands.

Restorable wetlands are manually identified, and models used by the tool generate estimates for the number of waterfowl breeding pairs that those restored wetlands will support.

The AIOM Tools were developed for ArcMap and ArcPro; supporting geodatabases and installation are described in Appendix 3.

After completing Section 4, take a moment to reflect on the contents.

You have now familiarized yourself with some of the issues with energy development in grassland and wetland ecosystems, the methods and results from Shaffer and Buhl (2016) and Loesch and others (2013), and the development of the Avian-Impact Offset Method and complementary decision-support tools.

If you have not done so previously, review the appendixes to view the field protocols used in Shaffer and Buhl (2016), the detailed species- and facility-specific results from Shaffer and Buhl (2016), and instructions on downloading the decision-support tools.

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Appendix 1. Field Protocols

Background

For the Shaffer and Buhl (2016) study, the responsibilities of the field crew were to conduct avian and vegetation surveys, set up and maintain survey grids, and enter and proof data. This appendix consists of protocols provided to the field crews for these duties.

Explanation of Study for Field Crews

The goal of this study is to determine whether placement of wind turbines in native prairie affects breeding-bird density and species composition. Specifically, the study is examining whether avoidance (also referred to as displacement) by birds of wind infrastructure occurs. To achieve this, the field crew will be gathering data on bird density in relation to distance from turbine. The field crew also will be gathering data on control areas without wind turbines. In addition, the field crew will measure vegetation structure to eliminate differences in vegetation among study plots as the source of variation in breeding-bird density.

The study uses a before-after-control-impact (BACI) study design. Before any turbines are constructed, the field crew will conduct avian surveys in areas where wind turbines will eventually be constructed and in control areas (sometimes also referred to as “reference” areas) where turbines will not be constructed (providing the “before” component). The field crew will conduct surveys in these same locations in the years after construction (providing the “after” component). The control areas are native prairies that are not currently slated for turbine development (providing the “control” component to compare against the “impact” [sometimes also referred to as the “treatment”]). The topography, habitat, and land use of control areas match impact sites as closely as possible. The field crew will be responsible for conducting avian surveys and vegetation surveys, setting up and maintaining survey grids, and entering and proofing data. A brief description of these duties is provided, followed by protocols for each.

Avian Surveys

Avian occurrence will be recorded by mapping locations of birds onto field datasheets that reflect the size and shape of the avian survey grid so that avian density (counts of birds observed per unit area) and distance of individual birds from the turbine can be determined back in the office. A protocol has been written that describes the characteristics and how to set up the avian survey grid (see “Protocol for Setting up and Maintaining Avian Survey Grids” section). A protocol has been written that describes how to conduct avian surveys (see “Avian Survey Protocol” section).

Vegetation Surveys

In addition to the presence of wind turbines, presence or absence of birds also may be influenced by vegetation characteristics. Data on vegetation structure are gathered to address the following questions:

- Is there variation in vegetation structure within turbine study areas owing to grazing (for example, differences in livestock grazing intensity on selected areas because of pasture boundaries or because of changes in landownership)?
- Is there variation in vegetation structure within turbine study areas owing to topographical changes?
- Are there vegetation differences between turbine and control plots?

The field crew will conduct vegetation measurements to evaluate the influence of vegetation on bird use of the study sites. A protocol has been written that describes how to conduct vegetation measurements (see “Vegetation Protocol” section).

Data Analysis

Analysis will primarily involve the comparison of densities of individual bird species in relation to the distance from the nearest wind turbine. Unit area will be based on the area of ever-increasing annuli that radiate outward from turbines. Locations of birds will be converted to distance to the nearest turbine. Variation in vegetation caused either by differential grazing pressure or changes in topography will be used to assess how that variation may have influenced bird occurrence.

Protocol for Setting up and Maintaining Avian Survey Grids

The following materials are needed:

- diagram labelled “Schematic of survey grid, isolated turbine” (fig. 1.1)
- plot description sheets
- plot maps
- fiberglass utility markers (also known as survey or “carsonite” markers)
- fiberglass fence posts
- thick, black magic markers
- electrical tape
- flagging tape
- tape measure
- rubber mallet
- compass
- binoculars

The following additional materials may be needed (some may be optional) for maintenance:

- hacksaw to saw off broken fiberglass survey markers
- extra hacksaw blades
- extractor tool for survey markers
- shovel
- wire pin flags

Using a Survey Grid

The field crew will survey birds and vegetation around wind turbines and on control plots (plots also may be referred to as “study sites” or simply “sites”) without turbines using a grid pattern. The study plan calls for conducting surveys within 800 meters (m; or 0.5 mile) of a turbine or turbine string in all directions. However, a grid may be smaller owing to changes in topography or land use.

The field crew will construct a grid around the turbines using fiberglass poles and fiberglass survey markers. The grid will keep an observer walking in a straight line as bird surveys are conducted, thus ensuring that the entire area within the grid is covered and eliminating double coverage. Locations of birds will be mapped on field sheets, and the grid will increase the efficiency of the mapping. A well-defined area within which to survey birds is further necessary to accurately calculate the area of the study plot that is surveyed, which is used in determining avian density. In addition, the locations for vegetation sampling lines will be described from grid intersections, as explained in the “Vegetation Protocol” section.

The study areas are grazed by cattle, and cattle are destructive to the equipment used to mark study plots. Past experience in grazed systems highlighted the futility of using polyvinyl chloride posts, wooden lathes, pin flags, or flagging tape. Cattle easily rub against and break off polyvinyl chloride posts and lathes, they chew pin flags and uproot them, and they chew on flagging tape. Metal rebar is too heavy and unwieldy to drag across the prairie, and cattle also rub against rebar stakes until they become loose and uprooted. Therefore, fiberglass posts and markers were deemed the best alternative. Unfortunately, fiberglass fence posts are available only in small circumferences, which can be difficult to see. It is also difficult to label them in such a way that the labels can be seen with binoculars from afar. Fiberglass survey markers are thin and flat and thus easily labeled, but they are expensive. Furthermore, when the markers break, they leave dangerous edges. Because of their cost, potential danger, and difficulty in removal, fiberglass survey markers should be used with discretion.

Basic Grid Characteristics

Note that some of these characteristics changed as the grid setup process was refined. Therefore, it is imperative that each member of the field crew read the plot description sheet for each particular plot. An example of the plot description sheet for the South Dakota Wind Energy Center is in the “Example of Plot Description—South Dakota Wind Energy Center” section.

A grid consists of parallel lines spaced 200 meters (m) apart across the study plot (fig. 1.1). Individual lines are labelled with letters, such as A, B, C, and so forth. Within a grid line, white fiberglass fence posts are spaced 50 m apart, and these within-line posts are marked with numbers every 50 m, representing their increasing distance either from a turbine (plots established early in the study are shown in figs. 1.1 and 1.2*A*) or from one end of a study plot (plots established later in the study or regridded at a later date are shown in fig. 1.2*B*). Essentially, a survey grid consists of a number of 200 by 50 m cells, and each cell is identifiable by its coordinates; for example, the cell in the uppermost-left corner of figure 1.1 could be defined as bounded by W800N to W750N and X800N to X750N. Cell identification is used for vegetation sampling.

The ends of lines are colored fiberglass survey markers, on which the pertinent line letter can be written with permanent marker in large print for ease in identifying from afar with binoculars.

During the beginning years of the study, line labels were established such that grid lines placed in an easterly direction from a turbine that was deemed “coordinate A0” were assigned a letter that ascended up the alphabet (for example,

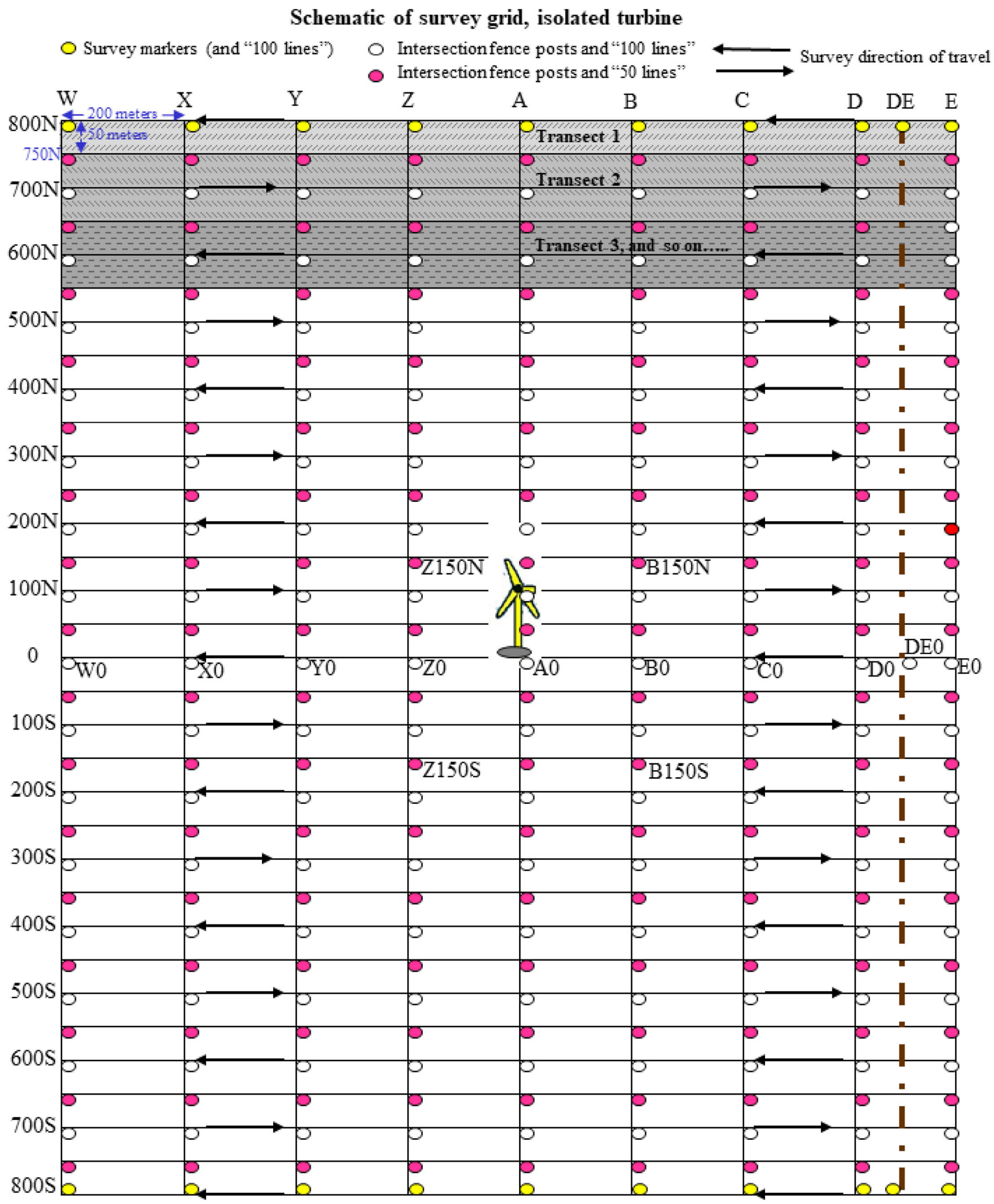


Figure 1.1. Schematic of an avian survey grid erected around wind turbines in which grid lines are 200 meters apart and fence posts within grid lines are 50 meters apart. The avian survey transects are walked perpendicular to the grid lines.

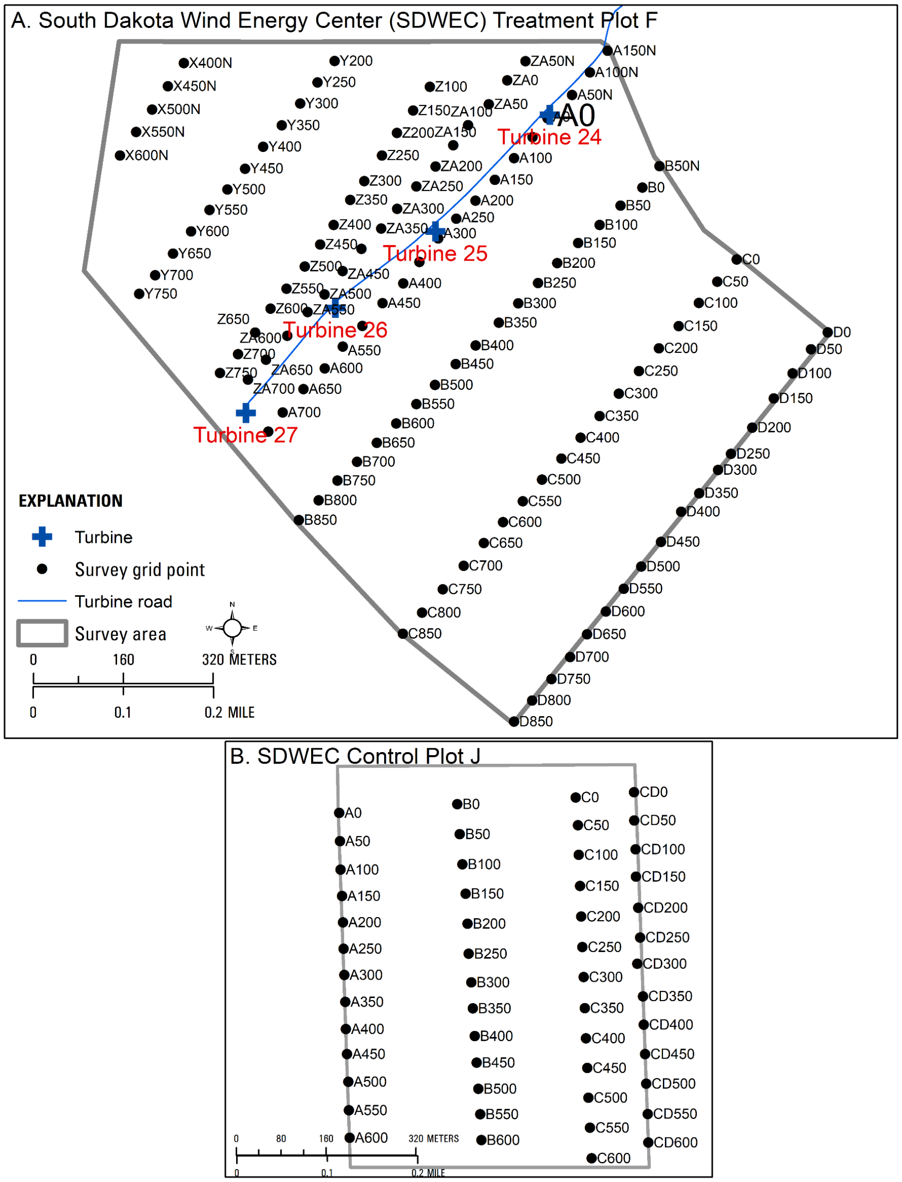


Figure 1.2. Example of plot maps in which the avian survey grid is erected. *A*, Survey grid following the line of the wind turbines. *B*, Survey grid is erected fenceline to fenceline.

A, B, C, and so forth), whereas grid lines placed in a westerly direction from the turbine at A0 were assigned a letter that descended down the alphabet (for example, Z, Y, X, and so forth; figure 1.1). This labeling convention was feasible because no plot was so large that the entire alphabet was used for labelling but proved to be confusing and was only implemented in early years, which is why reading the plot description sheets for each particular site is imperative. In later years and as plots were sometimes relabelled, the grid-line labeling was much simplified, with lines labelled “A” at one end of a grid and proceeding sequentially to the other end of the plot (fig. 1.2*B*).

Grid intersections are indicated with a combination of letters and numbers (for example, B150N). The first letter represents the grid line, and the first number represents the vertical distance from the turbine or the start of a row. The second letter represents whether the line is north or south of the turbine. This convention held true when study plots were laid out relative to turbine locations (for example, points A50N to A150N on fig. 1.2*A*; note that most points on this particular plot would have been “south,” but space was limited for electronic labelling, so the “S” was eliminated). Providing the “north” and “south” designations became unnecessary when plots were laid out fenceline to fenceline (fig. 1.2*B*). Read the plot description sheets for each particular study site.

The last grid line may not delineate the extent of the surveyable area. We survey fenceline to fenceline in many cases, even if the fence itself is not marked by posts or survey markers. The plot description sheet for any particular plot should explain the surveyable extent, but ask if uncertain.

Grids will not always come out in neat, equally spaced rectangles. When the distance between two grid lines at the edges of plots is less than 200 m, give the grid line the name of the lines that would flank it in an equally spaced plot. For example, a grid line that is not exactly 200 m to the right of line D would be labeled line DE (figure 1.1). Use this designation regardless of the distance (such as 50, 100, or 150 m) from the last “complete” grid line (for example, grid intersection DE0 in fig. 1.1; in this scenario, the plot would end at line DE, and line E would not exist).

Grid Characteristics Specific to Avian Surveys

The avian survey transects run perpendicular to the grid lines. The survey transect goes from one “100 line” to the other, using the “50 lines” to indicate the boundaries of a single survey transect. In figure 1.1, transect 1 is on the edge of the grid, so it is only one-half a transect that covers only 50 m to the south, as it starts at the top of a study plot and covers only the south end of the transect (from 800N line E to 800N line W). Thus, before starting to survey, observers need to be sure they understand the travel lines, what direction to start, and the width of the first transect. In figure 1.1, the observer is moving westward from 800N line E all the way to the end of 800N line W and then turns and starts transect 2 at 700N line W and walks eastward. Transect 2 will be the first complete transect, as it will cover 50 m on both sides of the direction-of-travel line.

Fence posts along the “100 lines” (for example, 800N, 700N, 600N, and so forth, in fig. 1.1) will be wrapped in black tape, whereas fence posts along the “50 lines” (for example, 750N, 650N, and so forth) will be marked with black electrical tape and pink flagging (fig. 1.3). This system may vary from site to site, so again, read the plot description sheets for each particular site.

Each pole will be labeled with the line number and the distance of the imaginary direction-of-travel line (for example, in fig. 1.1, the fencepost in the first grid line to the right and north of the turbine at A0 is labeled B150N). The intersections at 0 m will have no north/south designation.

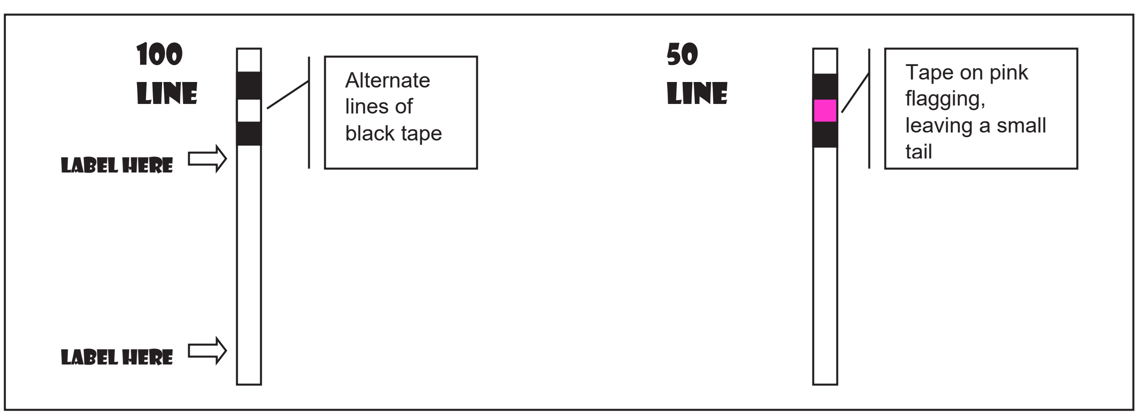


Figure 1.3. Illustration of marking posts within lines of the avian survey grid.

Setting Up the Survey Grid

The orientation of survey plots originally was dictated by the orientation of how a string of turbines was constructed (usually following a natural ridgeline), which created some irregular-shaped grids that were not intuitive to follow (fig. 1.2*A*). To address this issue, plots were later erected in which grid lines were laid out parallel to adjacent fence lines (fig. 1.2*B*), which created grids that were easier to lay out and to understand. This is why it is important that crew members read the plot description sheets and become familiar with the specific layout for each plot.

A simplistic example of a survey grid is shown in figure 1.1; however, all plots usually have multiple turbines (fig. 1.2*A*). The orientation of the ridge upon which the string of turbines is situated is obviously in the line created from Turbine 24 to Turbine 27 (fig. 1.2*A*). Grid lines are oriented parallel to this ridge. Turbine 24 was chosen as the location for post A0. To set up a plot like this, designate the turbine string as Line A. Ideally, line A will extend 800 m from each of the last turbines in a string, although land use changes or lack of landowner permission usually precluded such line lengths. Subsequent grid lines will be parallel to line A in eastern and western directions. The number of parallel grid lines also is dictated by land use changes and landowner permission, but fit as many lines as possible within the area extending 800 m from both sides of line A. Grid lines west of line A become line Z and so forth (there is a line labelled “ZA” because topography was such that an additional line was necessary for orientation; fig. 1.2*A*). Grid lines east of line A become line B and so forth.

To set up line A, locate the first survey post (A0) at the westernmost turbine and place the within-line fence posts every 50 m, in both directions if necessary (fig. 1.1). To set up the next grid line, determine the compass bearing (declination of 10 degrees east) that represents the angle of the ridge, and use this compass bearing to guide line placement, walking 200 m perpendicular from A0 to begin line B or line Z. Pacing out the distances is acceptable as long as crew members have established their individual pace. To create straight lines, it helps to walk toward a specific destination on the horizon along the compass bearing, even if it is something like a distinct shrub clump. As posts are being placed, check backwards often to make sure that a straight line is being established. It is helpful to work in groups of two; one person can stay at the beginning of the line to ensure that the walking person stays on the compass bearing.

Some study plots have a side that is an “edge” between two land uses. If the land use change is major, such as a gravel or paved road, back up 100 m. If the land use edge is a change in vegetation, such as cropland or wetland, back up 50 m. In this manner, the last survey line should be as far as possible away from the turbine (but within 800 m) and on the same angle as the turbine on the ridge, but the surveyable extent does not cover edge habitat. This last grid line in both directions may not be “complete” in the sense that it is 200 m from the previous line. Follow the instructions for labeling given in the “Basic Grid Characteristics” section.

The location of all posts must be recorded using Global Positioning System (GPS) units. Crew members may choose to make sure the site is set up satisfactorily before recording post locations, or the crew may record positions as posts are placed and labelled; the latter is recommended only after having gained experience. Periodically check the GPS unit to be sure that easting and northing are being collected using North American Datum of 1983 and that coordinates are Universal Transverse Mercator; record elevation in meters.

Control Plots

Line A should be oriented along the ridge, imagining a turbine string of about three turbines, and subsequent grid lines should be perpendicular to the ridge. Note again that in later years, control plots were set up using fence lines as guides; figure 1.2*B*. The line does not need to be longer than 800 m. Continue to work in all directions to the extent that land use and landowner permission allow; record GPS information.

Crew Familiarization with Survey Grids

Crews that initially set up plots have the advantage of familiarity with the plots. Crews in subsequent years will not have that advantage, so each year the crew is responsible for updating the plot description sheets. It is imperative that crew members record adjustments to the plots by indicating those changes on the plot maps (fig. 1.2), as well as following up with appropriate text in the plot description sheets (see “Example of Plot Description—South Dakota Wind Energy Center” section). Actions such as the addition of grid lines, lengthening or shortening of existing grid lines, locations where fiberglass survey markers are erected, and the color of replaced survey markers (because color may vary with supplier availability) should be indicated. The crew in the following year will depend on the plot description sheets to become familiar with the plots.

It is crucial that each crew member becomes familiar with each plot during the first week before beginning the avian surveys. Crew members should communicate with each other about how to maintain orientation on the plots. All crew members should walk the entirety of plots and discuss how to supplement the labeling in hilly sections that will make it difficult to maintain orientation while surveying (see “Tips for Keeping Travel Orientation” section). Consider walking each survey transect from the easiest point, such as the transect near a section line or a distinctive wetland, to become familiar with the plots and their transects.

Tips for Keeping Travel Orientation

The 200-m distance between grid lines is far enough apart on some hilly plots to lose the direction-of-travel line; therefore, it is good to have a strategy for maintaining the travel line so as not to miss any areas or double count any areas during the avian surveys. Here are some strategies:

- It is a necessity to label each colored fiberglass survey marker. Owing to their width, the markers can be read at a distance, so label both sides of the marker in large, black letters.
- Add additional grid lines between the 200-m lines (this was done to some plots in some years and is optional).
- Wrap dark electrical and flagging tape around the posts. Some field crews determined that securing a bit of bright pink or orange flagging tape with black electrical tape around the tops of posts worked well. To guard against cattle interference, label white fiberglass fence posts twice—once towards the top of the pole and once near ground level; this will reduce the likelihood that cattle will rub off all of the labels (fig. 1.3). If flagging is used, use on only the 50 or 100 poles, not both. For flagging, tie a small piece to the top but do not wrap around the pole or leave a long tail (the cattle likely will eat it); if cattle do eat the flagging, because of the electrical tape, one can still scan with binoculars during the survey and discern the alternating pattern of taped poles, and thus better determine the correct direction of travel.
- Label each fiberglass post. This will not help for reading posts from a distance because the posts are such a small diameter, but it will help when arriving at the post to verify position. This step is optional but is strongly suggested, especially for confusing portions of plots (such as in hilly terrain, or when one needs to walk around a wetland and get back to the direction-of-travel line).
- Use pin flags where topography is rugged and where seeing the next post along the direction-of-travel line is impossible. Cattle will likely destroy pin flags, but they may survive for a survey year.
- On plots surrounded by fences, try to label the fence by wrapping flagging tape around the strands of barbed wire, or driving in wooden lathes (on the opposite side of the fence as the cattle) and labelling them.
- If any new fences have been erected since the previous year, use the GPS unit to record a track file of the new fences. Do this during plot setup.

Plot Maintenance

The presence of cattle on the plots leads to broken and missing posts. Although fiberglass was chosen for its flexibility and durability, it is not foolproof against curious and itchy cattle. The first week should be spent replacing missing and broken posts. Survey markers may break and leave sharp points, which are a potential hazard to livestock, humans, and vehicle tires; therefore, remove all broken posts. It may be difficult to remove posts or markers that are broken at ground level. First, try to dig them out or use the survey extractor. If they cannot be dug out, saw them off at ground level.

Delineating the Area within the Survey Grid

The area surveyed is used to calculate avian density. Thus, any change in grid dimensions must be documented, and the survey perimeter of the affected plot should be retracked in a GPS and downloaded. The tracked polygon is used to calculate area surveyed. This step is unnecessary if none of the boundaries of the study plots change.

Example of Plot Description—South Dakota Wind Energy Center

Prior to beginning avian surveys, walk through all of the study plots to make sure that the white fiberglass fence posts and the colored fiberglass survey markers are standing and labelled. Survey markers on this plot are orange or blue. All fiberglass fence posts and survey markers were labeled with black marker. Fence posts ending in 100s were marked with black tape, whereas fence posts ending in 50s were marked with black electrical tape and pink flagging (but the pink flagging may be missing by the following spring). Crew members should share the responsibility of updating the plot description sheet for the next year's field crew, so keep note if the color of survey marker changes or if any other part of the protocol changes.

Turbine String 10–13 (Plot A)

The grid that has been established surrounding Turbines 10–13 begins 300 m west of Turbine 13 with YZ0. At Turbine 13 (A0), the plot goes south 50 m. At A50S, the plot extends to FG50S (this is the southeastern border of the plot). The FG, F, E and D lines continue to 650N lines; the B and C lines only go to 50N; and A, Z, and YZ go to 100N. Orange survey markers have been placed at the southern endpoints and at the 650N lines of the D, E, F and FG lines. The survey area was extended to the fence by flagging points on the fence.

Turbine String 14-19 (Plot B)

This is the largest plot. It consists of lines A, Z, Y, X, and additionally, the west fenceline (titled WX) serves as a census line. These lines run north to south. Orange survey markers are located at points X400N, Y400N, Z550N, A550N, X1650S, Y1700S, YZ 900S, Z900S, and A900S. The southern terminus of WX is marked with an orange survey marker, but the northern terminus is not.

Turbine String 20-23 (Plot E)

Plot E consists of lines A, B, C, D, ZA, and YZ. Orange survey markers are located at A100N, B50N, C0N, D0, D550S, C700S, B750S, A750S, ZA700S, and YZ650S.

Turbine String 24-27 (Plot F)

Plot F consists of lines A, B, C, D, Z, Y, and X (fig. 1.2*A*). Blue survey markers are located at A150N, B50N, C0, D0, D850S, C850S, B850S, A750S, Z750S, Y750S, X400N, X600, Y200N, and Z100N. Note that the “S” lines might not be designated, as all but a few posts were “south” posts.

Turbine String 8-9 (Plot G)

Plot G consists of lines A, B, BC, Z, YZ, and Y. Orange survey markers are located at Y0, Y450N, Z550N, A650N, B650N, BC550N, BC500S, B500S, A450S, Z450S, YZ450S, and YZ50S.

Control Plots (Plots H, I, J)

All control plots were set up simply with four lines (A to D) (for example, see fig. 1.2*B*). One can survey fenceline to fenceline, with fences flagged in lieu of fiberglass posts. Plots have orange survey markers at the 0 and 600 lines.

Avian Survey Protocol

The following field equipment is needed for an avian survey:

- directions to plot
- pertinent aerial photograph for the day’s surveys (for example, fig. 1.4)
- plastic page protector to protect against dew and drizzle
- mylar sheets
- felt fine-tip permanent-ink markers
- supply of paper clips and rubberbands
- these instructions if needed at beginning of field season
- American Ornithologists’ Union (AOU) codes if needed
- Clipboard
- pencil with a good eraser and pencil sharpener
- thermometer (attach to clipboard)
- watch
- binoculars
- cap, sunscreen, water, and food

Consider the following tips to avoid losing equipment:

- Tie dental floss to a writing utensil and to the clipboard. The length of floss must be long enough to enable one to write with the utensil over the entire area of the clipboard. To keep the floss from breaking, encase it in tape.
- Attach a small thermometer to the clipboard. Because the thermometer can bang against the clipboard and make noise, tape two large gauze strips, such as those found in First-Aid kits, to the back of the clipboard.
- Reduce “cheat sheets,” such as AOU codes or Beaufort wind scales, and tape them to the clipboard. Put a rubberband around datasheets on the clipboard to keep the wind from catching and tearing the sheets.

Bird surveys will run from mid-May to early July. Crew leaders should maintain a survey record that delineates who surveyed what plots and dates. Birds will be surveyed from half an hour after sunrise to 10:30 a.m., or earlier if the activity and singing of birds has noticeably diminished. Surveys will be conducted on days of good visibility and good aural detectability (that is, days with little or no precipitation and with low to moderate winds). Surveys will not be conducted during a steady drizzle, prolonged rain, fog, or wind velocities that exceed 40 kilometers per hour (25 miles per hour). Survey grids will be surveyed at least twice, and three times if possible. Reverse the route of the survey from one survey to another so that the ending location for the first survey is the starting location for the second survey.

Field Procedures

In the evening before the survey for a particular survey plot, drivers should look at the road map to ensure they know where they are going and the fastest way to get there. Remember that it will be dark in the morning, and landmarks may look different or not be visible.

For the particular day’s survey plot, make sure observers know the path that will be walked during the survey. Decide at what end of the plot the surveys will begin. If the survey is a

Figure 1.4. Example of an avian survey field sheet consisting of a spatial image of the portion of the study plot to be surveyed overlaid with labelled grid lines and turbine locations.

second or third one, do not start at the same point as the previous survey, but alternate start points; start where the surveys finished the last time. Check local wind speed on a weather radio, the radio, TV weather news, or online, or take an anemometer to the plot.

For the first survey of the year at any given plot, regardless of whether a particular plot ends on a “100” direction-of-travel line or a “50” line, always follow the direction of the arrows on the diagram in figure 1.1 (that is, even if a plot ends at 750 m rather than 800 m, begin the survey on the 700 m direction-of-travel line, traveling from west to east). Position the aerial photograph on the clipboard with the mylar over it (figs. 1.4 and 1.5). Fasten the mylar to the aerial photograph with paper clips. Fasten the aerial photograph and mylar to the clipboard with a rubberband. With the sharpie, put a square at each post to have a reference on the mylar layer to the aerial photograph layer when the two are separated and the mylar is scanned. At a minimum, the four outermost grid points per sheet must be delineated on the mylar for accuracy in georeferencing in ArcMap (fig. 1.5). Also, scanning will go much quicker if north is indicated on the mylar sheets.

At the first post on the predetermined travel route, and before surveying, write down the plot name, survey number (for example, 1 or 2), date (include year), sheet number and total number of sheets (for example, 1 of 3), observer, grid location where survey started, start time, presence or absence of cattle, estimated number of cattle, whether wind-turbine blades were moving (this last piece of information will not apply the first year [pretreatment year] or to controls), estimated wind velocity converted to Beaufort scale, wind direction, temperature, and cloud cover. If

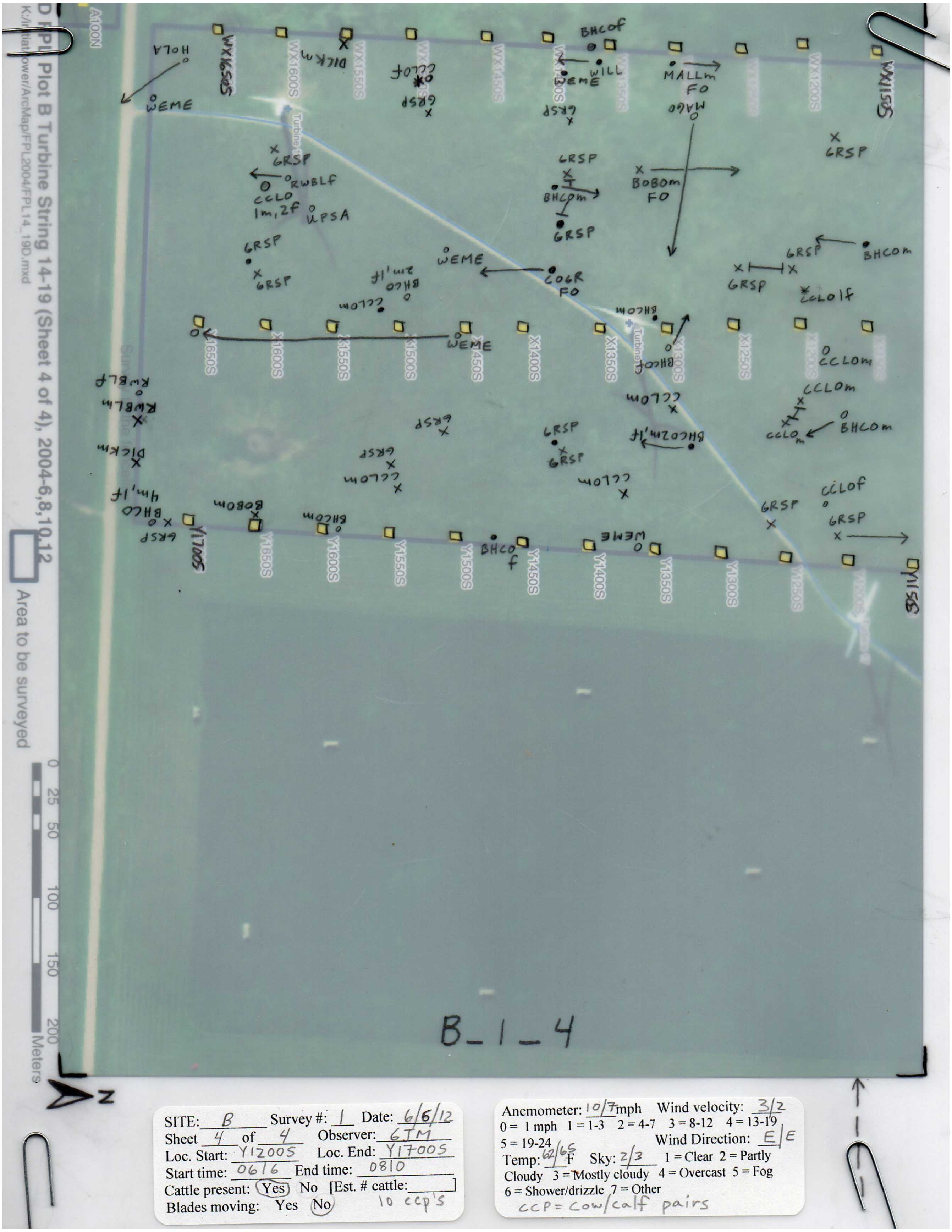


Figure 1.5. Example of the completed avian survey, with results recorded on a mylar sheet placed over the avian survey field sheet.

cattle are present in only certain areas of the grid, draw that area on the mylar and return to that area to survey when the cattle are no longer present.

It is very important that all mylar sheets are labeled. Sheet 1 of 1 will have two white labels where the above information is to be recorded. At a minimum, subsequent sheets should have the plot name, sheet number, total number of sheets, date (include year), survey number, and the observer if different than on the first sheet (fig. 1.5).

Begin walking to the first survey post on the direction-of-travel line, paying close attention to chipping and flushing birds. Plot on the mylar the approximate locations of birds that are seen or heard within 50 m on either side of the direction-of-travel line (unless, of course, it is the end of a plot, whereby the observer may only be recording on one side of the line). Consider the survey to be almost a continuous-walking survey (this is an "almost" because the observer will need to stop periodically and record the location of each bird onto the mylar). Under the condition of low bird activity, the observer may feel comfortable mapping while walking; other times, under the condition of high bird activity, the mapping is most easily done by stopping momentarily at each post. Under the scenario of encountering an unfamiliar bird (either visually or aurally), it is important to stop long enough to make an accurate identification.

Although in general the observer will plot only birds within 50 m of the travel line, mark down the potential locations of counter-singing males that are more than 50 m away and within the next transect. When in closer proximity to the counter-singing bird on the pertinent transect, plot a more precise location (have a good eraser handy!). For meadowlarks (*Sturnella* species), which have large territories, fly around, and are not easy to get close to, pay careful attention to their locations at the beginning of the survey and continue to map when seen, not just within the 50 m. Meadowlarks sometimes sing from posts, so the observer may be able to use this behavior to map them from their post locations. Use the codes shown in figure 1.6 to indicate vocalizations, behaviors, and sex as bird locations are plotted.

Use the AOU abbreviations for species' names next to the codes (fig. 1.6). If the differentiation between male and female is possible, then note the sex next to the name (for example, BHCO ♂). Make sure to write legibly so that codes are clear. Spend time memorizing the AOU code abbreviations. If unsure of a code abbreviation, write down the full name of the species and check later; do not make up abbreviations.

Try to locate every bird by sight to get a more precise distance estimate and location. Practice estimating distance during the first days of the field season. If two birds are believed to be paired, take a second to watch them and clearly indicate on the mylar if they are indeed paired because clear notation that two birds are paired helps during data entry. Become familiar with how to assign indicated pairs (refer to the "Guidance for Assigning Indicated Breeding Pairs" section).

While traversing the survey plot, consider noting the posts by checking off each post on the mylar as it is approached. By physically indicating the arrival at the next expected post in the survey transect, the observer can focus primarily on surveying and less on navigating. Do not underestimate how easy it is to become disoriented on a plot; it is very possible to become so disoriented as to end up walking towards and ending up at the next row of survey posts than the row intended. The likelihood of this happening increases as the numbering on the posts wears off from exposure to the elements and as posts get knocked down by cattle and overlooked when lying on the ground. Do not assume that just because a post is visible on the near horizon, it is the next expected post on the intended direction-of-travel line. Losing track of what post should come next or missing even a single downed post can be enough to cause observer deviation in the intended direction-of-travel. Checking off posts on the mylar sheet at arrival greatly decreases the chances of disorientation.

When the survey is completed, record the ending time and how many datasheets were needed for the particular study plot. Verify that the number of sheets is correct. If there are six sheets per plot per survey, the label on the first sheet should indicate 1 of 6; subsequent sheets should be 2 of 6, and so forth. It may not be possible to survey the entirety of large study plots in 1 day. When the time has reached 10:30 a.m., note on the datasheet the post at which surveying stopped and the time. The next day, record the start time and other particulars and begin surveying at the post at which surveying ceased the previous day.

After surveying, make sure notations are legible and dark on the mylar (fig. 1.5), so that all notations are visible on scans and photocopies during the data-entry process. Also after surveying, go through the sheets to ensure that sex for dimorphic species, sex composition of groups of dimorphic species, and pairing of birds are clearly indicated (fig. 1.7). The observer should make the decision about whether birds are paired or not so that the person entering the data can make an informed decision.

Guidance for Assigning Indicated Breeding Pairs

All individual birds seen or heard within survey transects will be counted and recorded by their AOU code. Birds flying overhead will be counted as breeding pairs if they are flying low and presumably feeding (for example, swallows [Hirundinidae]), hunting (for example, northern harrier [*Circus hudsonius*]), or using the plot as potential sites for brood parasitism (for example, brown-headed cowbird [*Molothrus ater*]). Birds that appear to be flying over the plot with no intention of using it for feeding, hunting, or scoping out the potential for parasitism should be indicated as "fly-overs" by the abbreviation "FO" (for example, FO: 2 AMGO ♂). Clearly mark whether or not birds using airspace are being counted as breeding pairs.

Examples of sexually dimorphic species likely to be encountered in the study areas for which sex determination can be noted include northern harrier, ring-necked pheasant (*Phasianus colchicus*), dickcissel (*Spiza americana*), chestnut-collared longspur (*Calcarius ornatus*), bobolink (*Dolichonyx oryzivorus*), red-winged blackbird (*Agelaius phoeniceus*),

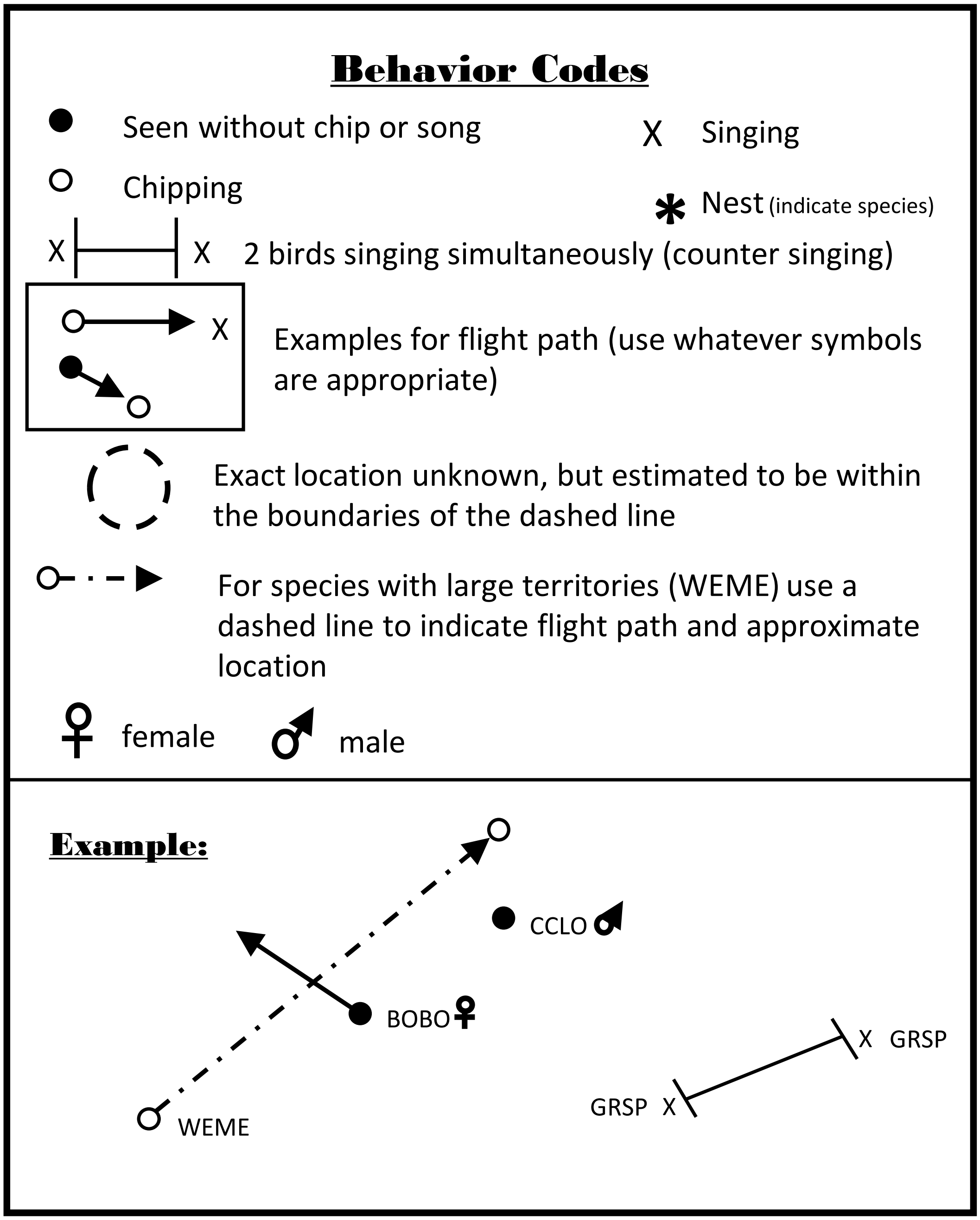


Figure 1.6. Codes used during avian surveys to indicate vocalizations, behavior, and sex of birds.

yellow-headed blackbird (*Xanthocephalus xanthocephalus*), brown-headed cowbird, and American goldfinch (*Carduelis tristis*). For sexually dimorphic birds, sex of bird will be recorded by writing “m” or “♂” for male and “f” or “♀” for female after the AOU code. Lone individuals or pairs will indicate breeding pairs. For polyandrous Wilson’s phalaropes (*Phalaropis tricolor*), lone females and segregated pairs will indicate breeding pairs. For polygynous red-winged blackbirds and yellow-headed blackbirds, total number of breeding pairs will be based on number of males. For the brood parasitic brown-headed cowbird, total number of breeding pairs will be based on number of females. For groups of dimorphic species, indicate the number of individuals and sexual composition (for example, 3 BHCO ♂, 2 BHCO ♀ or 3 MALL ♂, 2 MALL ♀).

For waterfowl groups, number and sexual composition will be recorded. Rules will follow those of Dzubin (1969), Hammond (1969), and Cowardin and others (1995). Estimated number of breeding pairs will be tabulated as follows. In general, single pairs, lone males of dabblers or divers, and lone females of diving ducks each will be considered an estimated

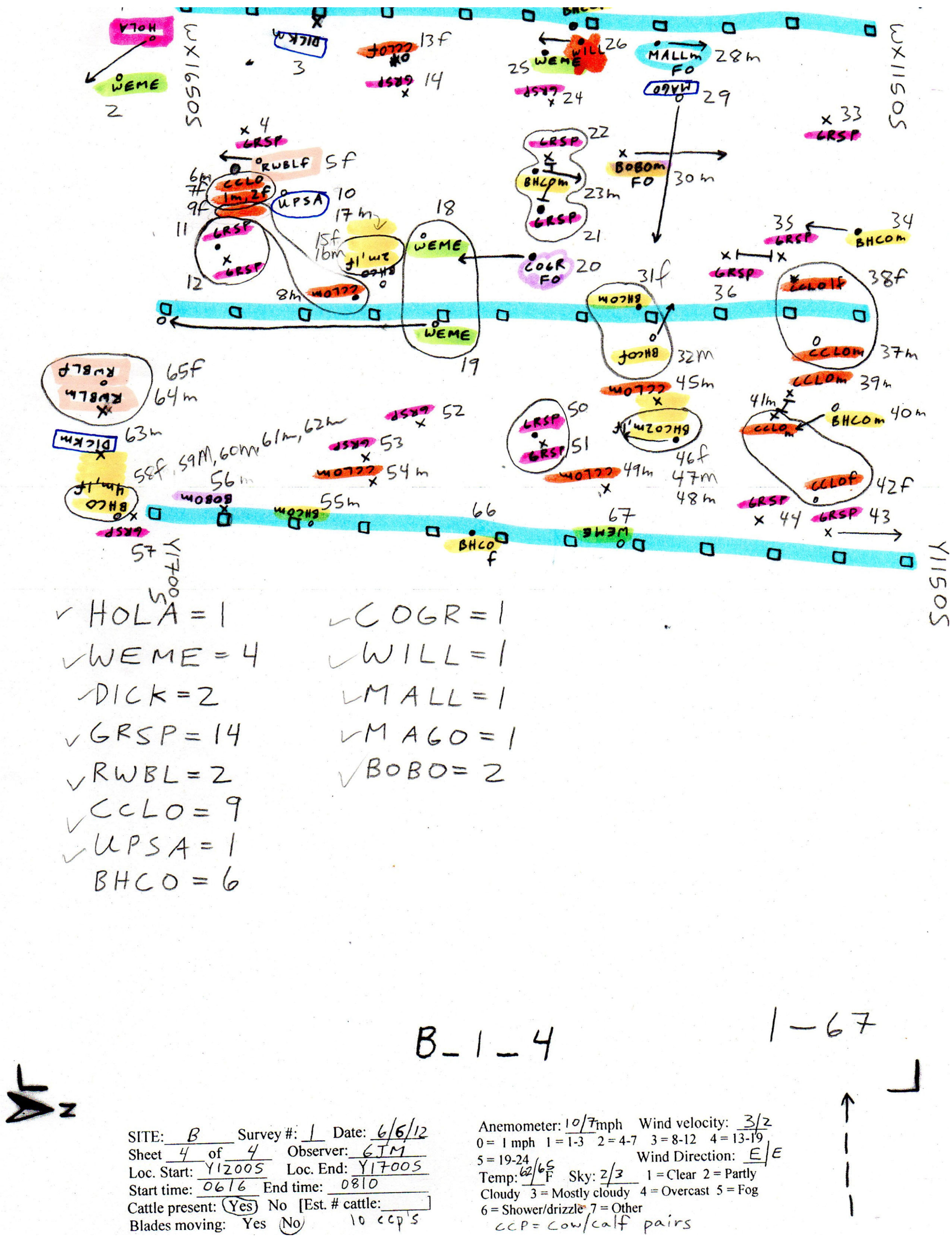


Figure 1.7. Example of the photocopied and highlighted version of the mylar sheet, with bird observations assigned unique identifying numbers and with notation clarifying appropriate sex. Breeding-pair decisions are clearly marked.

breeding pair. With the exception of the cases indicated below, each male dabbling duck in a flock of less than or equal to five individuals will be tallied as a breeding pair. Each female diving duck in a flock of less than or equal to five individuals will be tallied as a breeding pair. Ducks in flocks with greater than five individuals will not indicate breeding pairs. For American wigeon (*Mareca americana*), northern shoveler (*Spatula clypeata*), and northern pintail (*Anas acuta*) encountered prior to June 5, all lone males, pairs, all grouped males, and all males in aerial flights on ponds will be considered as pairs. After June 5, only grouped males of less than or equal to five individuals, lone males, males in aerial flights, and pairs will be considered breeding pairs. For gadwall (*Mareca stepera*) and blue-winged teal (*Anas discors*), the above rule will apply, but the cutoff date will be June 10.

For wide-ranging or colonial-nesting species that are not sexually dimorphic (for example, shorebirds, coots, grebes, and swallows), one or two individuals indicate a pair. Monomorphic species in groups, such as colonial species, swallows, and chimney swifts (*Chaetura pelagica*), will be tallied by counting the total number of birds, dividing by two, and rounding up to the nearest whole pair. Lone individuals or pairs of sexually monomorphic songbird species, such as the grassland sparrows and western meadowlark (*Sturnella neglecta*), will be tallied as indicated breeding pairs. Either sex of monomorphic raptor and owl species when seen alone or in pairs will indicate breeding pairs.

Office Procedure

Prepare the mylar sheets for scanning by making sure all notation is dark and legible, including the behavioral symbols that indicate locations of birds, the accompanying AOU codes, the four outer-most grid points, the north arrow, and the sheet number (fig. 1.5). Legible symbols, grid points, and a north arrow are very helpful for orientation in the georeferencing process (that is, assigning x,y coordinates to bird locations). The sheet number is used as the computer file name, and the sheet is saved as a .jpg. Computer file naming conventions will, at a minimum, involve the study's primary location, current year, wind facility's name abbreviation, study plot letter(s), observer, survey number, and sheet number.

Photocopy the mylar sheet, highlight all species, and assign each bird location/observation with a unique number (fig. 1.7). Make bird-pairing decisions. Highlighting the pairs and assigning numbers on a hard copy makes filling out the computer attribute table during the ArcMap process much easier.

ArcMap will be used for georeferencing. The grid points that constitute the survey plots were previously uploaded into ArcMap to make the plot and vegetation maps, and thus already exist as a .shp file. A .jpg file of a mylar sheet is added as a layer, and the corresponding grid points in the .shp file are used to georeference the mylar file. Save this new .jpg file, retaining the naming convention as already described.

Use this georeferenced .jpg layer to georeference the bird locations. The georeferenced bird locations are used to determine the distance of the bird from the nearest turbine. This step involves entering the bird-location and pairing-assignment data into an attribute table (table 1.1), a template of which will be added as a .shp layer and renamed following the standardized naming convention. Each bird is entered as a point feature, and the following corresponding data are added to the attribute table:

- For site (plot): "Site_Letter" (enter the appropriate letter[s] indicating site [plot], such as A–W, OBA–OBB, or OLA–OLE)
- For survey number: "Survey" (1–2)
- For date: "Month" (written out), "Day" (no zeros in front of single digits), "Year" (full year, such as 2006)
- For observer: "Observer" (3-letter initials, such as JAS)
- For species: "Species" (AOU code, followed by m=male, f=female, n=nest, u=unknown sex)
- For the X Coordinate: "Loc_X" (georeferenced coordinate)
- For the Y Coordinate: "Loc_Y" (georeferenced coordinate)
- For match: "Match" (field to be able to match females and (or) nests to males to indicate pairing)
- For unique number: "Bird_Id" (the whole number assigned to each observation during the highlighting process)
- For sheet information: "Sheet_Id" (a combination of site letter_survey and number_sheet number)

Save the georeferenced bird locations and underlying attribute table (table 1.1) according to the standardized naming convention. The attribute table is proofed by selecting one point at a time and comparing the entered data to the highlighted photocopy.

Vegetation Protocol

The purpose of this protocol is to characterize the vegetation in each study area to determine variation in vegetation owing to differential grazing pressure and changes in topography. Equipment needed for vegetation protocol includes:

- maps of aerial photographs with vegetation sampling cells
- field datasheets
- clipboard

Table 1.1. Example of an attribute table in ArcMap (essentially, a spreadsheet) for entering bird-observation data.

[HOLA, horned lark; m, male; --, bird not matched as part of a breeding pair; WEME, western meadowlark; DICK, dickcissel; GRSP, grasshopper sparrow; RWBL, red-winged blackbird; f, female; CCLO, chestnut-collared longspur; UPSA, upland sandpiper; u, unknown sex; BHCO, brown-headed cowbird]

Site_letter	Survey	Month	Day	Year	Observer	Species	Loc_X	Loc_Y	Match	Bird_Id	Sheet_Id
B	1	June	6	2012	GJM	HOLAm	462405.9	4911257.9	--	1	B_1_4
B	1	June	6	2012	GJM	WEMEm	462435.7	4911246.5	--	2	B_1_4
B	1	June	6	2012	GJM	DICKm	462391.9	4911378.0	--	3	B_1_4
B	1	June	6	2012	GJM	GRSPm	462469.9	4911329.8	--	4	B_1_4
B	1	June	6	2012	GJM	RWBLf	462490.9	4911338.5	--	5	B_1_4
B	1	June	6	2012	GJM	CCLOf	462498.8	4911321.0	--	7	B_1_4
B	1	June	6	2012	GJM	CCLOm	462498.0	4911321.9	7	6	B_1_4
B	1	June	6	2012	GJM	CCLOf	462496.2	4911321.9	--	9	B_1_4
B	1	June	6	2012	GJM	CCLOm	462586.5	4911413.1	9	8	B_1_4
B	1	June	6	2012	GJM	UPSAu	462512.9	4911357.8	--	10	B_1_4
B	1	June	6	2012	GJM	GRSPf	462554.1	4911313.1	--	12	B_1_4
B	1	June	6	2012	GJM	GRSPm	462565.5	4911318.4	12	11	B_1_4
B	1	June	6	2012	GJM	CCLOf	462411.2	4911443.7	--	13	B_1_4
B	1	June	6	2012	GJM	GRSPm	462437.5	4911442.9	--	14	B_1_4
B	1	June	6	2012	GJM	BHCOm	462576.0	4911433.2	--	16	B_1_4
B	1	June	6	2012	GJM	BHCOf	462576.0	4911433.2	16–17	15	B_1_4
B	1	June	6	2012	GJM	BHCOm	462576.0	4911433.2	--	17	B_1_4
B	1	June	6	2012	GJM	WEMEf	462604.9	4911472.7	--	19	B_1_4
B	1	June	6	2012	GJM	WEMEm	462540.0	4911460.4	19	18	B_1_4

- pencils
- step-point sampler
- Robel pole
- meter stick

Vegetation Measurements

The step-point sampler of Owensby (1973) measures percent composition of six basic life forms: bare ground (that is, bare ground, rock, cow pie), grass, forb, shrub, standing residual vegetation (that is, dead vegetation greater than or equal to 45 degrees), and lying litter (that is, dead vegetation less than 45 degrees). The meter stick measures litter depth and vegetation height in centimeters. The Robel pole of Robel and others (1970) measures the height and density (visual obstruction reading) of vegetation in decimeters.

Conduct vegetation measurements when vegetation is dry. Do not measure vegetation when it is wet, such as during early morning hours and within 1 hour after rain. When possible, conduct vegetation measurements after livestock have spent 2 weeks on the pastures, because one of the factors we want to measure is grazing intensity. If by mid-June, no livestock have been present, proceed with the vegetation surveys.

Location of Vegetation Lines and Points

Vegetation measurements will be taken in systematic fashion within each 200 by 50 m cell that is formed by the survey grid (fig. 1.8). Each cell will be assigned a unique number to aid in identifying cells for data entry.

Within each grid cell will be two sampling lines of 50 m in length along which the vegetation measurements are taken (fig. 1.9). The first line will cover the interval from approximately 25 to 75 m of the lower half of the cell. Using the example of the cell bounded by grid points A0, A50N, B50N, and B0 (fig. 1.9), pace 10 m along the transect from point A0 to point A50N and pace 25 m from the 10-m location. Begin the first 50-m sampling line at this location. The second sampling line will cover the interval from approximately 125 to 175 m of the upper right quarter of the cell. Pace 40 m along the transect from point A0 to point A50N and pace 125 m from the 40 m location. Begin the second 50-m sampling line at this location.

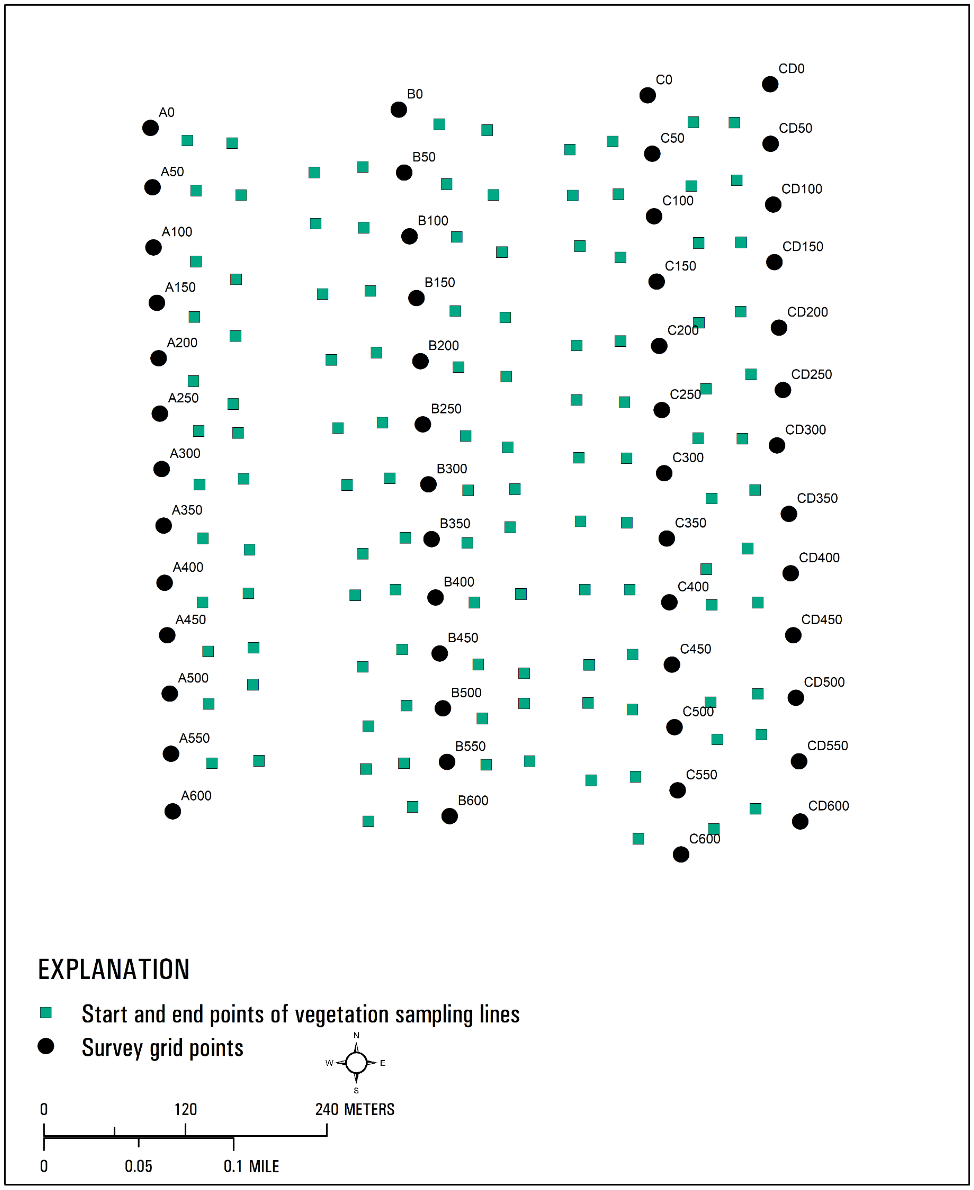


Figure 1.8. Diagram indicating rough approximations of locations for vegetation sampling lines on a control plot.

Waypoint Naming Convention for Sampling Lines

With a GPS unit, take waypoints of vegetation sampling lines (fig. 1.10). Waypoints should be taken at the 10- and 50-m sampling point locations. Waypoint labelling will follow a naming standard so that data management is easier at the end of the field season. Lines should be named following this convention: [alphabetical plot designation], [vegetation sampling cell number], [sampling line], and [year]; for example, A009S107 for a line on Plot A, cell 9 (represented as a 3-digit number), sample line 1, year 2007. Datasheets reflect this naming convention (fig. 1.11), and the MSAccess data-entry program is designed to accept this naming convention.

Taking Vegetation Measurements

From the beginning locations of the sampling lines, work along an imaginary 50-m line that parallels the angle of the survey lines. Along each line, take five measurements with the step-point sampler, with the Robel pole, and with the meter stick at each of the 10-, 20-, 30-, 40-, and 50-m points (fig. 1.10). With three people, one can record data, one can work the step-point sampler and the meter stick, and one can take Robel readings.

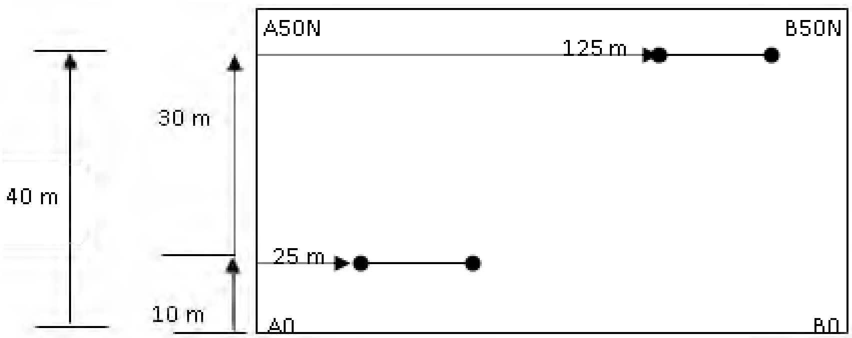


Figure 1.9. Diagram indicating locations of vegetation sampling lines within a single survey grid cell under the scenario of two sampling lines per grid cell.

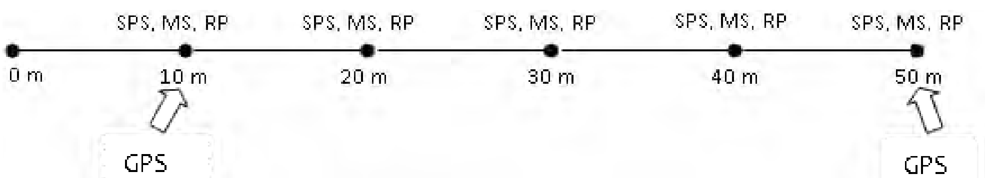


Figure 1.10. Diagram of a vegetation sampling line indicating that global positioning system (GPS) waypoints are to be taken at 10 and 50 meters and that measurements with the step-point sampler (SPS), the meter stick (MS), and the Robel pole (RP) are to be taken at 10, 20, 30, 40, and 50 meters.

Step-Point Sampler

At the appropriate location for a sampling line within a grid cell (fig. 1.9), pace 10 m to the first spot where the step-point sampler will be used (fig. 1.10). Plant the "V" legs of the sampler at the end of the crew member's shoe on the right leg. Lean the sampler frame back towards the leg and then forward until contact is made between the point rod and a plant (dead or alive) or bare ground.

Visual Obstruction Reading with Robel Pole

At the approximate location where the point rod of the step-point sampler makes contact with the ground, place the Robel pole. Record the maximum height (to the nearest 0.5 decimeter [dm]; 1 dm=10 centimeter) that is 100 percent obscured by vegetation from a distance of 4 m and a viewing height of 1 m. For each Robel reading, take four measurements—one in each cardinal direction.

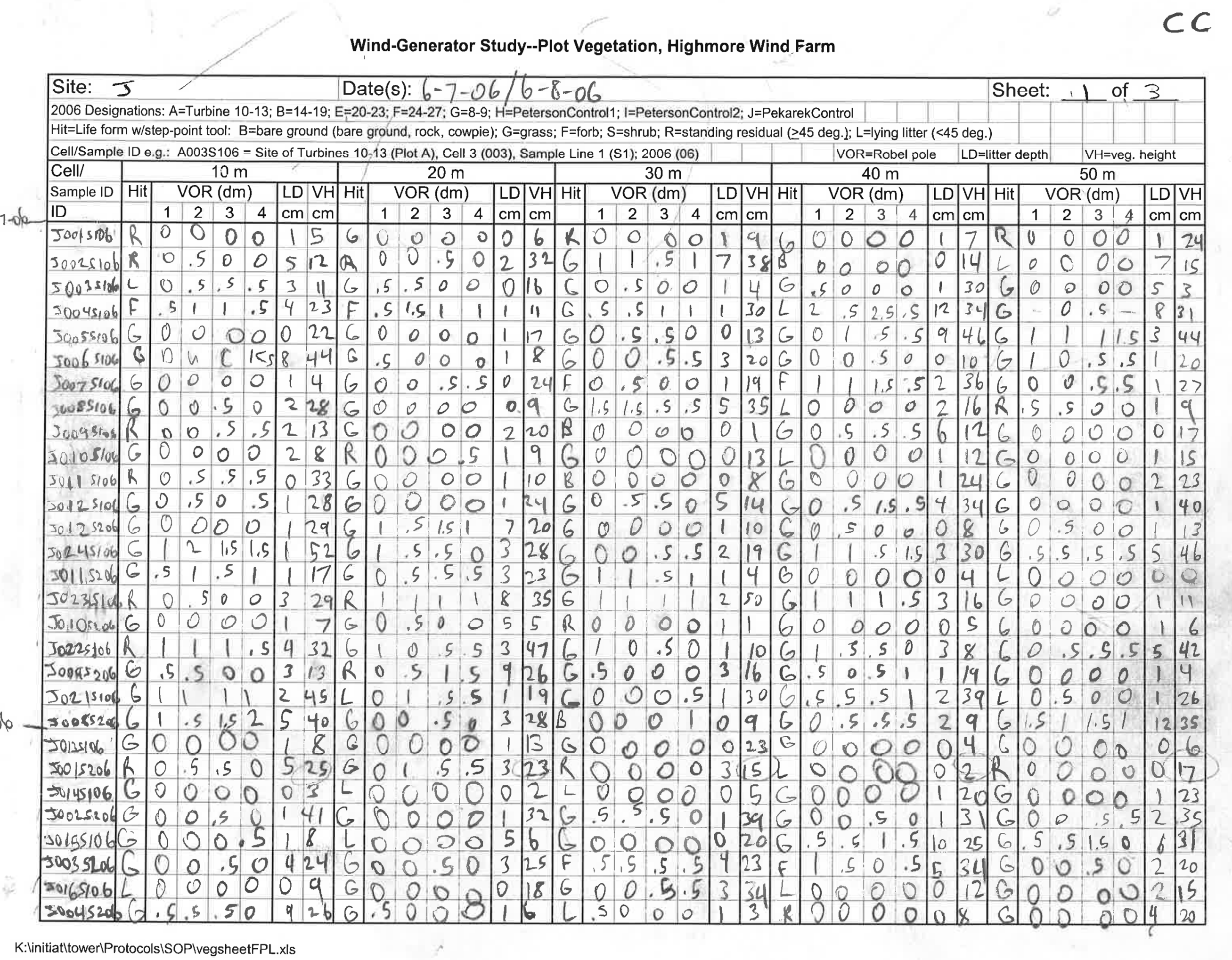
The Robel pole is marked off in red, underlined, 1-dm intervals; intervals of 0.5 m are in black. Basically, the person taking the Robel reading is looking for any portion of the lowest line that is not covered by vegetation. Record the 0.5 dm below the line that is visible (for example, if the red line underneath the number 4 is visible, record 3.5; if the 4.5 line and most of the number 4 is visible but the red line below the 4 is not visible, record 4). If the Robel pole is to be placed on a steep slope such that the person taking the Robel reading would be standing above or below the pole for two of the measurements, take only the two measurements that are on the contour of the slope.

Litter Depth with Meter Stick

At the Robel pole, take a litter depth measurement with the meter stick and record litter depth to the nearest centimeter. Estimate the height at which the meter stick is totally covered by horizontally lying dead plant material if viewing horizontally. Use a dry grass stem to help estimate litter depth by poking it horizontally through the vegetation.

Vegetation Height with Meter Stick

At the Robel pole, record the height of the plant (dead or alive) to the nearest centimeter at the highest level where the plant touches the meter stick.



Wind-Generator Study--Plot Vegetation, Highmore Wind Farm

Site: J Date(s): 6-7-06/6-8-06 Sheet: 1 of 3

2006 Designations: A=Turbine 10-13; B=14-19; E=20-23; F=24-27; G=8-9; H=PetersonControl1; I=PetersonControl2; J=PekarekControl

Hit=Life form w/step-point tool: B=bare ground (bare ground, rock, cowpie); G=grass; F=forb; S=shrub; R=standing residual (≥45 deg.); L=lying litter (<45 deg.)

Cell/Sample ID e.g.: A003S106 = Site of Turbines 10-13 (Plot A), Cell 3 (003), Sample Line 1 (S1); 2006 (06) VOR=Robel pole LD=litter depth VH=veg. height

K:\initiat\tower\Protocols\SOP\vegsheetFPL.xls

Figure 1.11. Example of a completed datasheet for vegetation sampling.

Dealing with Unequal-Sized or Heterogeneous Cells

Here are the criteria for locating vegetation sampling lines in survey grid cells that are not completely 50 m by 200 m in dimension or that have heterogeneous vegetation characteristics:

- If the grid cell is three-fourths the normal size, try to get in the two vegetation sampling lines.
- If the cell is one-half the normal size, place one vegetation sampling line in the approximate center of the area that is available within the cell.
- The important thing to remember about placing vegetation sampling lines in cells where one cannot follow the usual placement rule is to be unbiased in the line placement. Do not place the sampling line based on characteristics of the vegetation. Instead, place the sampling line in the approximate center of the area available within the partial grid cell, or place to allow two sampling lines rather than one.
- If a grid cell cannot fit the entirety of the 50-m vegetation sampling line within it, do not conduct vegetation measurements in cells.
- If a survey grid cell is partially in one grazing regime and partially in another, treat the cell as two cells for the purposes of placing vegetation sampling lines. The two cells will be given unique numbers. If the portion of the cell in one grazing regime can accommodate two sampling lines, place two sampling lines in that portion of the cell. If the remainder of the cell in the second grazing regime can only accommodate one sampling line, place one sampling line in that portion of the cell (fig. 1.12).

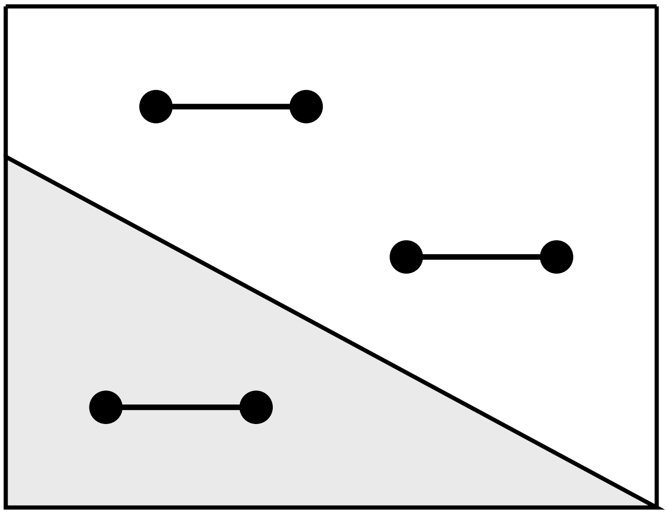


Figure 1.12. Diagram depicting placement of vegetation sampling lines within a survey grid cell containing two different grazing regimes.

- If a vegetation sampling line would be placed through a wetland or clump of woody vegetation, move the sampling line to the nearest available patch of grassland while remaining within the boundaries of the same cell. Wetlands and large areas of wooded vegetation should have been eliminated from the area covered by the survey grid. However, smaller wetlands and small, isolated clumps of woody vegetation may have been included. Wet areas may form in low-lying areas during wet years that were largely dry in dry years. Map the wet areas and clumps of woody vegetation on the aerial photograph (refer to the "Mapping of Habitats and Landscape Features" section). Note that it is difficult to judge from aerial photographs whether the vegetation is homogeneous or heterogeneous in terms of grazed grassland. If a crew member disagrees with one of the sampling locations, document why and the approximate new location of the sampling line. Field crews should be sampling all grassland, even slightly wet grassland (like near wetlands), and shrubby areas, like patches of buckbrush, but should not be sampling wetland vegetation or large clumps of trees, like those present in ravines. However, sampling near an occasional, isolated tree is permitted.

Differences in Sampling between Large and Small Survey Plots

On smaller plots, there may be two sampling lines per cell even if cells are less than the 200 by 50 m area and the vegetation is homogeneous. This was done to ensure adequate sample sizes.

On large plots where sampling two lines per cell was not feasible owing to time constraints, one sampling line was placed within a regular-sized (200 by 50 m) cell. Alternating lines were "stair-stepped" (that is, one line was placed in the approximate middle of one-half of the cell, whereas the sampling line for the subsequent cell was placed in the other half of the cell). Where vegetation appeared to become heterogeneous, two lines were placed within a cell, following the vegetation protocol of locating two sample lines per cell.

On very large plots, where sampling even one line per cell was not feasible, sampling lines were placed every third or fourth cell, depending on the plot size and time availability of the crew.

Mapping of Habitats and Landscape Features

With the GPS unit, create waypoints or track the perimeter of larger features that affect vegetation composition and avian use of study areas, such as prairie dog towns, large rock piles, and barren areas owing to recurrent livestock presence (fig. 1.13). Also map areas that are vegetated but that are not grassland, such as tree clumps and wooded ravines, in addition to mapping wetlands. Although some of these features may be obvious on the aerial photograph of the plot map, the actual areal coverage for the current year should be documented. For example, wetlands may be larger or smaller than the size reflected on the aerial photograph based on whether the aerial photograph was taken during a wet or dry year. Tracking the size of wooded areas, wetlands, and prairie dog colonies is essential, because the perimeters of these areas are removed from the area deemed as breeding habitat for grassland bird species, thus affecting the breeding-bird density estimate.

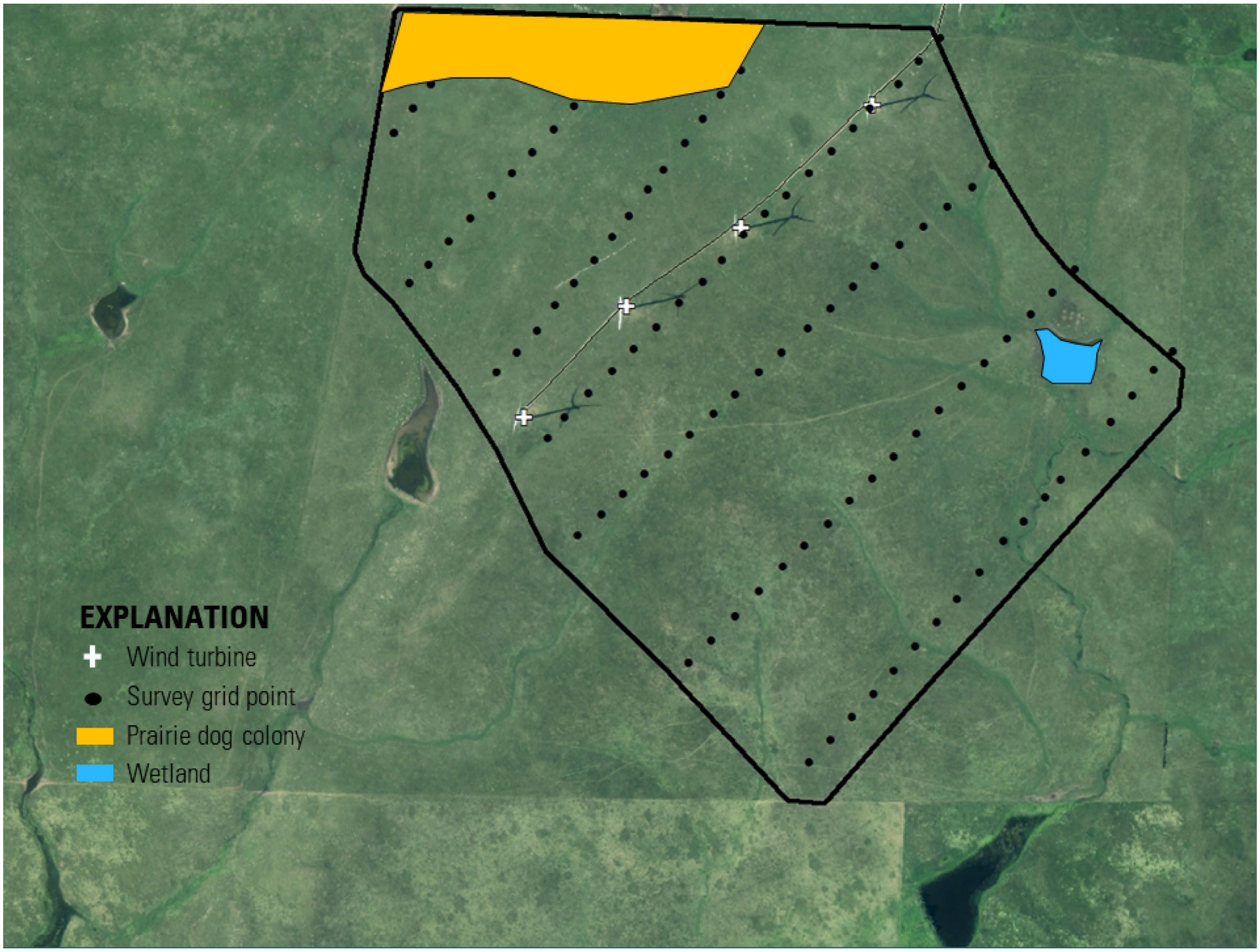


Figure 1.13. Habitat map for a study plot showing locations of a prairie dog colony and a wetland that would not be deemed breeding habitat for some grassland bird species.

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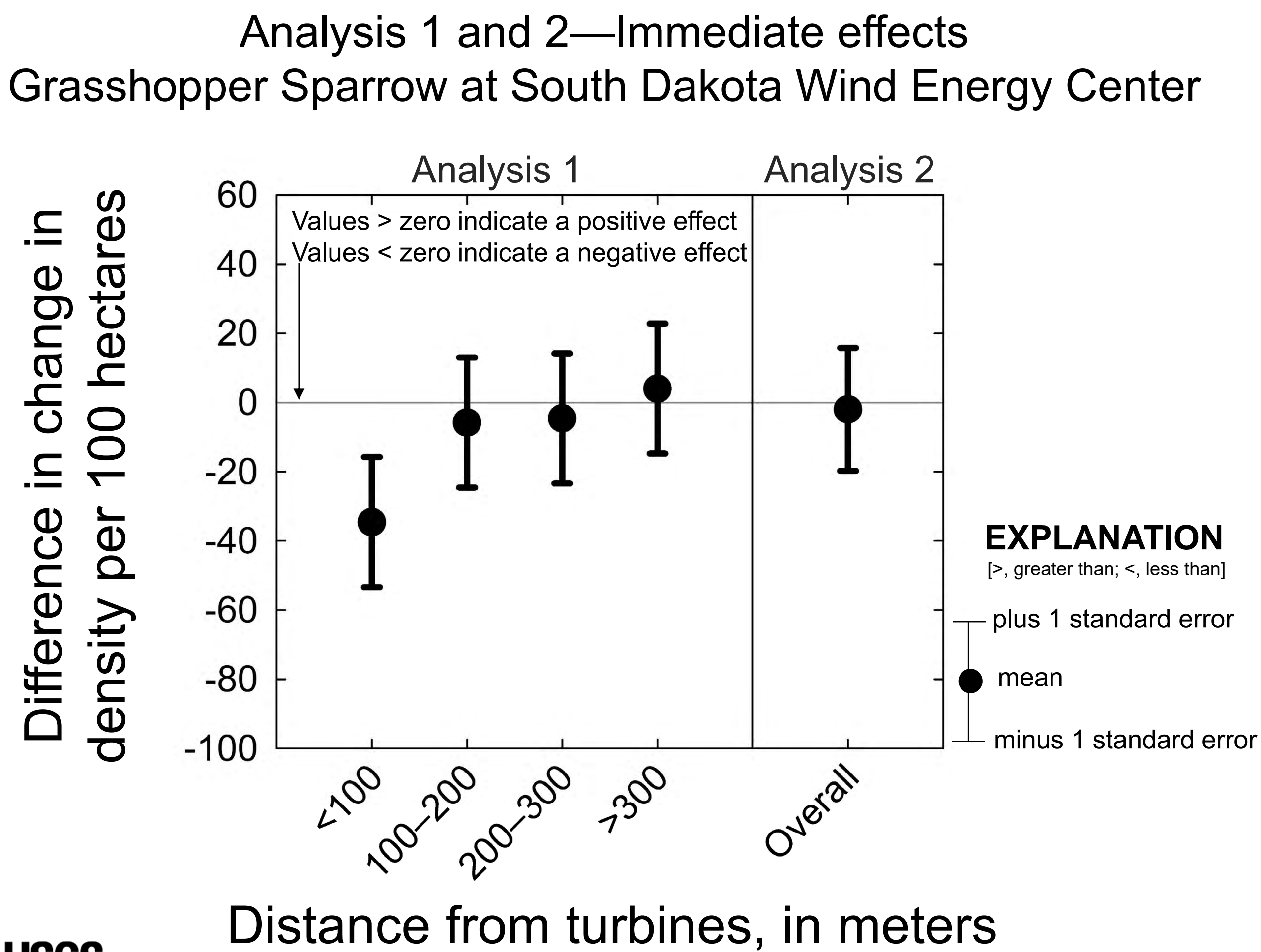
Shaffer, J.A., and Buhl, D.A., 2016, Effects of wind-energy facilities on breeding grassland bird distributions: Conservation Biology, v. 30, no. 1, p. 59–71. [Also available at https://doi.org/10.1111/cobi.12569.]

Appendix 2. Grassland Bird Results

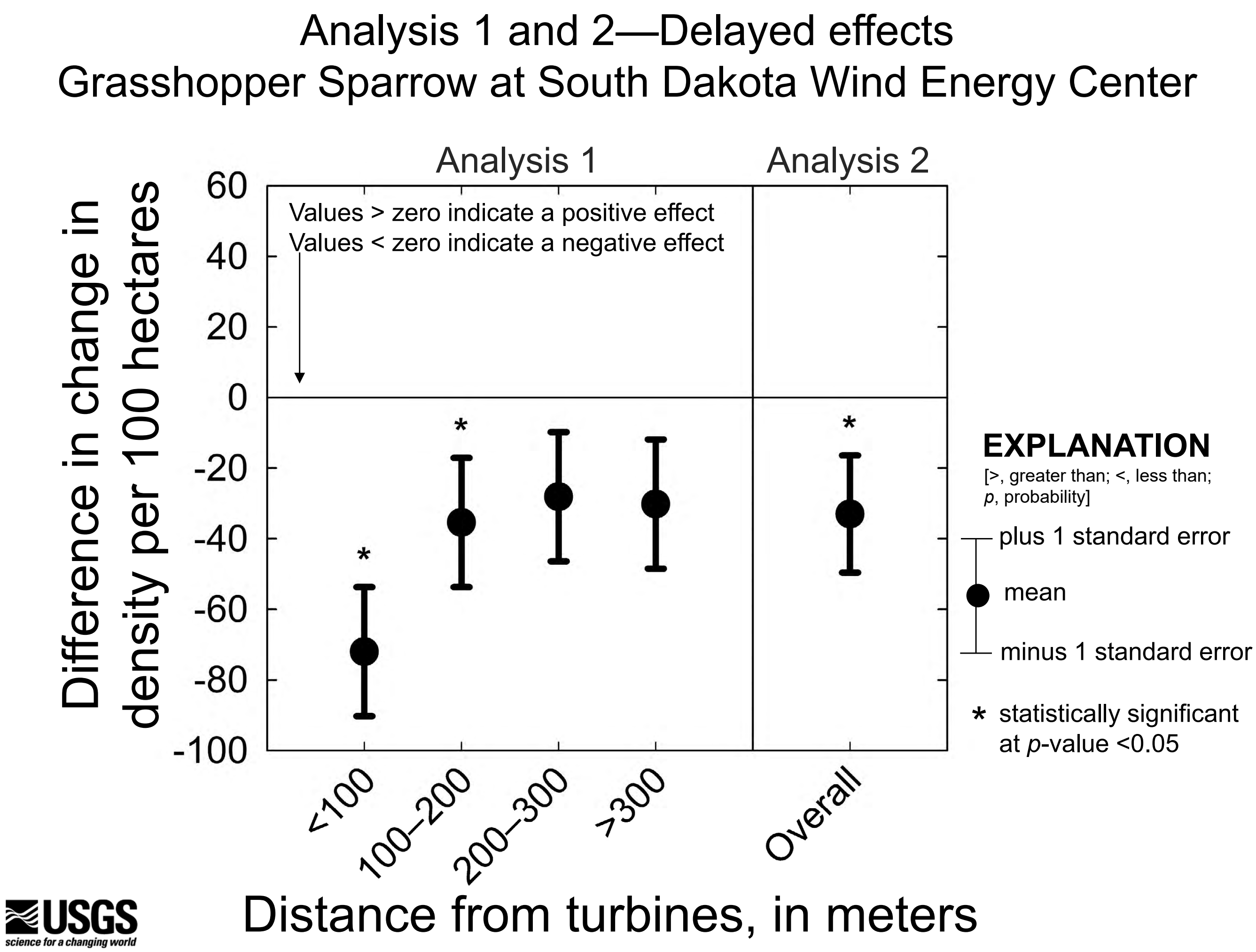
Appendix 2

Appendix 2 provides detailed results for all nine focal species by study area, analysis (by distance band and overall), and time period. The two time periods are immediate (1-year posttreatment) and delayed (2–5-years posttreatment).

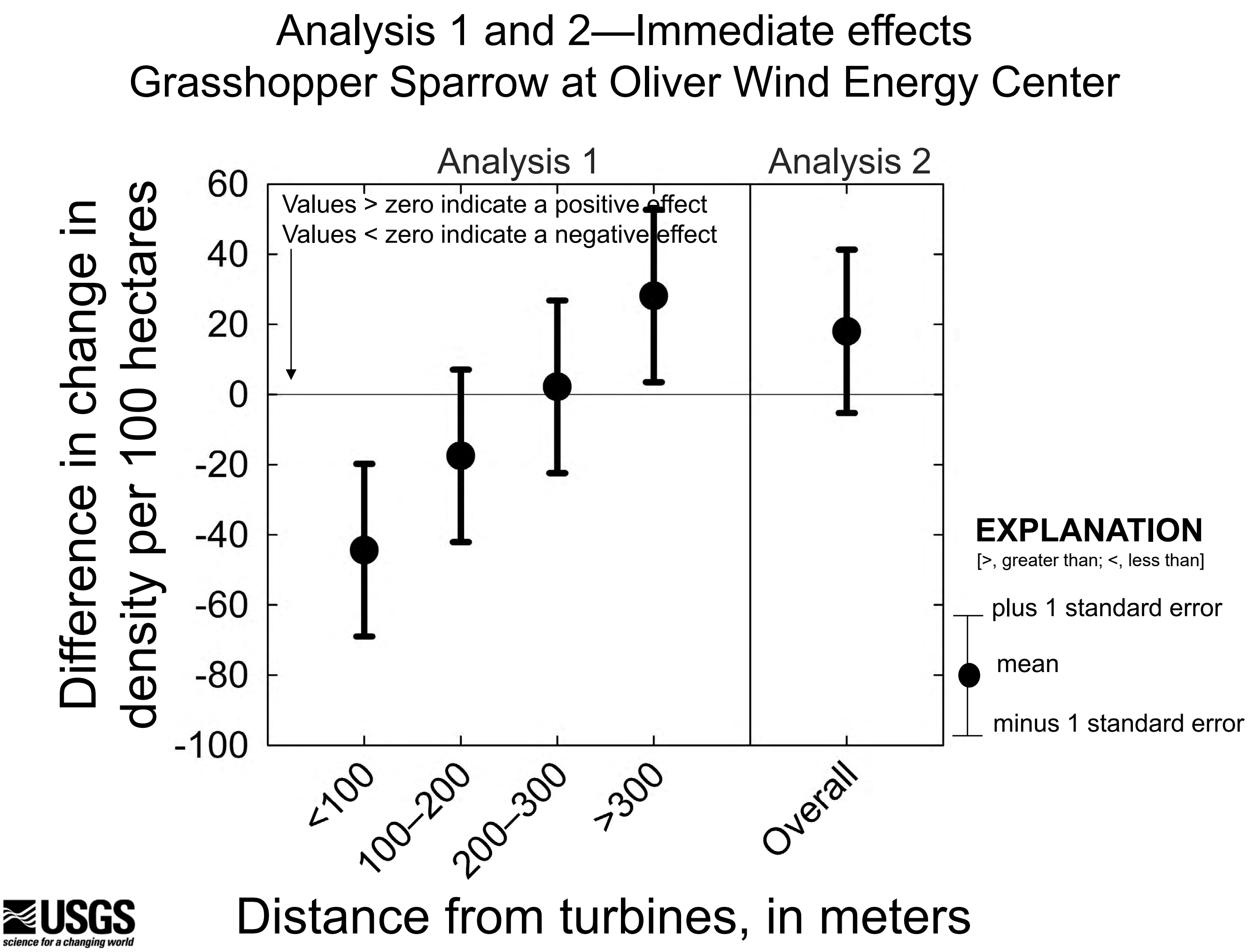
Detailed results from Shaffer and Buhl (2016) for only the grasshopper sparrow (Ammodramus savannarum) and summaries of results for the other eight species are provided in the “Section 2—Displacement Research” section of the main report. Appendix 2 provides detailed results by study area, analysis, and time period for all focal species. The nine focal species are grasshopper sparrow, western meadowlark (Sturnella neglecta), bobolink (Dolichonyx oryzivorus), killdeer (Charadrius vociferus), upland sandpiper (Bartramia longicauda), chestnut-collared longspur (Calcarius ornatus), Savannah sparrow (Passerculus sandwichensis), clay-colored sparrow (Spizella pallida), and vesper sparrow (Pooecetes gramineus). The study areas are NextEra Energy’s South Dakota Wind Energy Center, Acciona’s Tatanka Wind Farm, and NextEra Energy’s Oliver Wind Facility. The two analyses are distance (from turbine) band and overall effects. The two time periods are immediate (1-year posttreatment) and delayed (2–5-year posttreatment). Statistically significant effects were indicated by p-values less than 0.05. Statistically significant negative effects were labelled as displacement, whereas statistically significant positive effects were labelled as attraction.



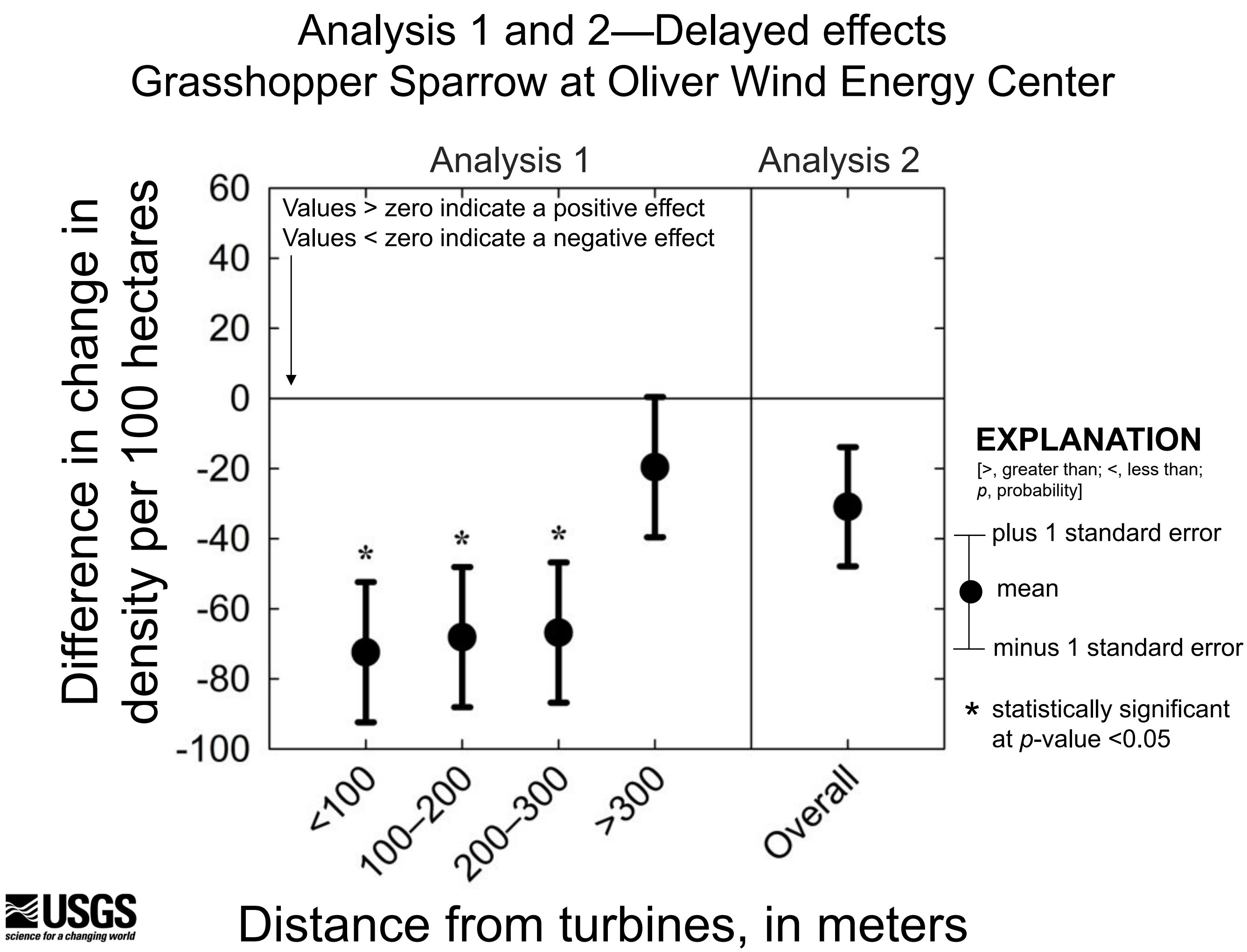
At the South Dakota Wind Energy Center, grasshopper sparrows exhibited no statistically significant displacement effects by distance category or overall during the immediate time period; however, the change in density of about 35 fewer bird pairs per 100 hectares within 100 meters may be biologically important.



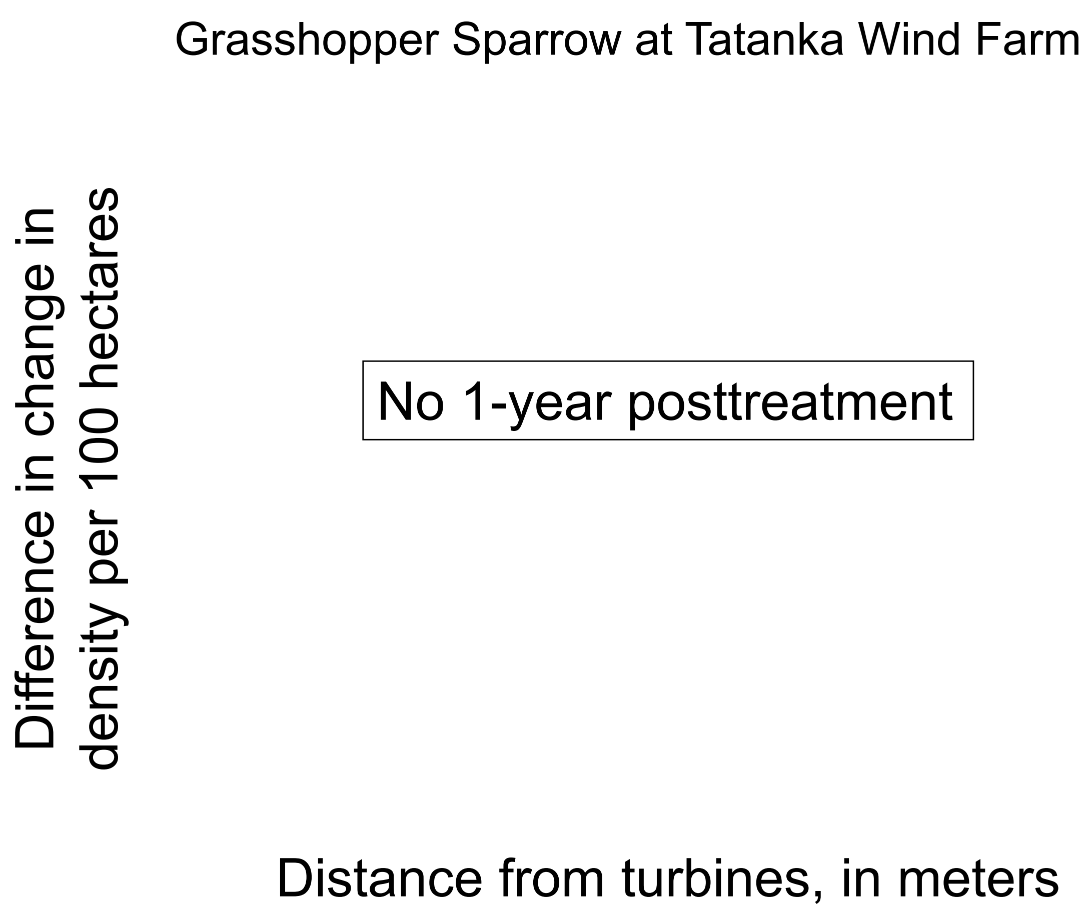
At the South Dakota Wind Energy Center, grasshopper sparrows exhibited delayed displacement effects within 200 meters and overall.



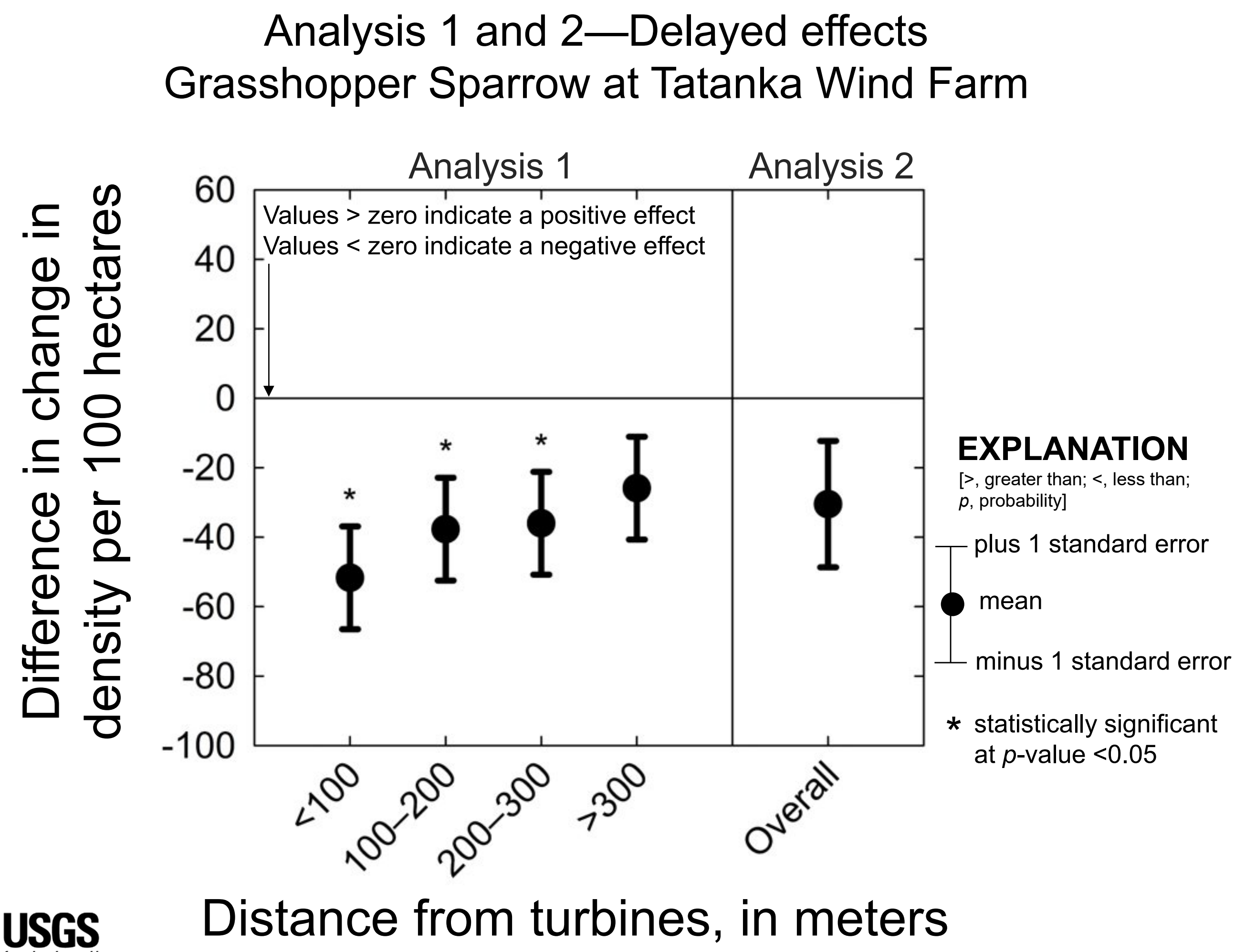
At the Oliver Wind Energy Center, grasshopper sparrows exhibited no statistically significant displacement effects by distance category or overall during the immediate time period. However, similar to the case at the South Dakota Wind Energy Center, there were large negative differences within 200 meters of the turbines compared to reference sites. At the distance band for greater than 300 meters from turbines, and overall, there were positive differences, which may indicate that birds are not being displaced entirely off the study area but are being displaced onsite to areas farther from turbines.



At the Oliver Wind Energy Center, grasshopper sparrows showed delayed displacement effects within 300 meters of turbines and no significant overall effect.



The Tatanka Wind Farm was not accessible during the first year posttreatment, so there are no tests of immediate effects for this study area.

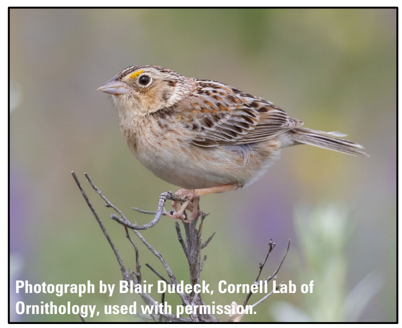


At the Tatanka Wind Farm, grasshopper sparrows exhibited delayed displacement effects within 300 meters.

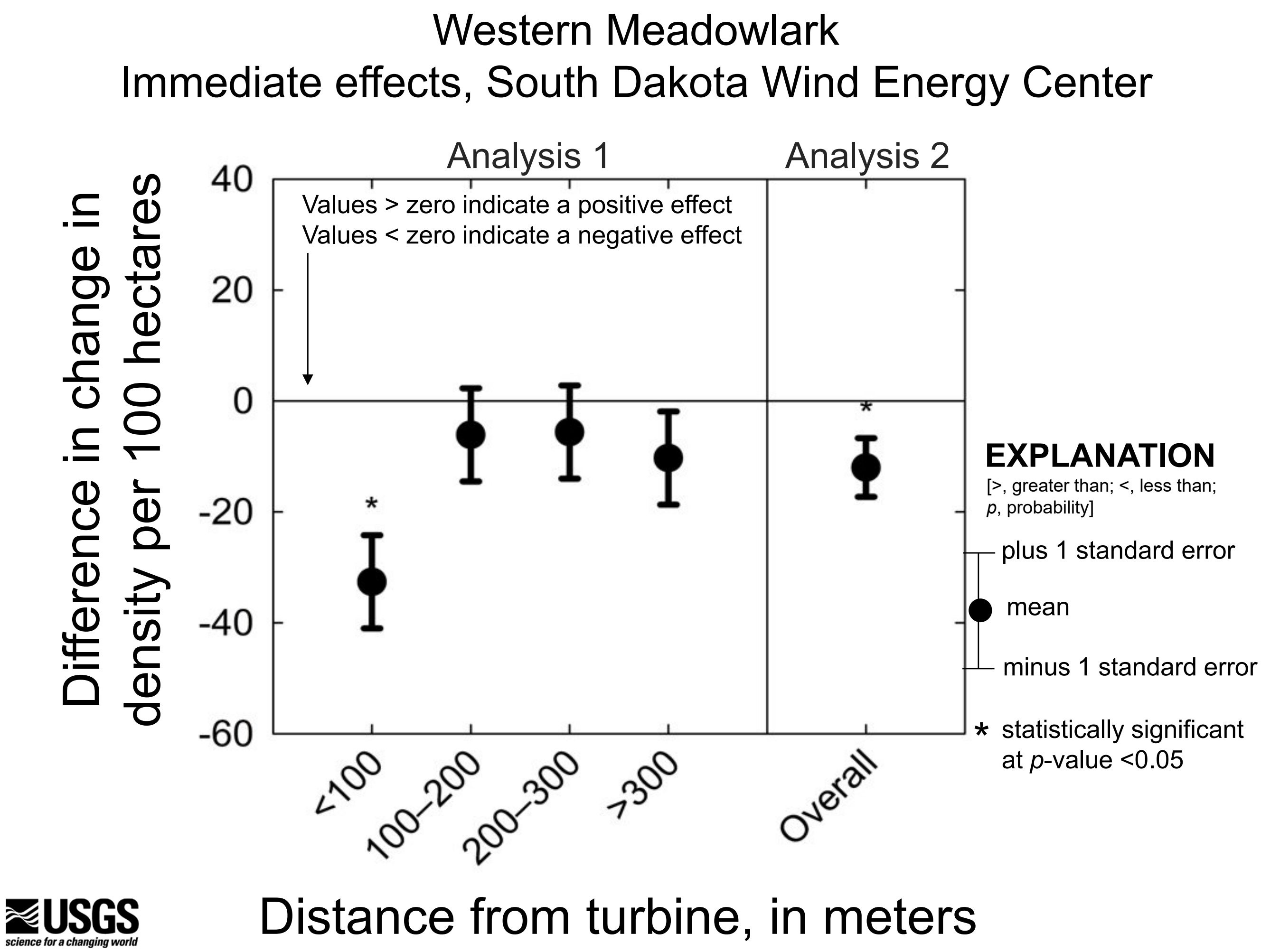
Conclusion for Grasshopper Sparrow

No significant immediate displacement; however, large negative effects within 100 m of turbines may be biologically important

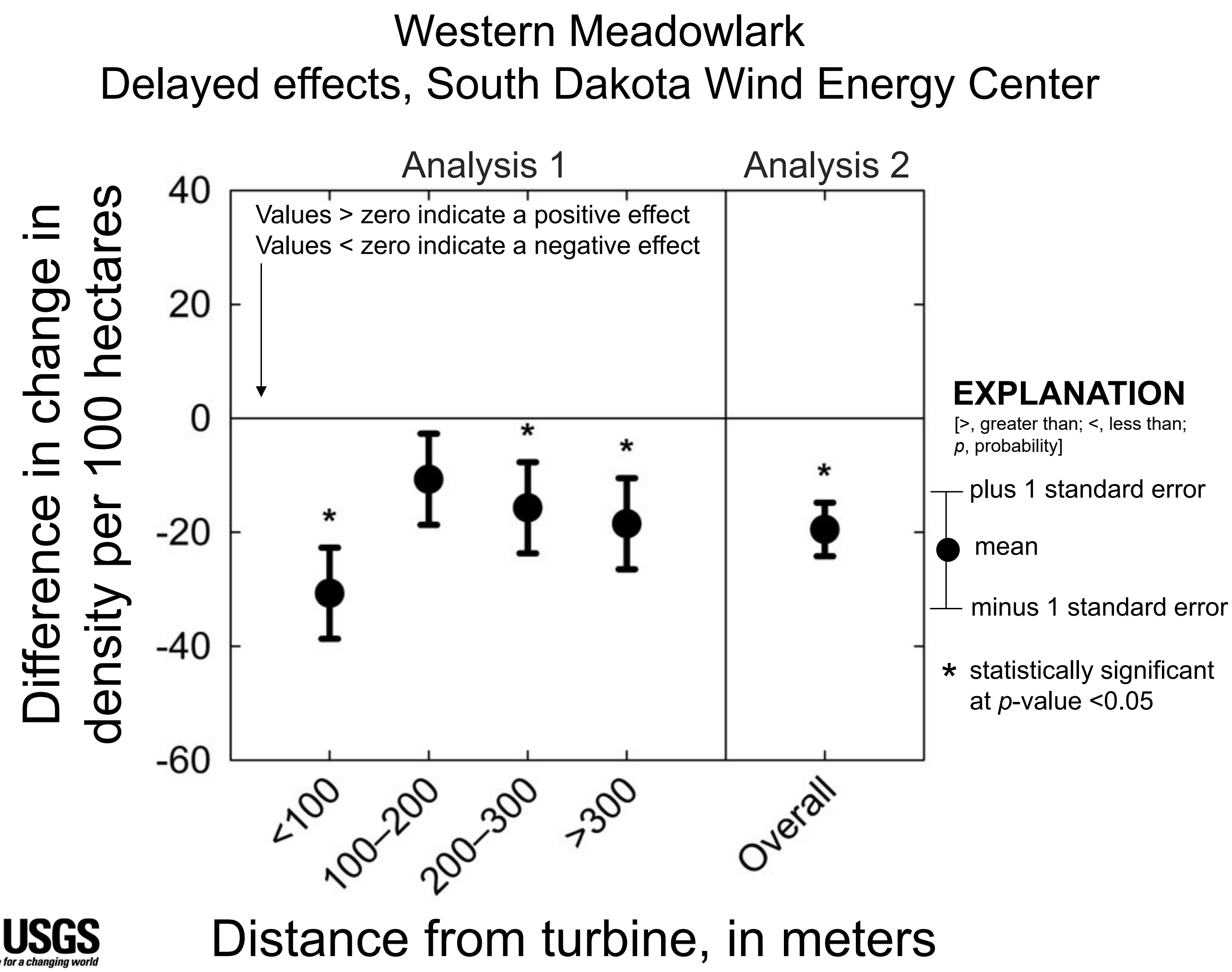
Significant negative delayed effects were observed within 200 m of turbines and usually extended out to 300 m


Photograph by Blair Dudeck, Cornell Lab of Ornithology, used with permission.

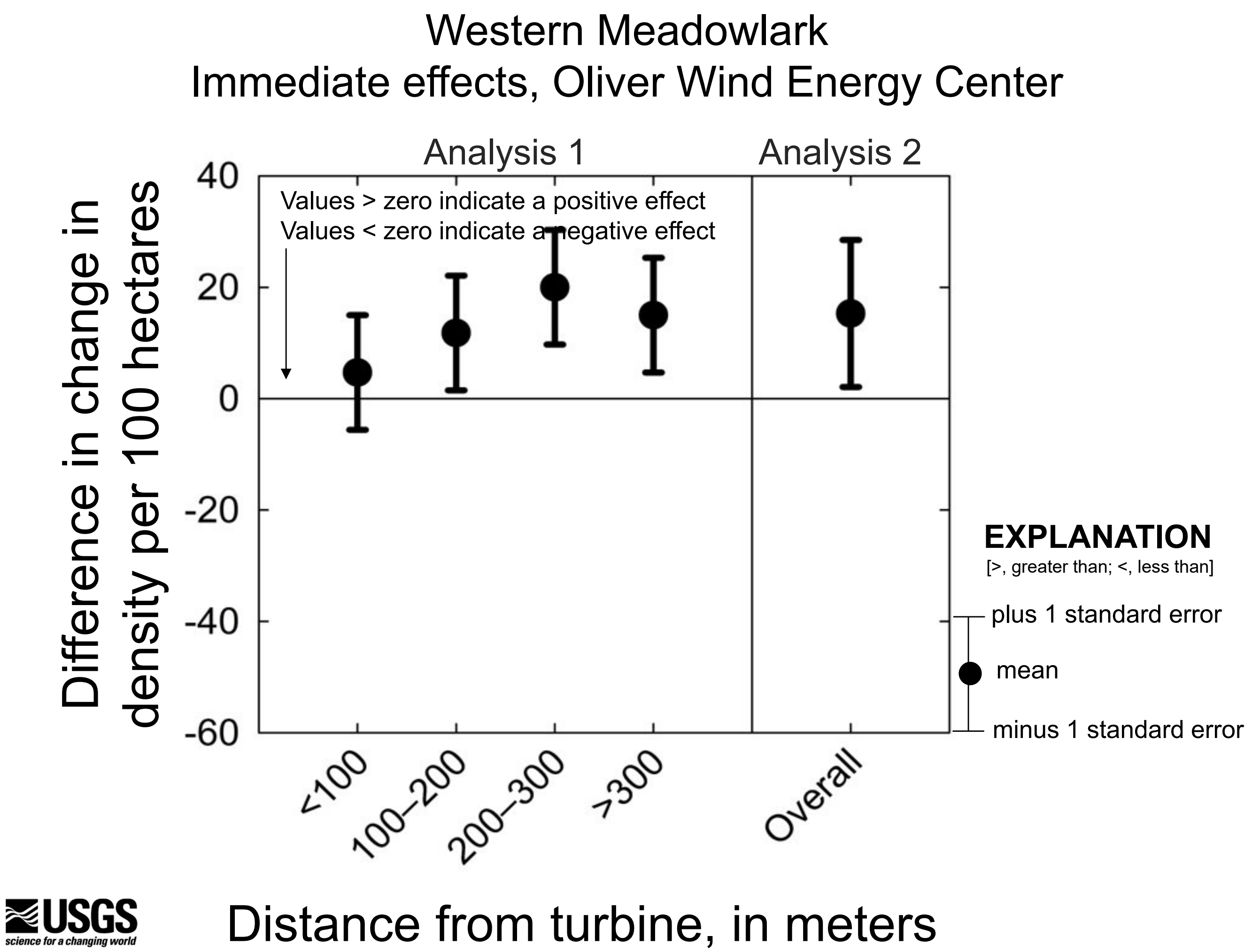
Grasshopper sparrow summary. In conclusion, although no statistically significant immediate displacement effects were apparent, the large negative effects within 100 meters (m) of turbines may be biologically important. Significant negative delayed displacement effects were observed within 200 meters of turbines and usually extended out to 300 meters.



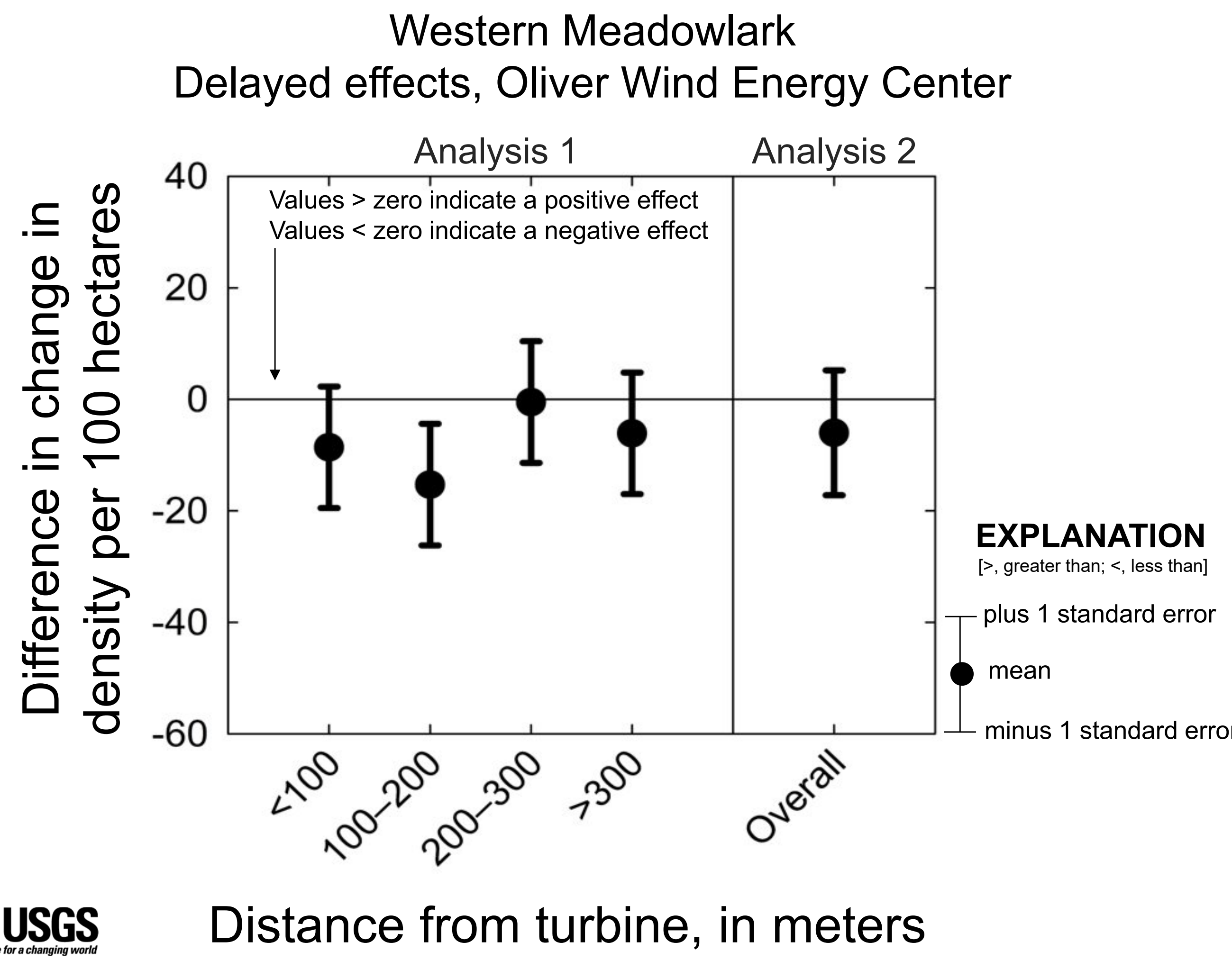
At the South Dakota Wind Energy Center, western meadowlarks exhibited immediate displacement effects within 100 meters of turbines and overall.



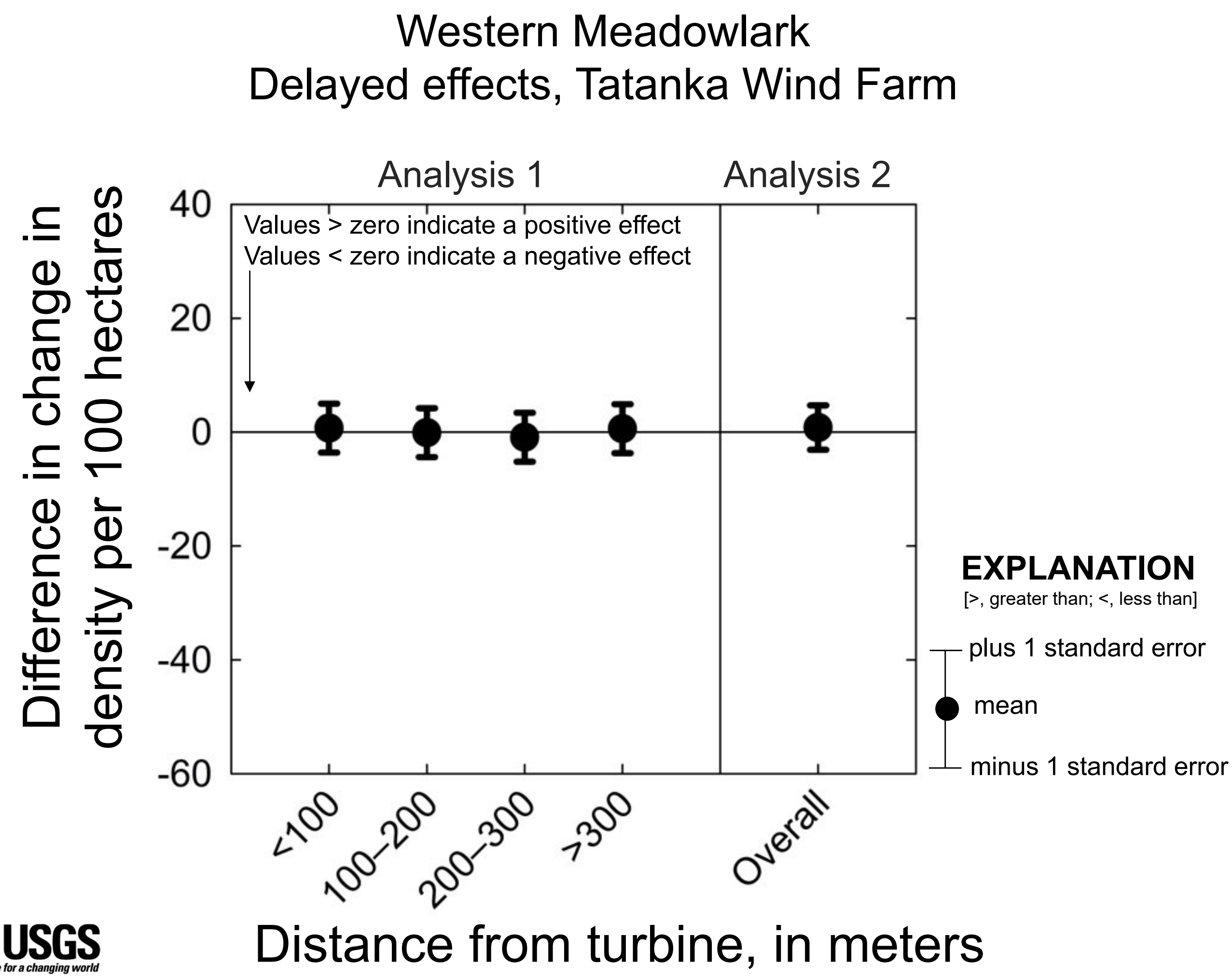
At the South Dakota Wind Energy Center, western meadowlarks exhibited delayed displacement effects at 3 of 4 distance categories and overall.



At the Oliver Wind Energy Center, western meadowlarks exhibited no immediate displacement effects either by distance band or overall.



At the Oliver Wind Energy Center, western meadowlarks exhibited no delayed displacement effects either by distance band or overall.



At the Tatanka Wind Farm, western meadowlarks exhibited no delayed displacement effects either by distance band or overall.

Conclusion for Western Meadowlark

SDWEC: Immediate and delayed displacement were observed within 100 m and overall

Oliver: No effect

Tatanka: No effect

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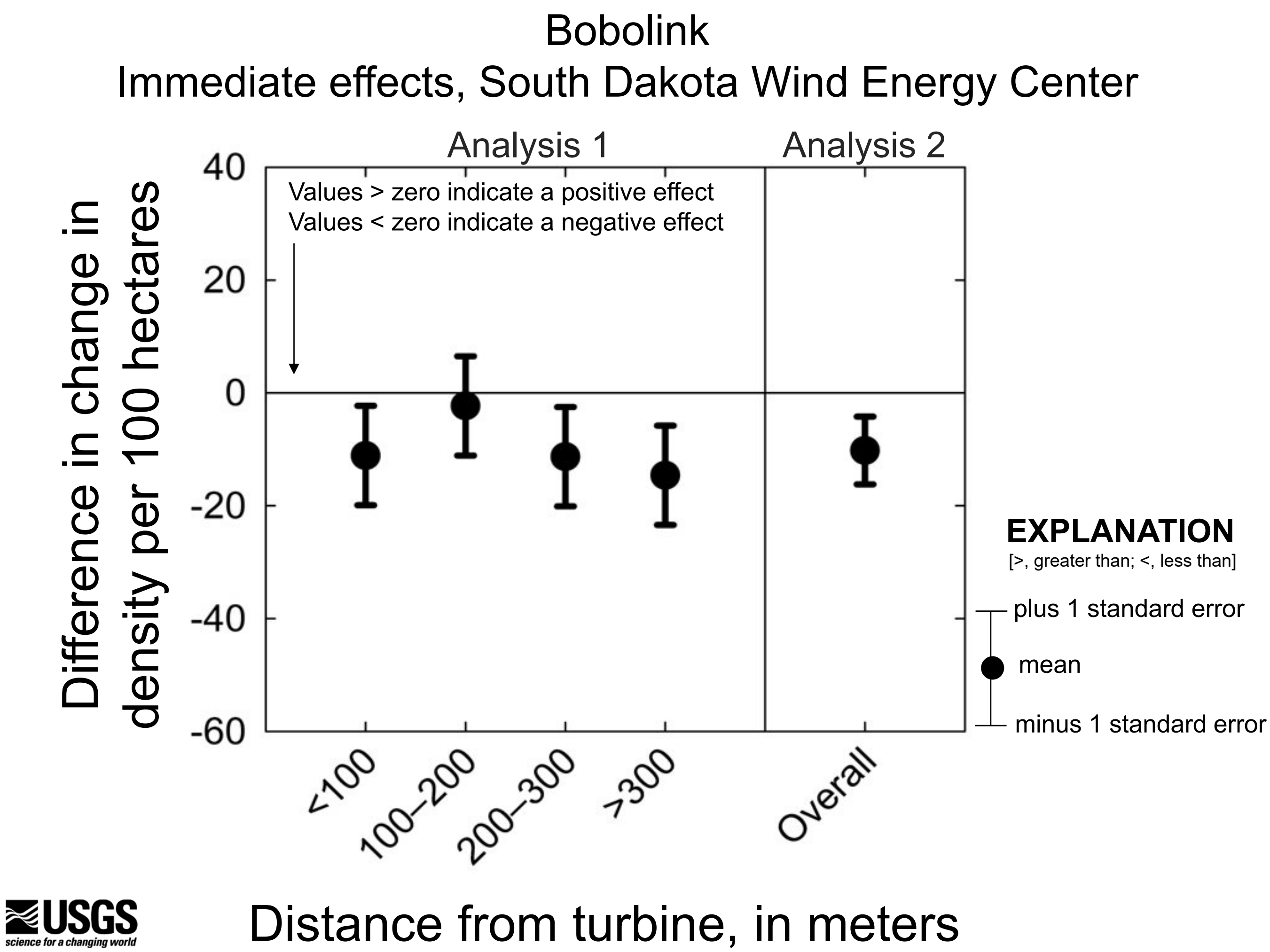
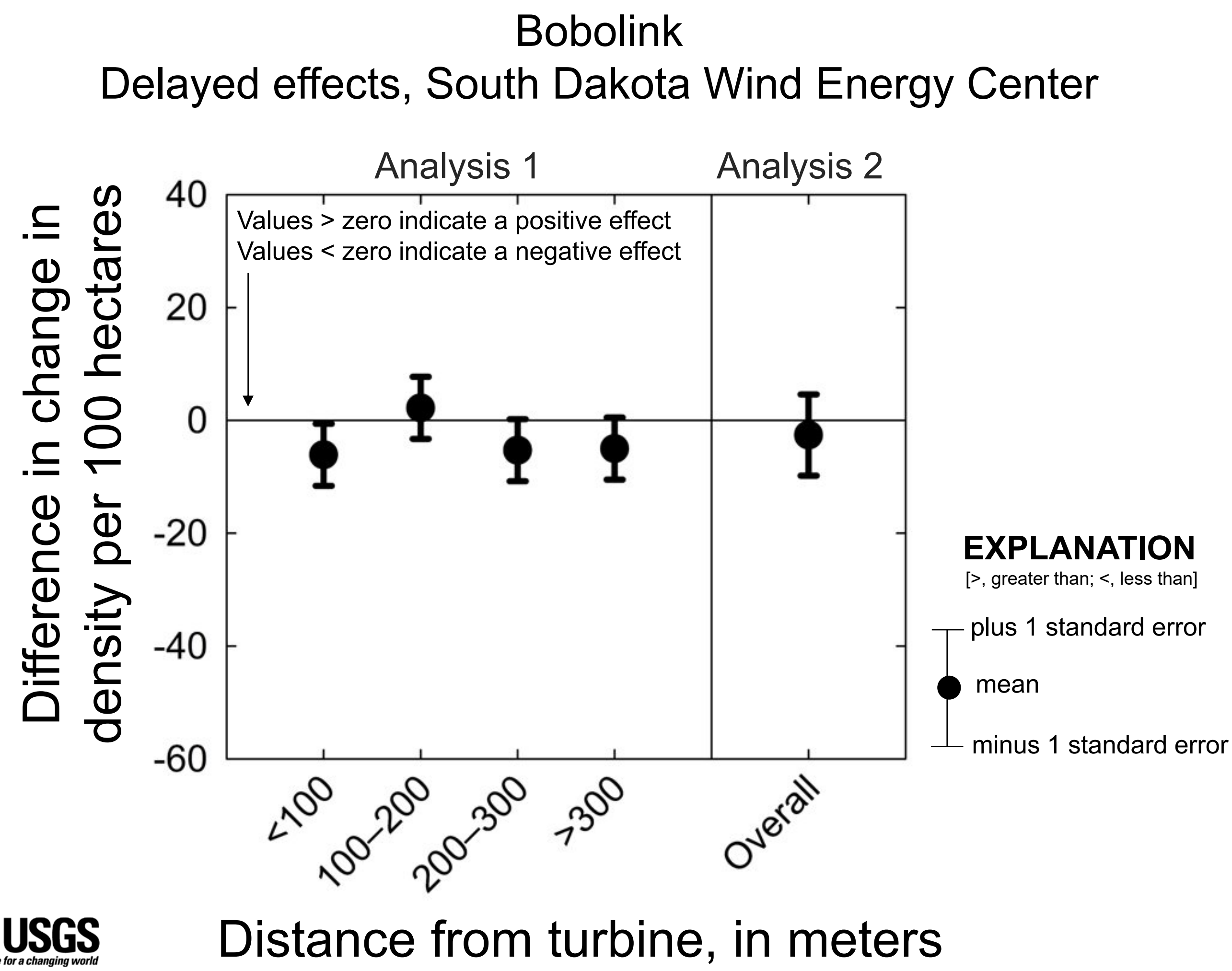
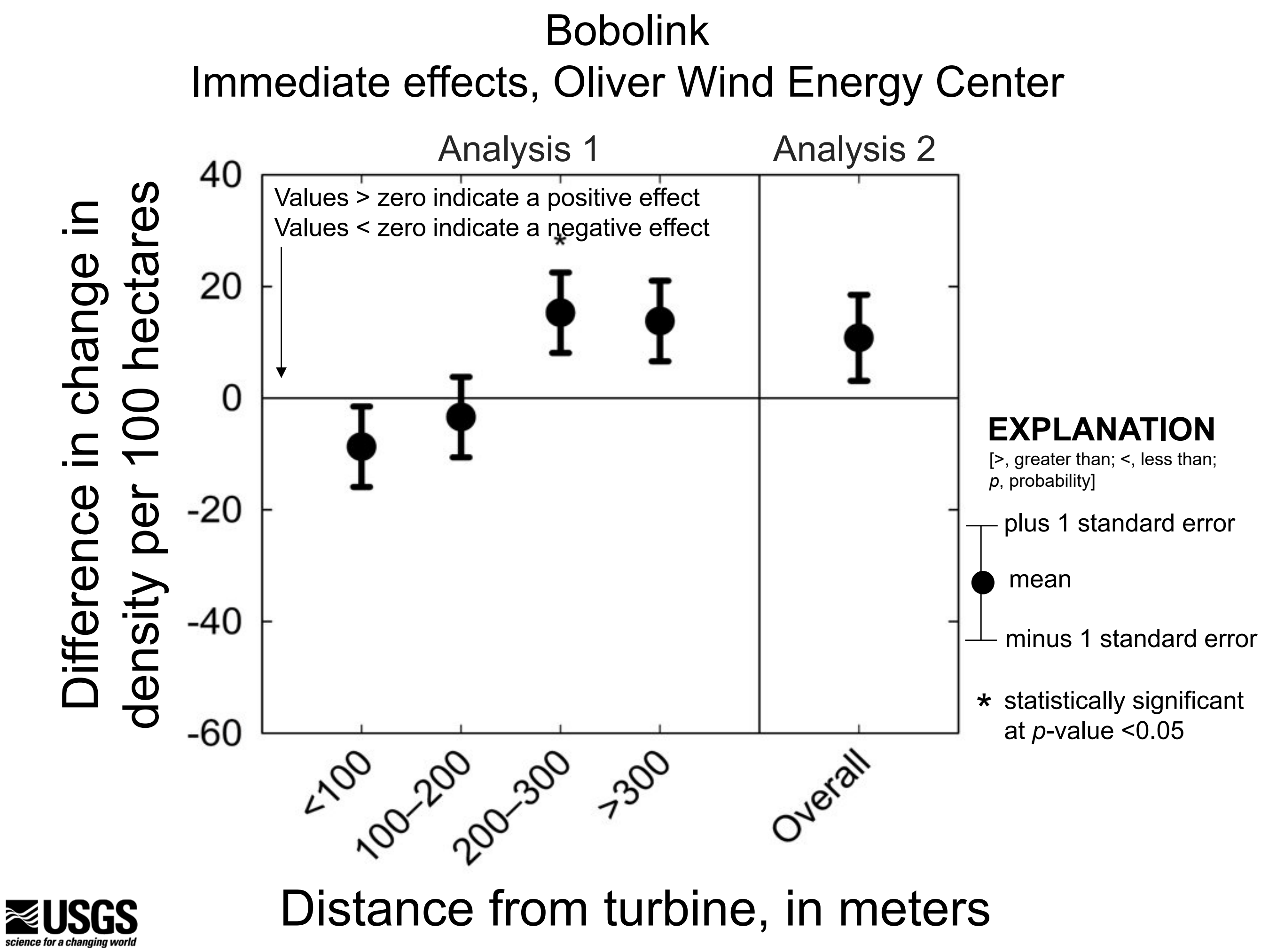
Western meadowlark summary. Immediate and delayed effects (sustained displacement) occurred only at the South Dakota Wind Energy Center. Sustained effects could not have been detected for the Tatanka Wind Farm, because data during the first year postconstruction were not gathered. The species did not exhibit displacement at the Oliver Wind Energy Center or the Tatanka Wind Farm. These wind facilities were in areas with fewer anthropogenic structures and more intact grassland landscapes, which may have influenced western meadowlarks.



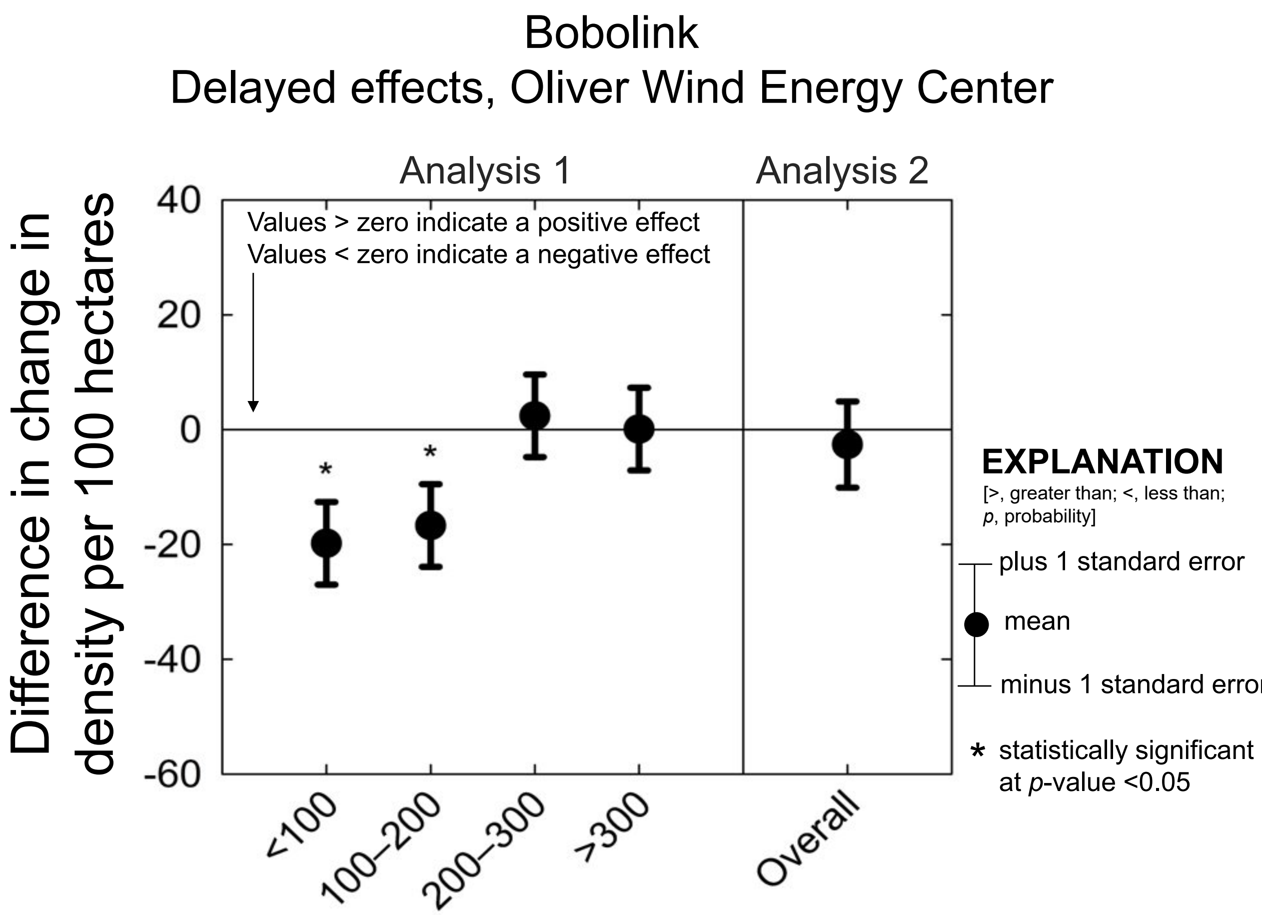
At the South Dakota Wind Energy Center, bobolinks exhibited no immediate displacement effects either by distance band or overall.



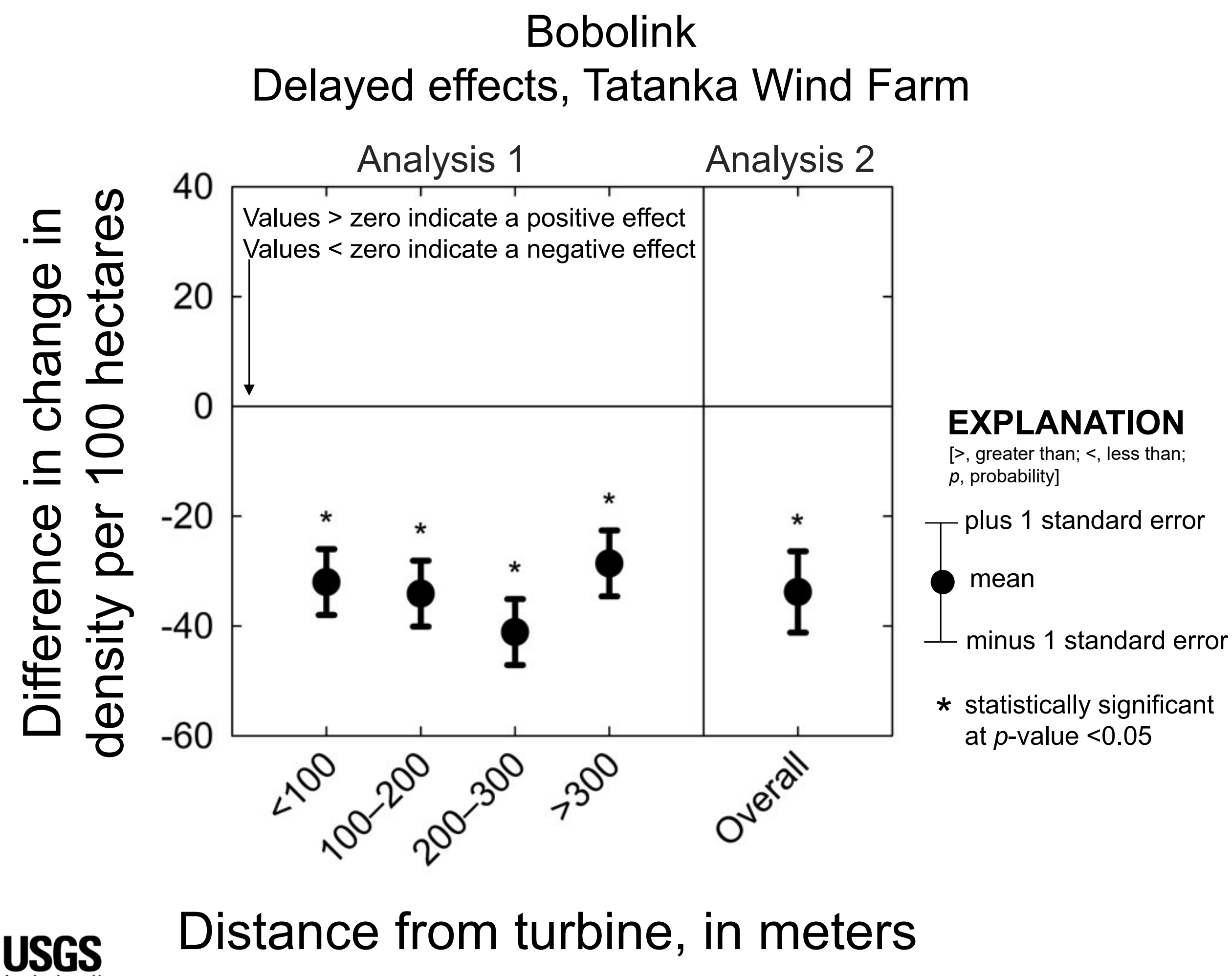
At the South Dakota Wind Energy Center, bobolinks exhibited no delayed displacement effects either by distance band or overall.



At the Oliver Wind Energy Center, bobolinks exhibited positive immediate effects (attraction) in the 200–300-meter distance band. There was no overall effect.



At the Oliver Wind Energy Center, bobolinks exhibited delayed displacement effects within 200 meters.



At the Tatanka Wind Farm, bobolinks displayed strong delayed displacement effects at all distance bands and overall, indicating that this species is displaced off the site.

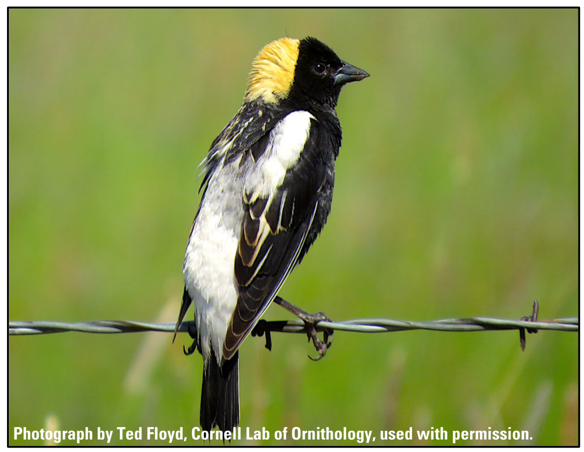
Conclusion for Bobolink

Displacement varied by study area

SDWEC: No displacement

Oliver: Internal, delayed displacement

Tatanka: Strong displacement



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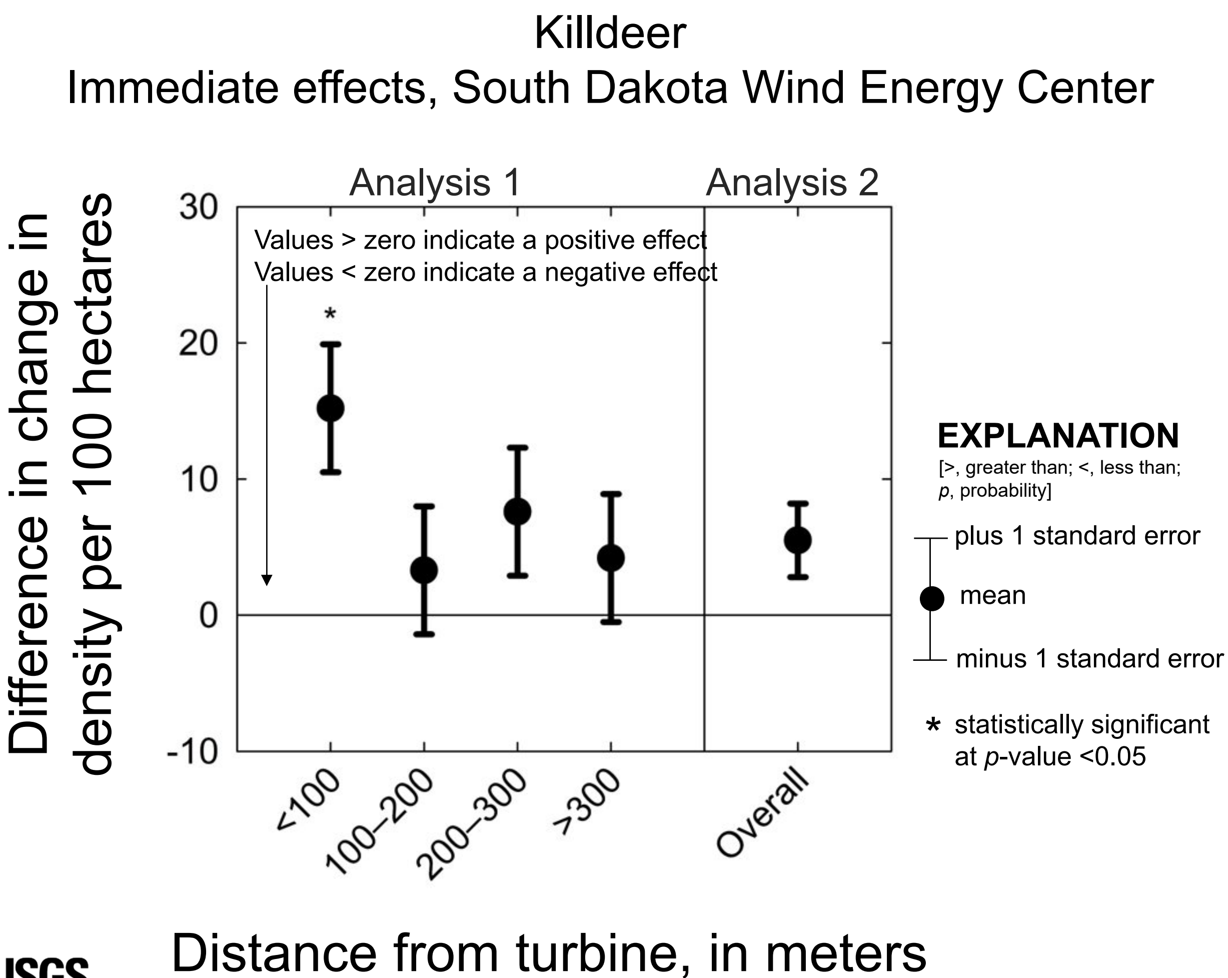
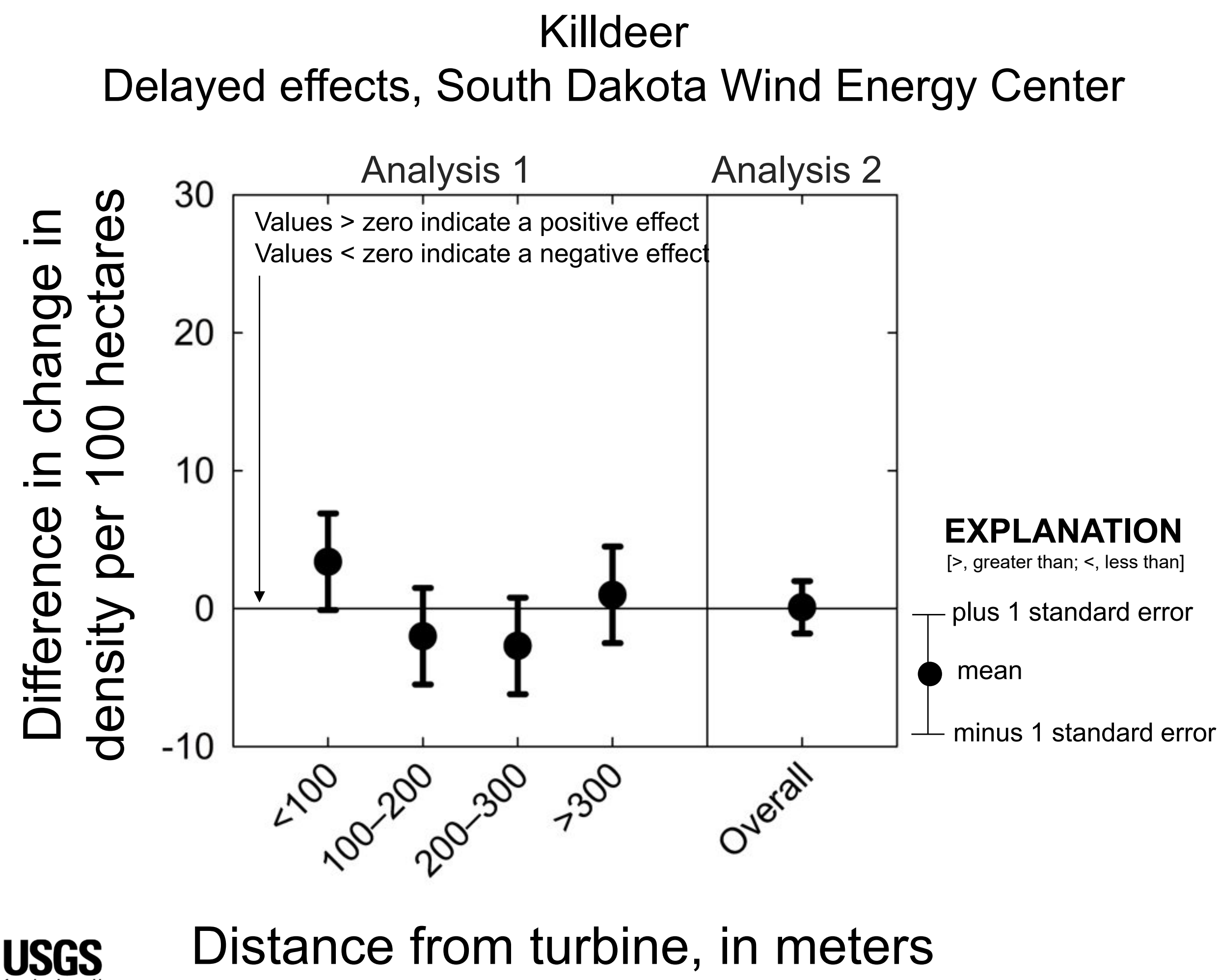
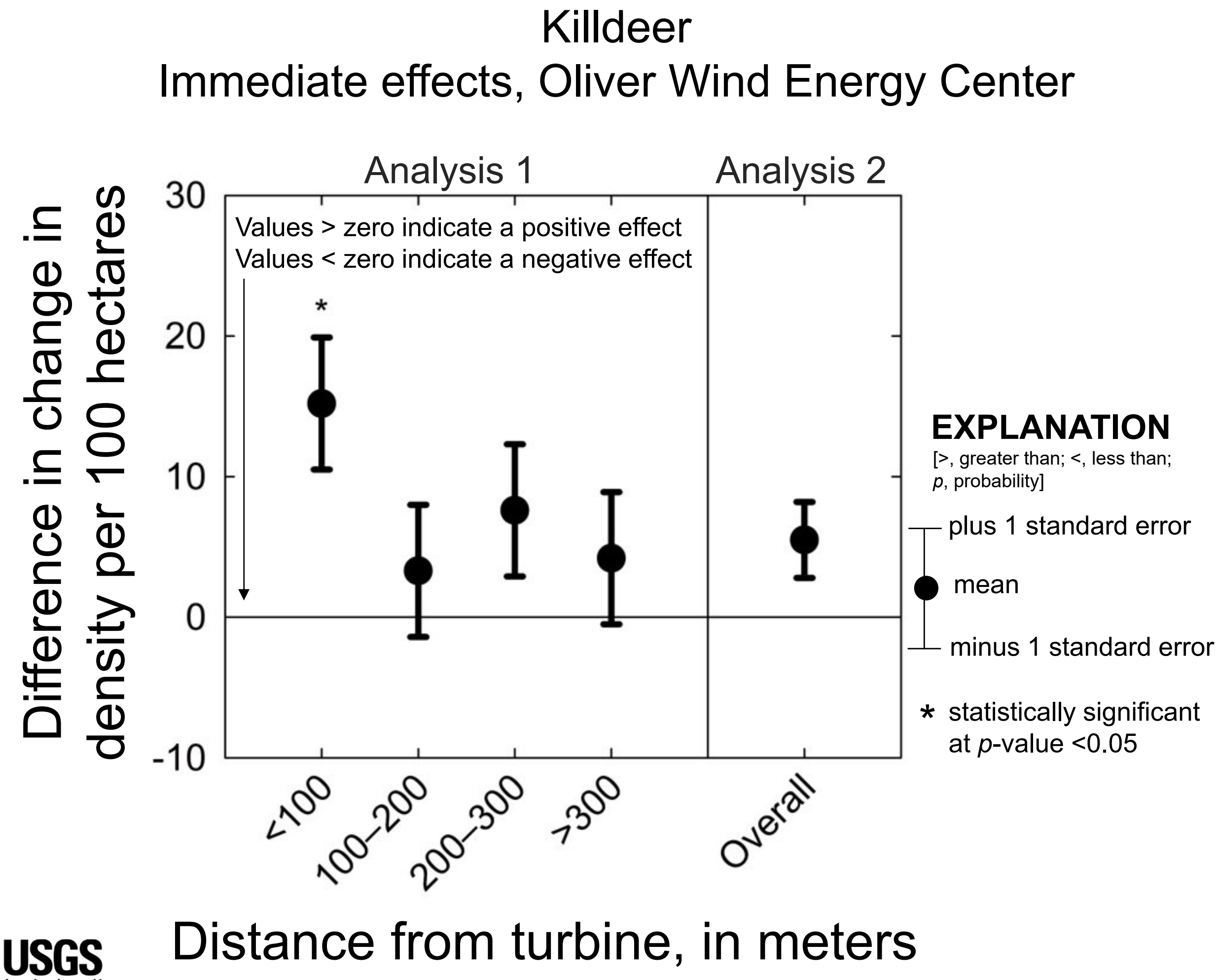
Bobolink summary. Displacement effects varied by study area. Whereas bobolinks displayed no displacement at the South Dakota Wind Energy Center, they exhibited delayed displacement at the Oliver Wind Energy Center and at the Tatanka Wind Farm—possibly being displaced off the study area at the Tatanka Wind Farm.



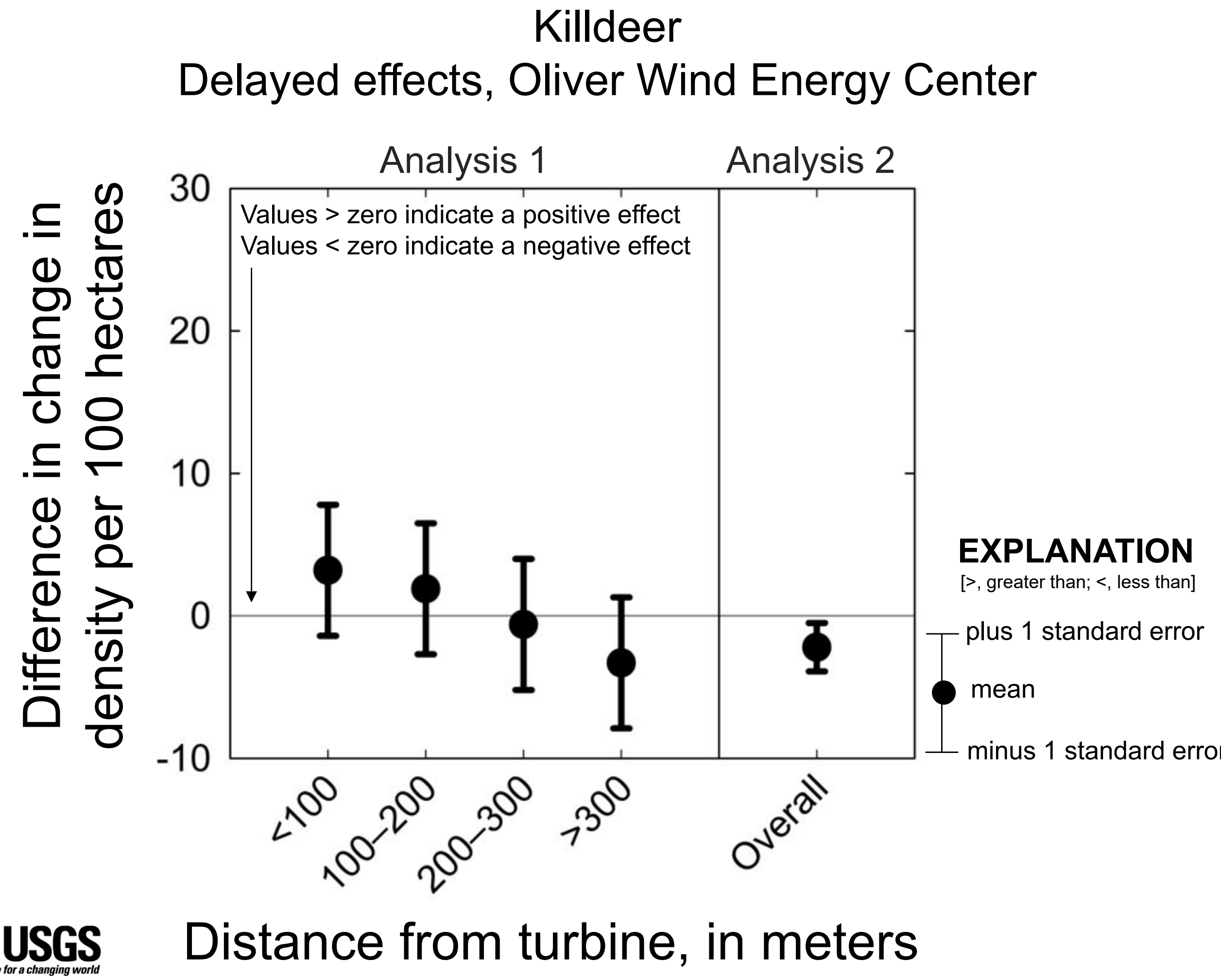
At the South Dakota Wind Energy Center, killdeer exhibited immediate attraction effects within 100 meters of turbines but no effect overall.



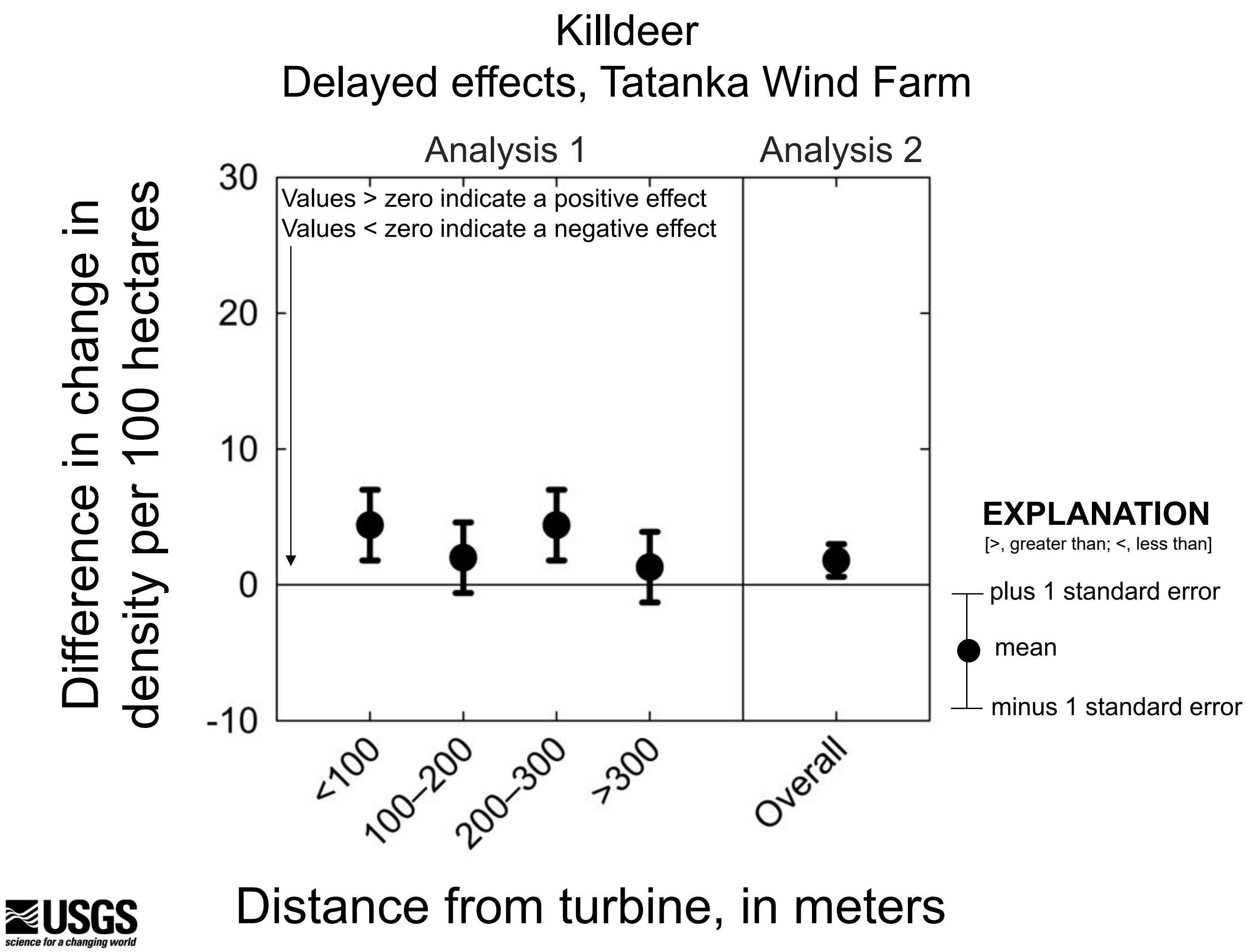
At the South Dakota Wind Energy Center, killdeer exhibited no delayed significant effects by distance band or overall, either positive or negative, indicating that the immediate attraction effects were not sustained.



At the Oliver Wind Energy Center, killdeer exhibited similar results as at the South Dakota Wind Energy Center, with an immediate attraction effect within 100 meters of turbines and no overall effect.



At the Oliver Wind Energy Center, as at the South Dakota Wind Energy Center, killdeer exhibited no delayed significant effects by distance band or overall, either positive or negative, indicating that the immediate attraction effects were not sustained.



At the Tatanka Wind Farm, as at the South Dakota Wind Energy Center and the Oliver Wind Energy Center, killdeer exhibited no delayed effects, either positive or negative, by distance band or overall.

Conclusion for Killdeer

Significant, positive immediate effects (attraction) within 100 meters

No delayed effects

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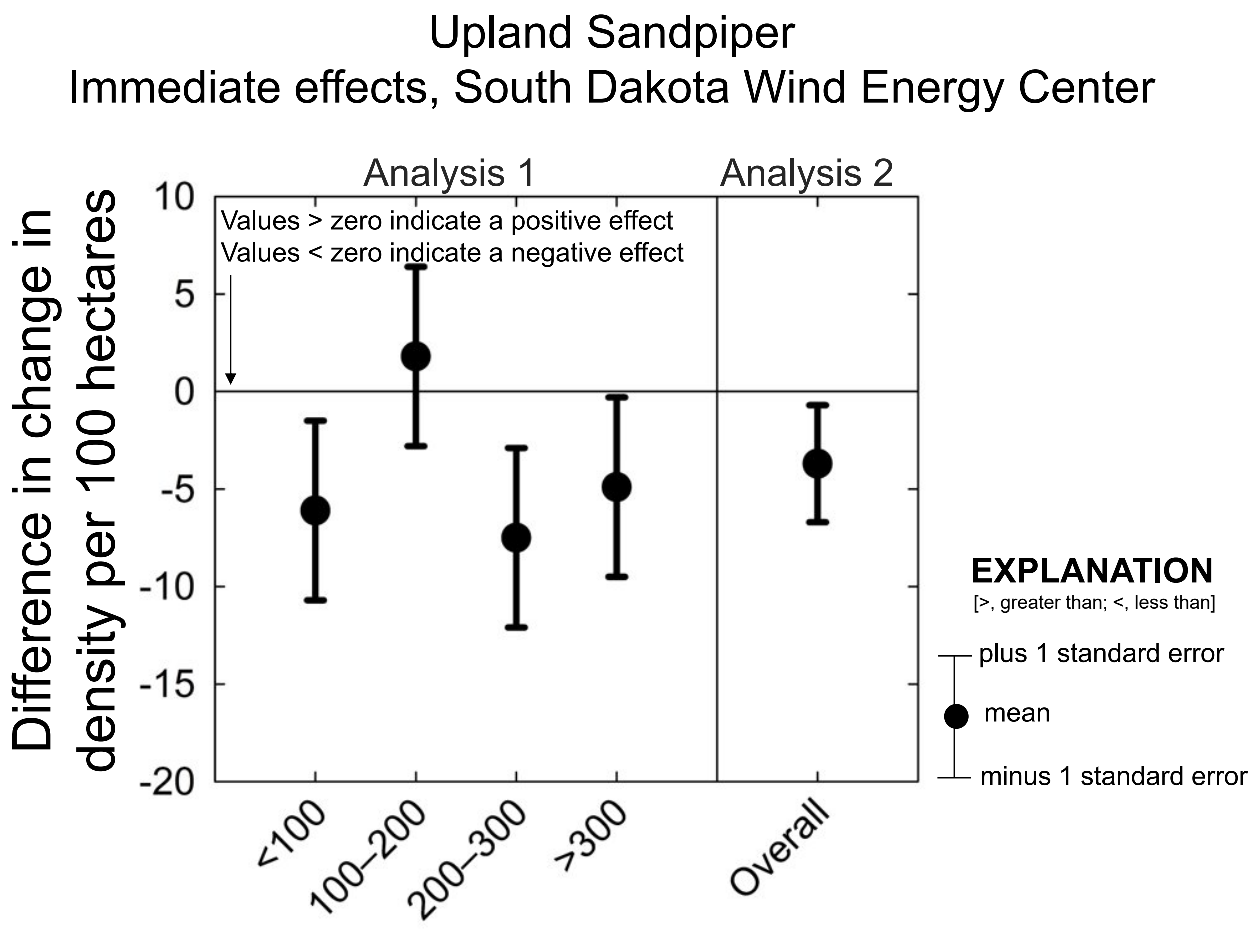
Killdeer summary. Significant, positive immediate effects (attraction) were observed within 100 meters of turbines at the two study areas where immediate effects could be determined. The species did not exhibit delayed effects; thus, the immediate effect did not translate into a sustained effect, and the attraction shown the first year postconstruction appeared to be restricted to that first year.

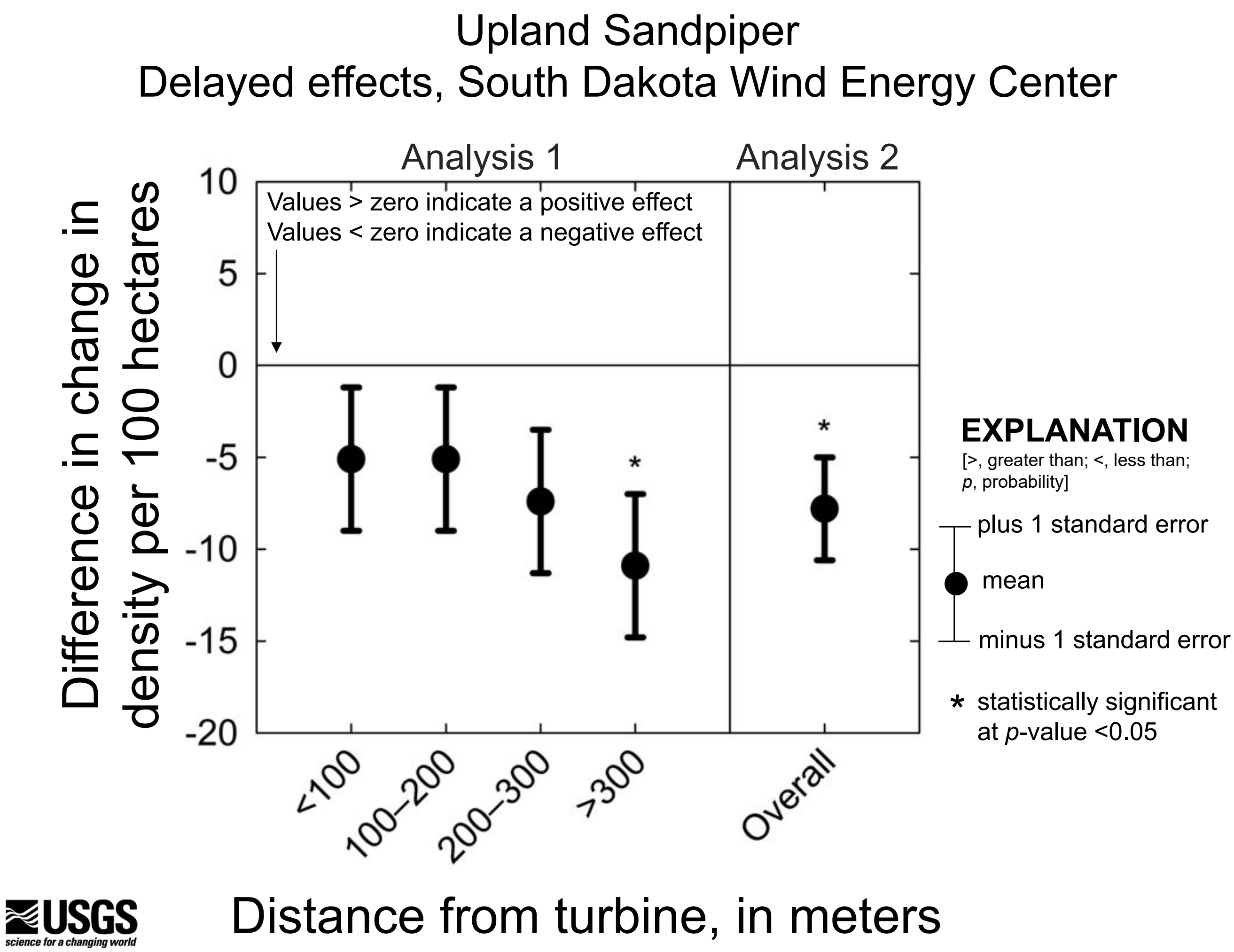
Killdeer

Photograph by Jill A. Shaffer, used with permission.

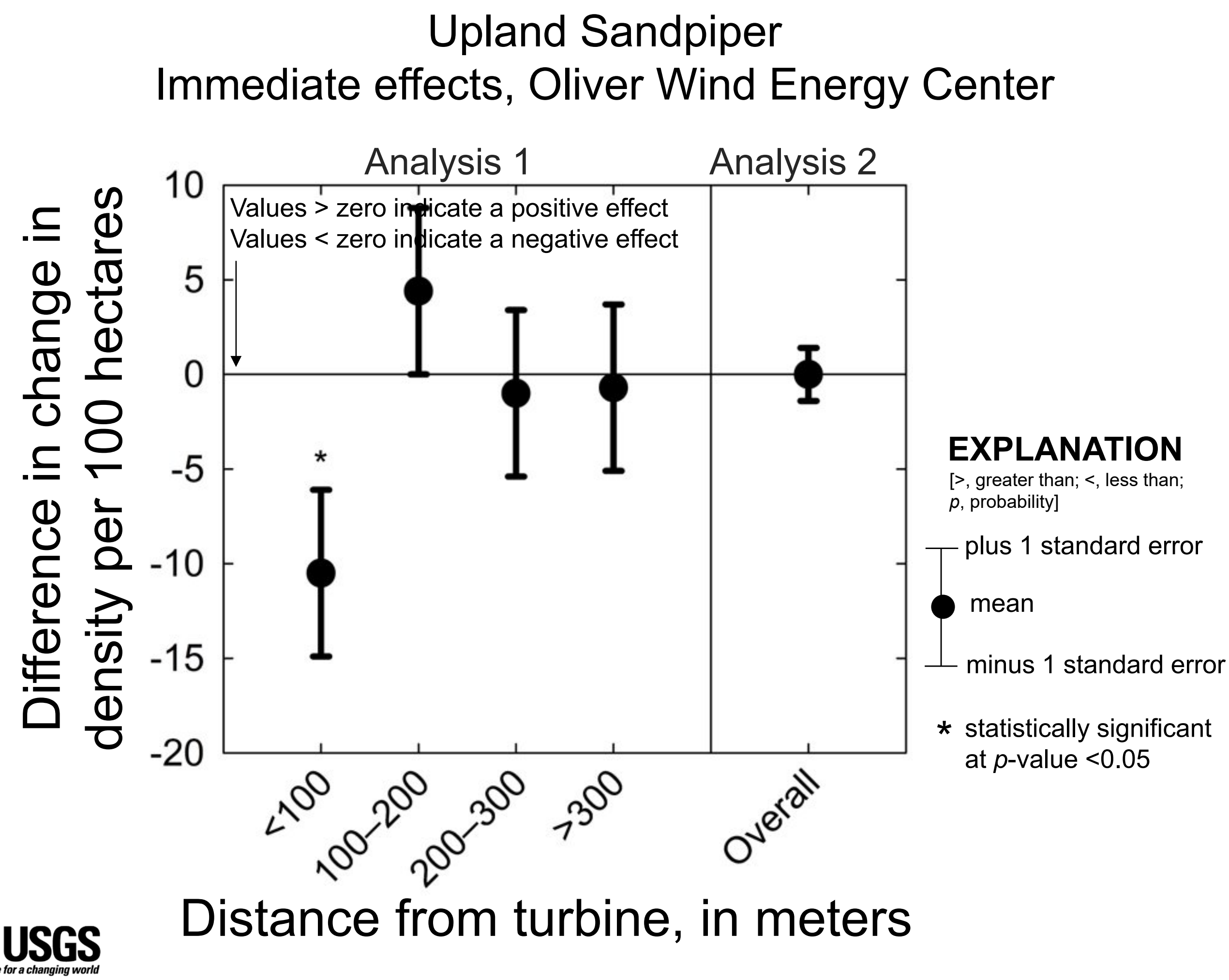
The attraction, rather than displacement, of killdeer is not surprising given the species' preference for nesting on gravel substrate, such as that provided by turbine roads, which would occur within 100 meters of wind turbines. However, even though this additional suitable habitat remained beyond the first year postconstruction, killdeer did not display attraction beyond the first year.



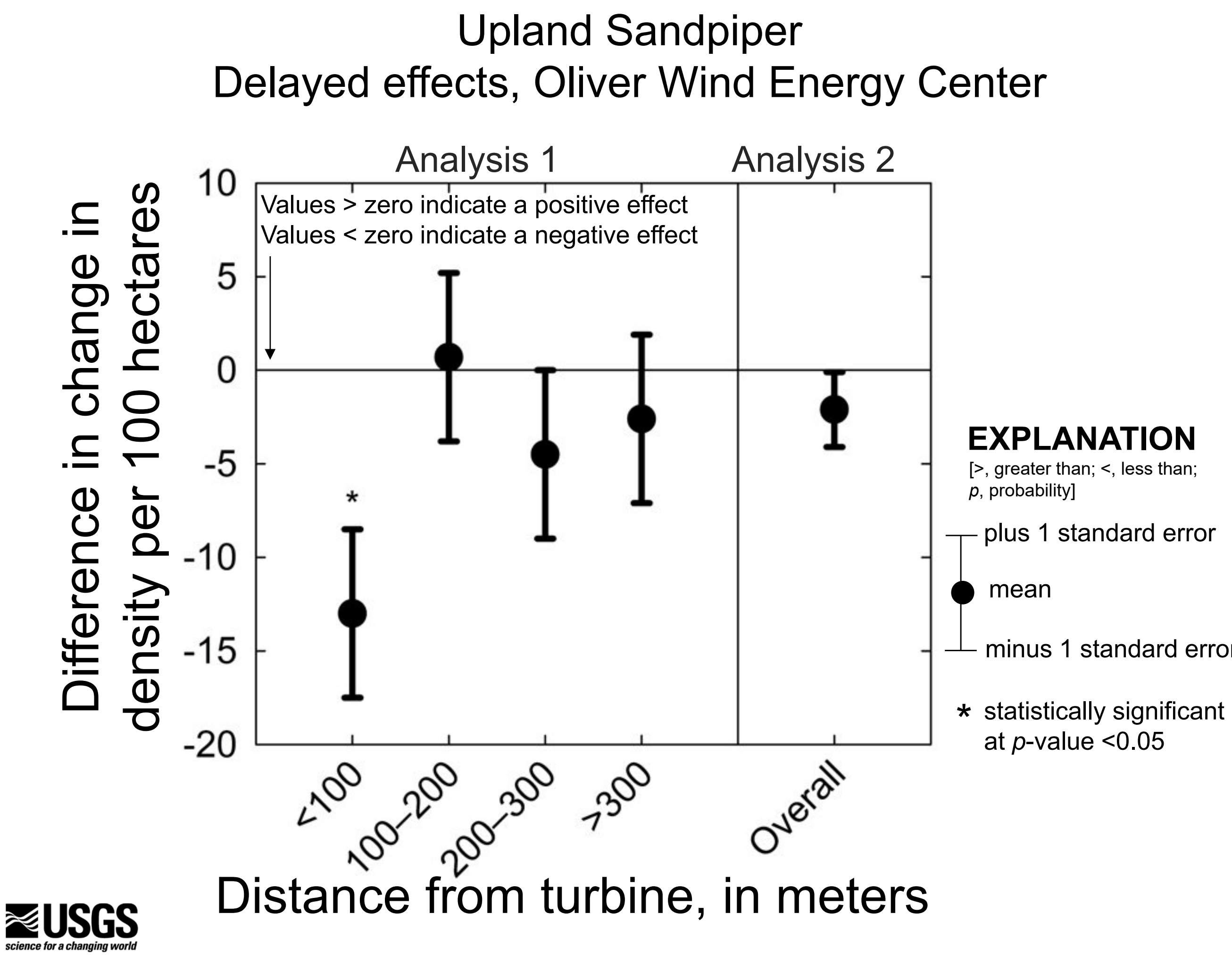
At the South Dakota Wind Energy Center, upland sandpipers exhibited no immediate displacement effects.



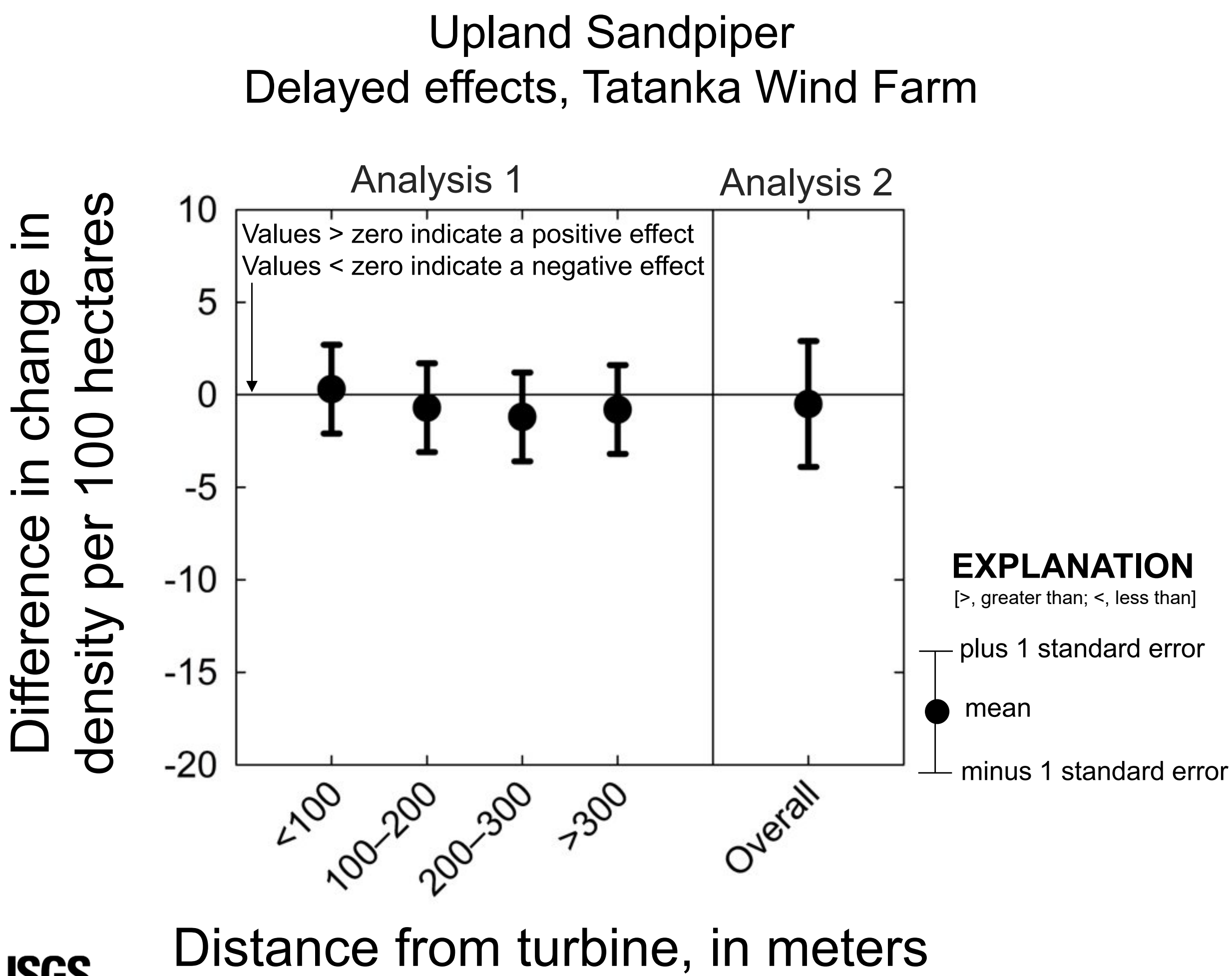
At the South Dakota Wind Energy Center, upland sandpipers exhibited delayed displacement effects at greater than 300 meters and overall.



At the Oliver Wind Energy Center, upland sandpipers exhibited immediate displacement effects within 100 meters.



At the Oliver Wind Energy Center, upland sandpipers exhibited delayed displacement effects within 100 meters. Immediate displacement effects within this same distance band indicate a sustained displacement effect occurring within 100 meters.



At the Tatanka Wind Farm, upland sandpipers exhibited no delayed displacement effects.

Conclusion for Upland Sandpiper

Displacement varied by study area

SDWEC: Delayed effect

Oliver: Sustained effect within 100 meters

Tatanka: No effect

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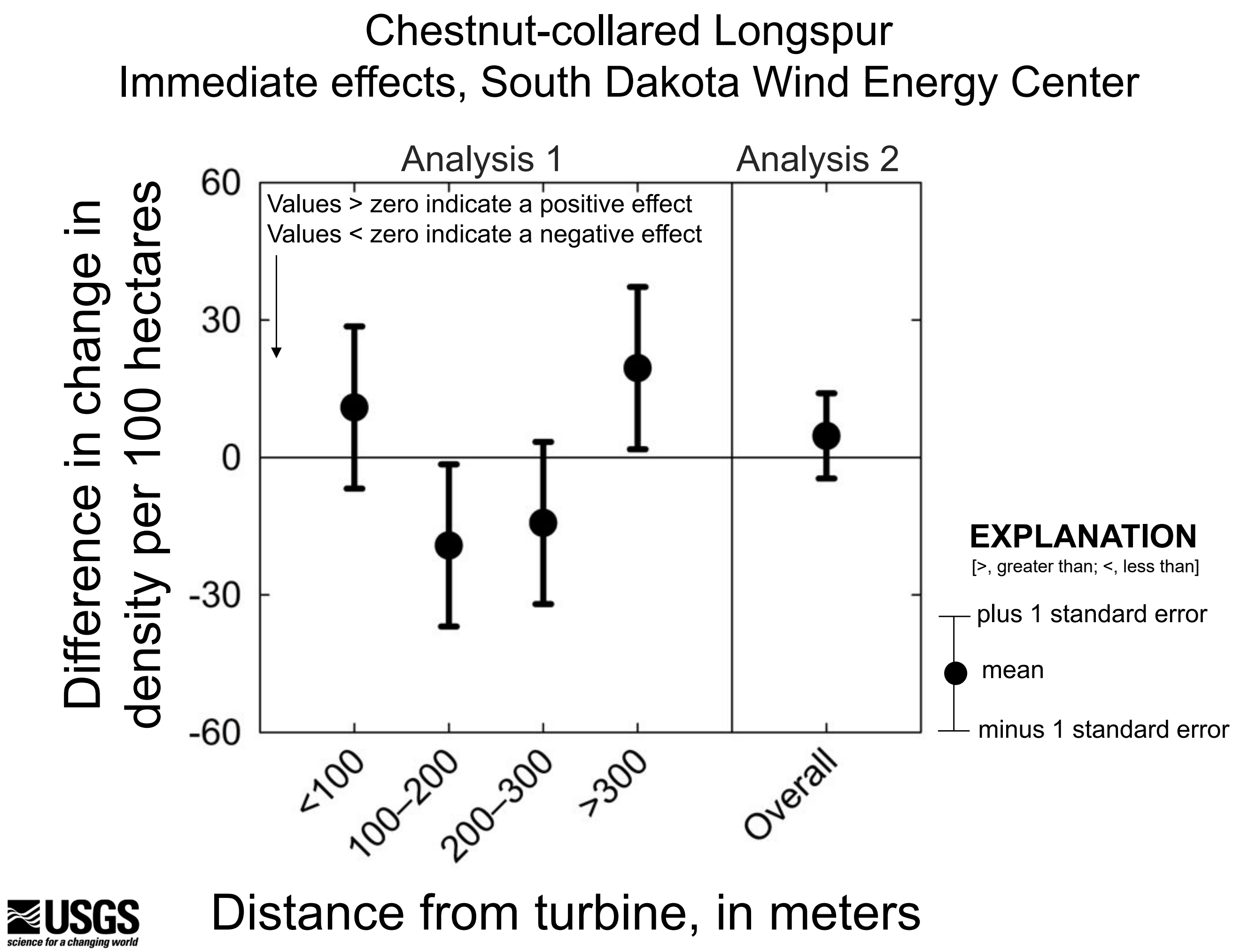
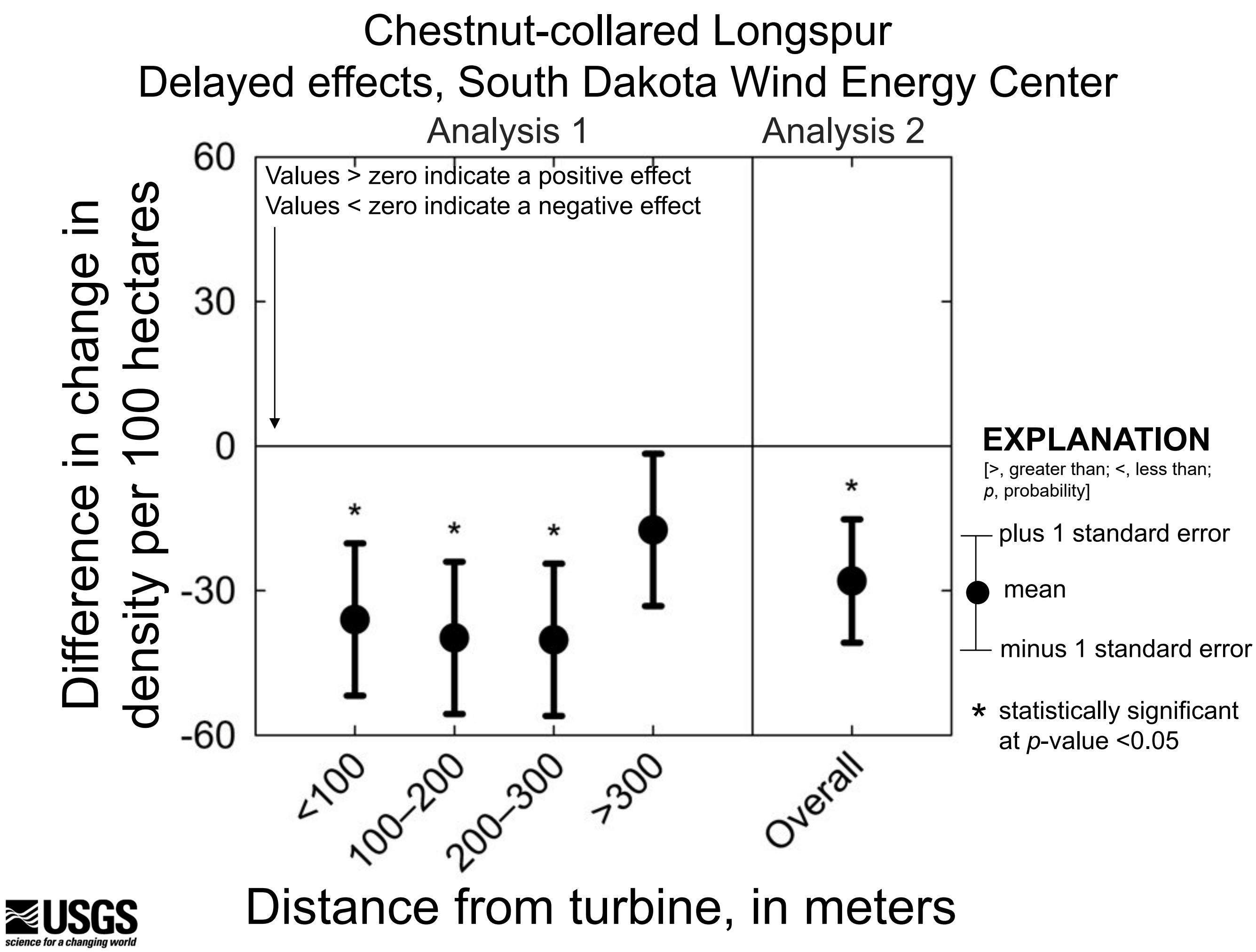
Upland sandpiper summary. Displacement effects varied by study area—a delayed effect beyond 300 meters and overall at one wind facility, a sustained effect (within 100 meters) at the second wind facility, and no effect at the third wind facility.



The chestnut-collared longspur occurred only at the South Dakota Wind Energy Center and not at the other two wind facilities. Chestnut-collared longspur exhibited no immediate displacement effects, but did exhibit possibly important biological impacts, at 100–300 meters. The species may have exhibited movement within study sites to areas beyond 300 meters.

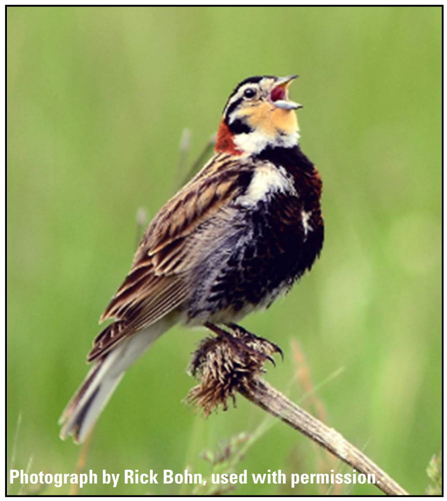


At the South Dakota Wind Energy Center, chestnut-collared longspurs exhibited delayed displacement effects within 300 meters and overall.

Conclusion for

Chestnut-collared Longspur

SDWEC: Strong delayed displacement



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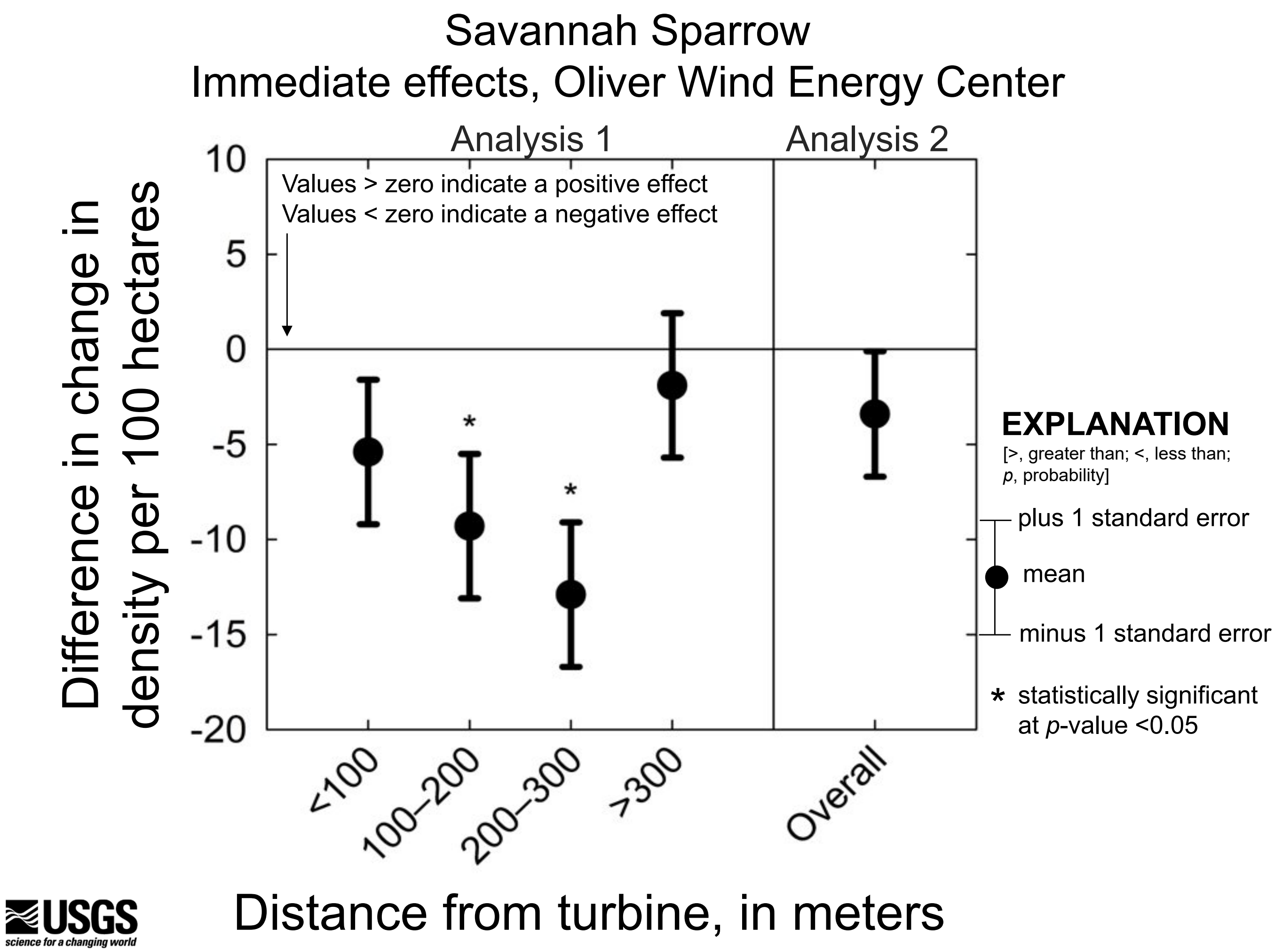
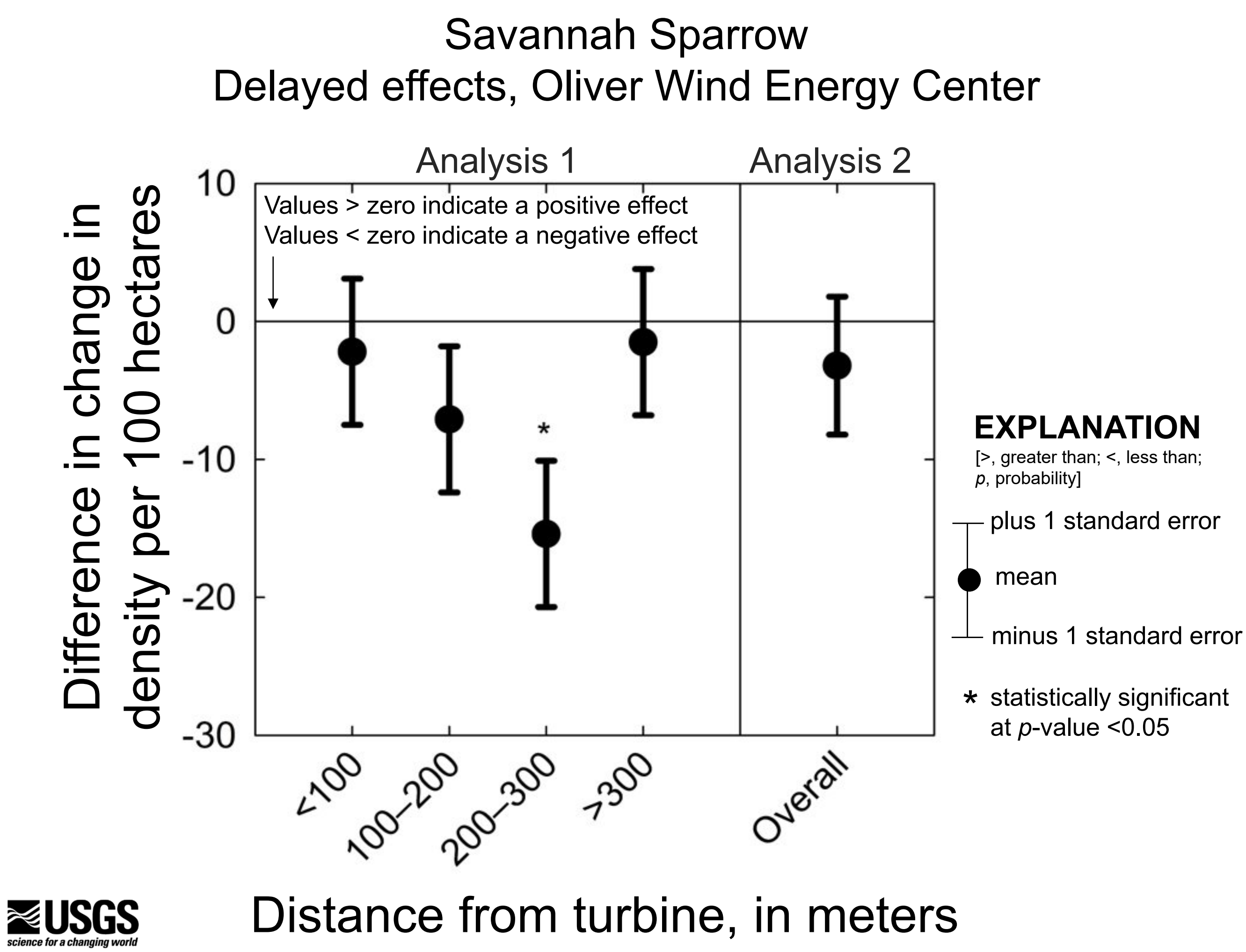
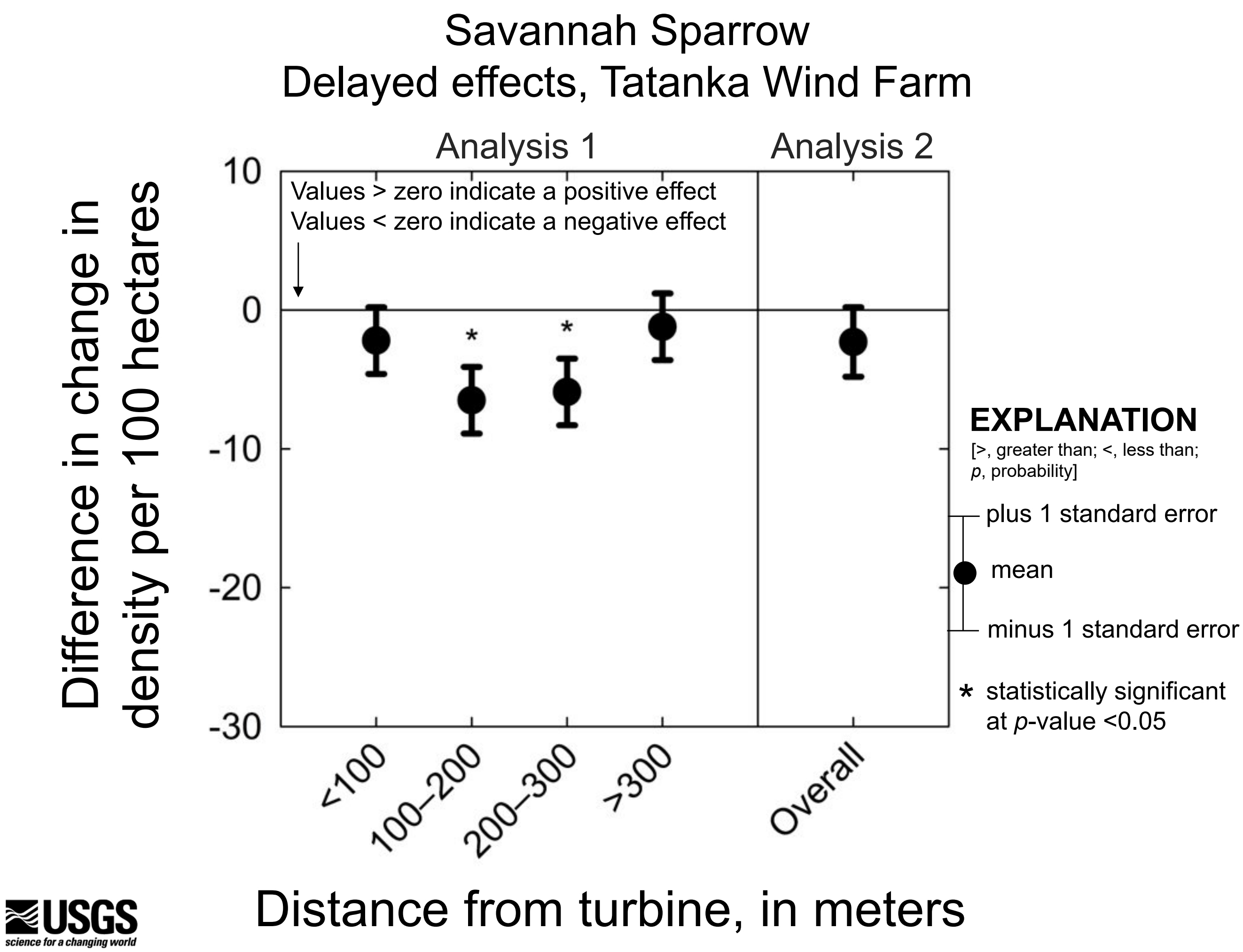
Chestnut-collared longspur summary. At the only study area in which chestnut-collared longspurs occurred, the species exhibited a high magnitude of difference (greater than or equal to 20 bird pairs per 100 hectares) between turbine and reference sites, indicating potential biological impacts during the immediate time period. The species exhibited delayed displacement—possibly being displaced off the study area.



The Savannah sparrow did not occur at the South Dakota Wind Energy Center. At the Oliver Wind Energy Center, based on the distance bands in which they did occur, Savannah sparrows exhibited immediate displacement effects between 100 and 300 meters, indicating potential movement within the study site away from turbines.



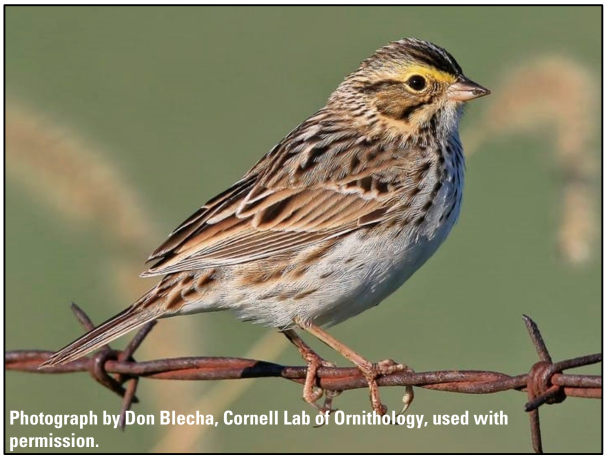
At the Oliver Wind Energy Center, Savannah sparrows exhibited the same trend during the delayed time period as the immediate time period, indicating sustained effects within 200–300 meters.



At the Tatanka Wind Farm, the Savannah sparrow exhibited delayed displacement effects. Similar to the situation at the Oliver Wind Energy Center, Savannah sparrows exhibited displacement between 100 and 300 meters, indicating potential movements within the study site away from turbines.

Conclusion for Savannah Sparrow

Displacement between 100-300 meters



Photograph by Don Blecha, Cornell Lab of Ornithology, used with permission.

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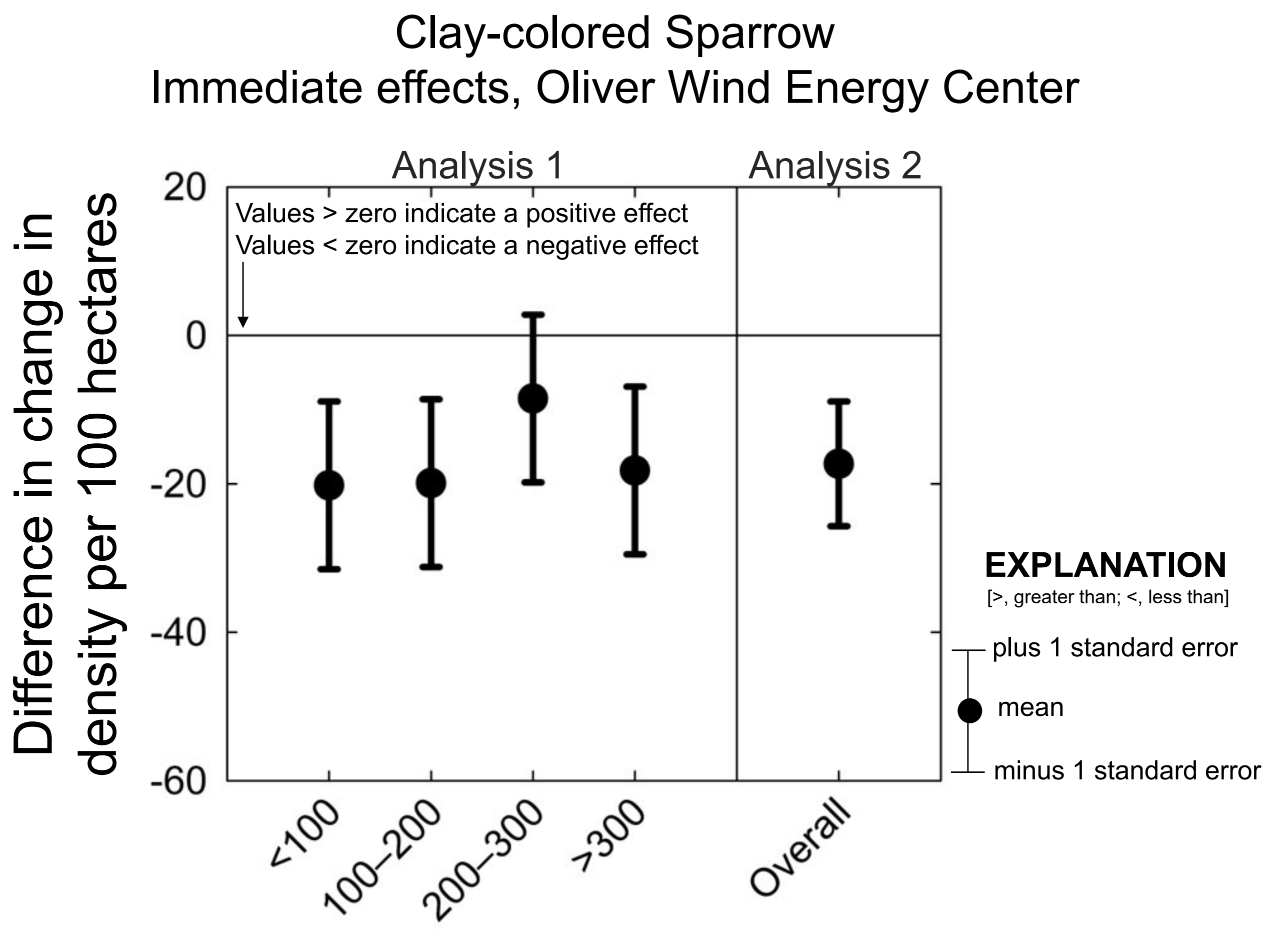
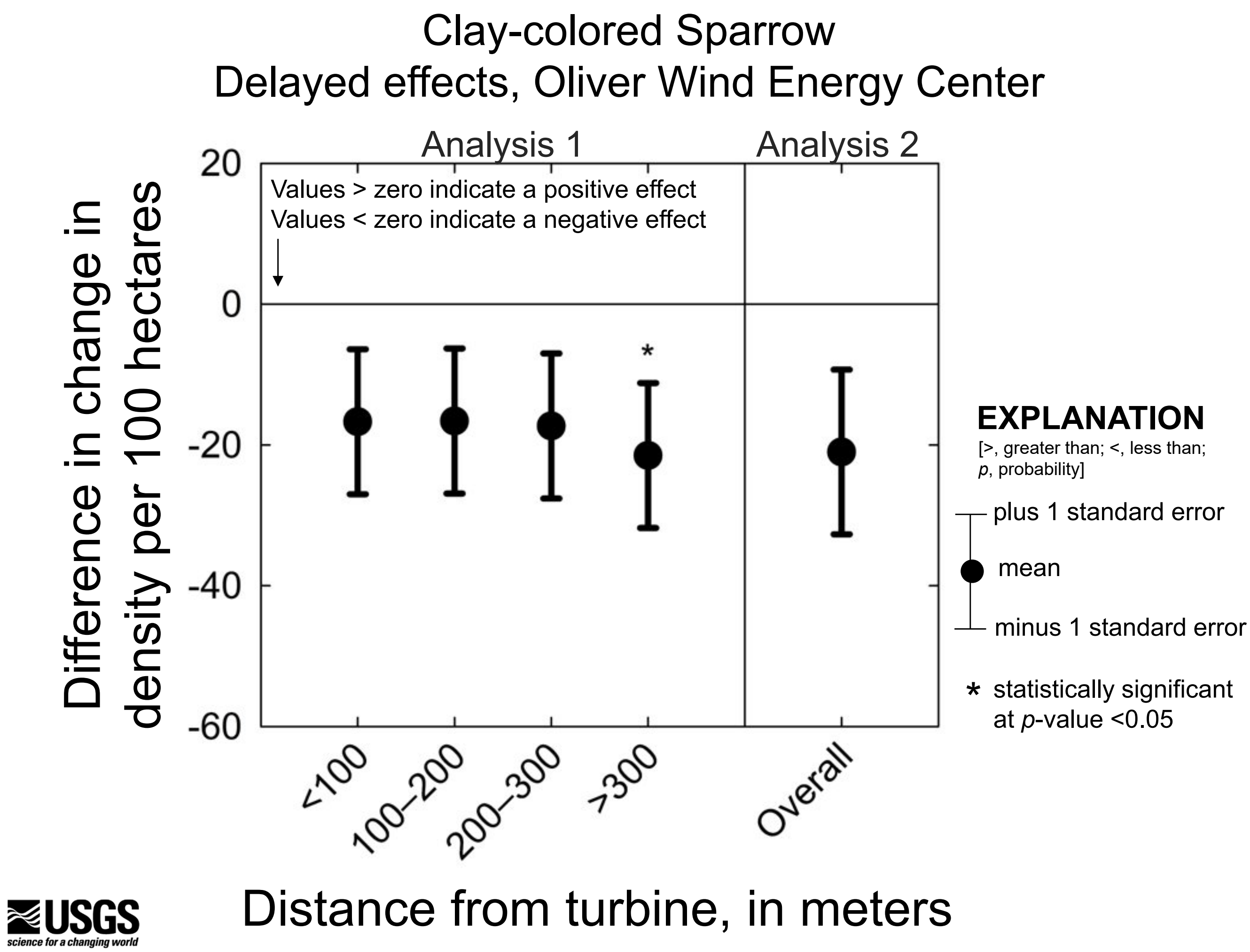
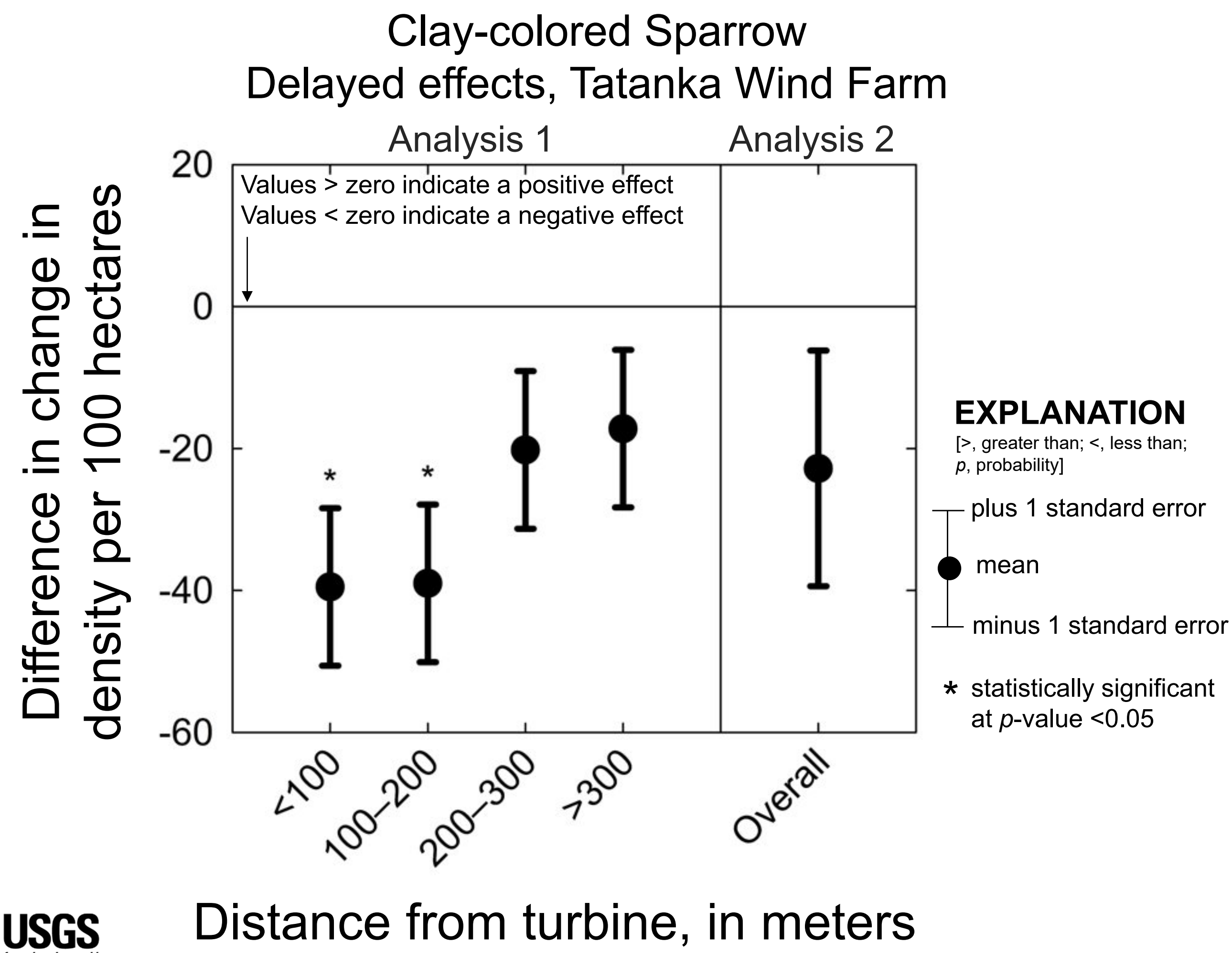
Savannah sparrow summary. Displacement effects occurred within 100–300 meters, possibly causing movements within the study site.



The clay-colored sparrow did not occur at the South Dakota Wind Energy Center. At the Oliver Wind Energy Center, the clay-colored sparrow exhibited no immediate displacement effects, but did exhibit potentially important biological effects, within 200 meters and overall.



At the Oliver Wind Energy Center, the clay-colored sparrow exhibited delayed displacement effects greater than 300 meters and potentially important biological effects overall.



At the Tatanka Wind Farm, the clay-colored sparrow exhibited delayed displacement effects within 200 meters, with potentially biologically important effects beyond 200 meters and overall.

Conclusion for Clay-colored Sparrow

Immediate biologically important effects overall and within 200 m and > 300 m
Delayed impacts within 200 m

[m, meter; >, greater than]

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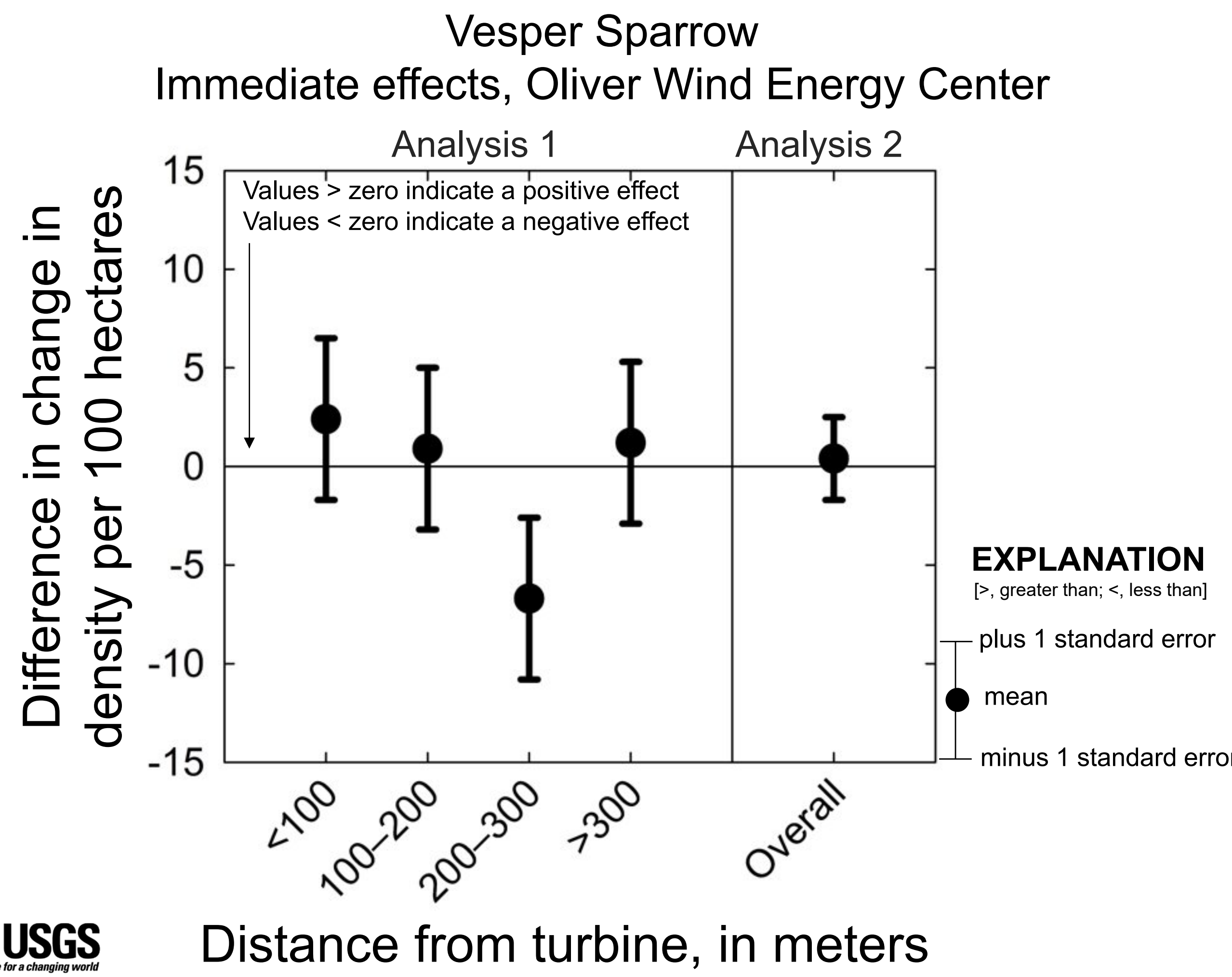
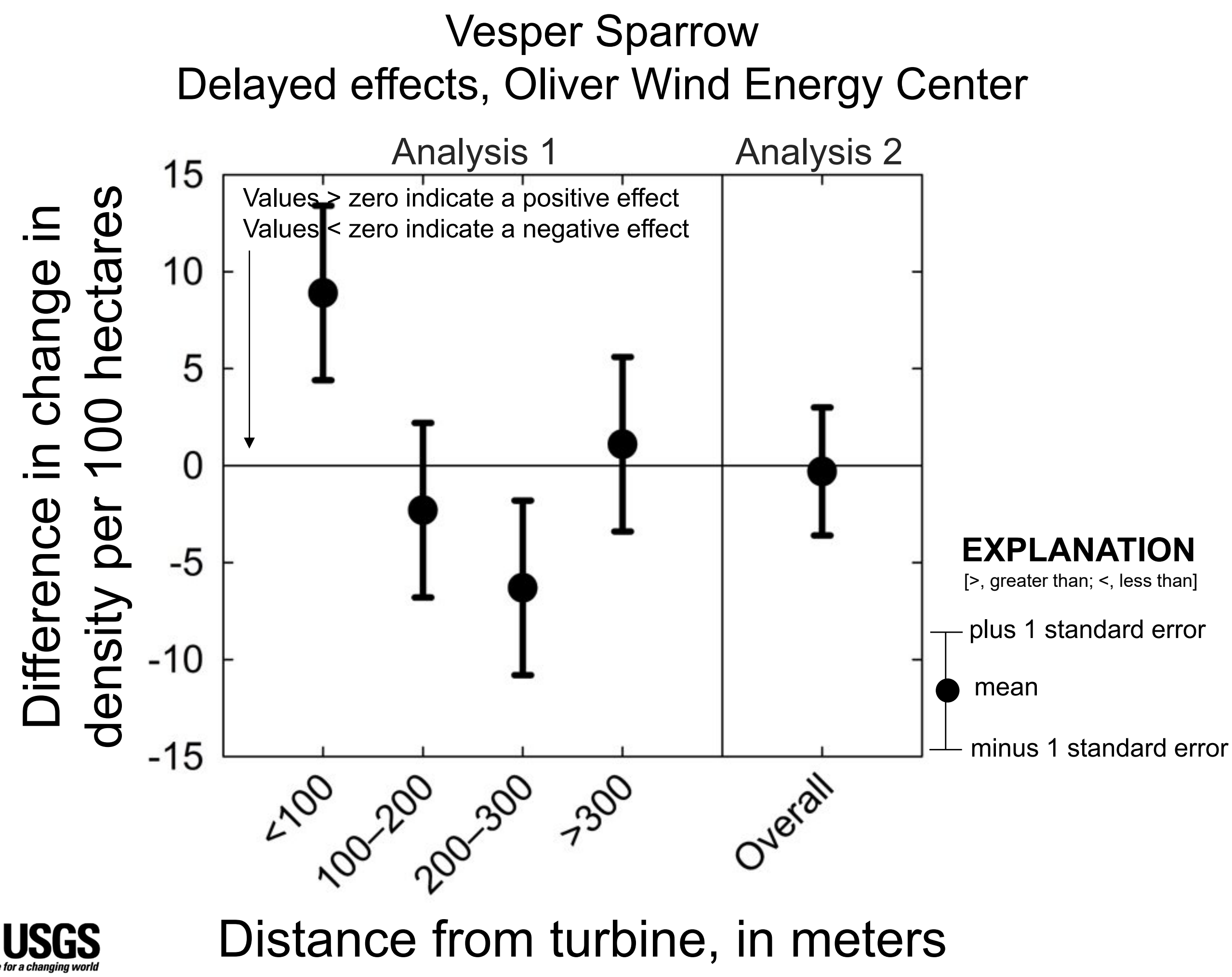
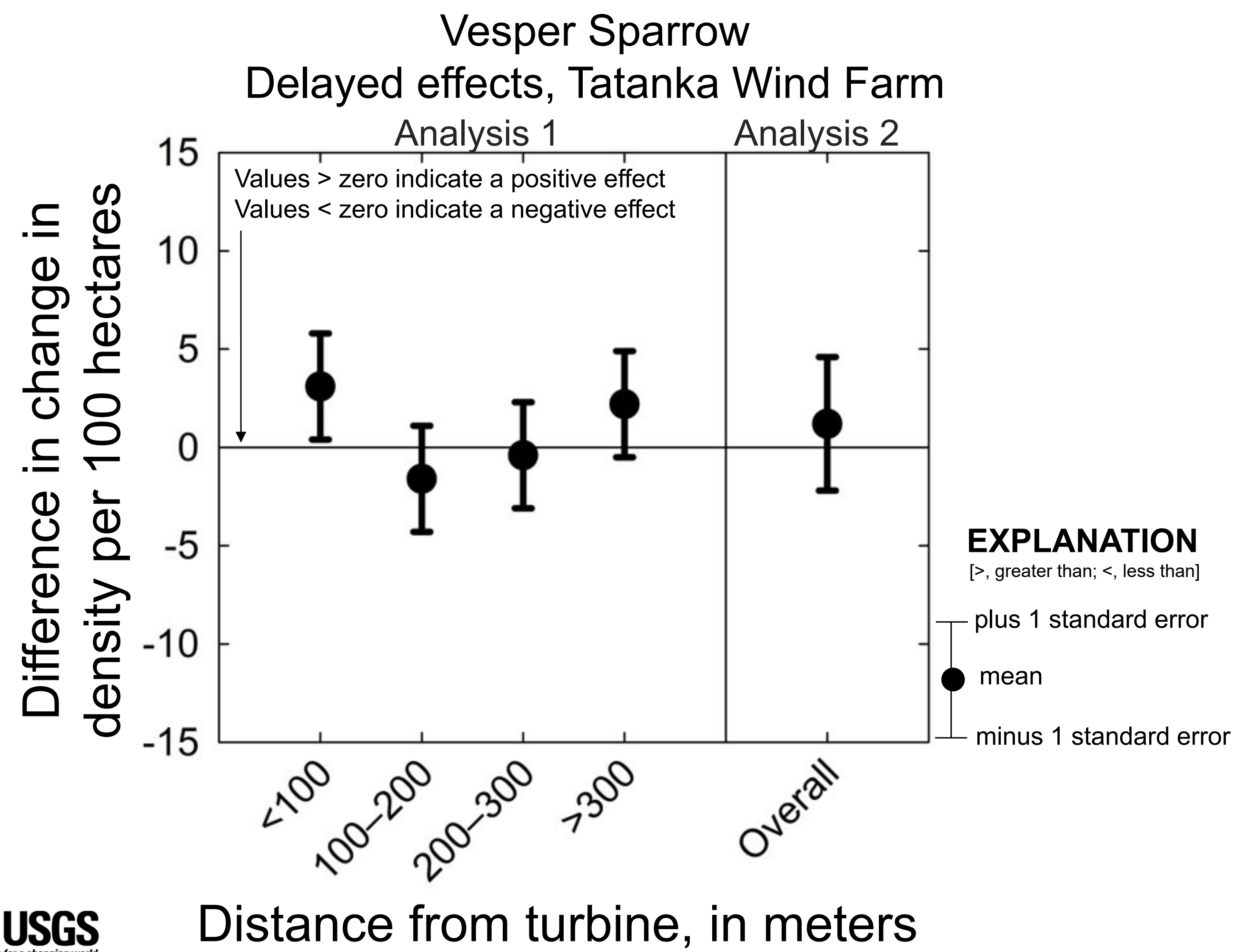
Clay-colored sparrow summary. At the two study areas in which clay-colored sparrows occurred, the species exhibited a high magnitude of difference (greater than or equal to 10 bird pairs per 100 hectares) between turbine and reference sites, indicating potential biological impacts during the immediate and delayed time periods. The species exhibited delayed displacement within site as well as potentially being displaced off the study site.



The vesper sparrow did not occur at the South Dakota Wind Energy Center. At the Oliver Wind Energy Center, vesper sparrows exhibited no immediate displacement effects within distance bands or overall.



At the Oliver Wind Energy Center, vesper sparrows exhibited no delayed displacement effects within distance bands or overall.



At the Tatanka Wind Farm, vesper sparrows exhibited no delayed displacement effects within distance bands or overall.

Conclusion for Vesper Sparrow

No evidence for displacement

Vesper sparrow summary. The vesper sparrow was the only species of the nine studied that did not show attraction or displacement.

References Cited

Shaffer, J.A., and Buhl, D.A., 2016, Effects of wind-energy facilities on breeding grassland bird distributions: Conservation Biology, v. 30, no. 1, p. 59–71. [Also available at https://doi.org/10.1111/cobi.12569.]

Appendix 3. Instructions for Applying Decision-Support Tools to Support the Avian-Impact Offset Method

Background

The Avian-Impact Offset Method (AIOM) was developed to facilitate the estimation of offsets that compensate for behavioral avoidance (otherwise referred to as “displacement”) resulting in anthropogenic disturbance (Shaffer and others, 2019). The method identifies five metrics that are required to estimate the grassland area needed to offset breeding grassland bird avoidance and the wetland area and number of wetlands needed to offset breeding waterfowl avoidance. To aid in the calculation of these estimates, two decision-support models were developed using Model Builder in ArcMap 10.6.1 and ArcPro 2.7.4—one for grassland birds and one for waterfowl. The results also can be used to identify suitable landscapes for offset locations where grassland could be protected or restored.

Computer Installation

Although there is no formal installation necessary for the decision-support tools, the databases and tools must be stored on the user’s computer in a folder location labelled as c:\AvianOffsetDSTModelData.

1. Copy the AvianOffsetDSTModelData.zip file to the folder “C:\Users\Public.”
2. Unzip the file.

The resulting geospatial grassland bird and waterfowl data used by the tools are provided in two ArcMap 10.6.1 file geodatabases and two Model Builder toolboxes with two models each (fig. 3.1). The files included in the zip file are described in the following sections.

ArcMap and ArcPro File Geodatabases

AvianImpactOffsetMethodDST.gdb contains three rasters and one feature class to support use of the AIOM tools. Note that models are based on values input in the English system of acres.

ND6SpecSumProbOcc—Raster of the sum of the probability of occurrence for western meadowlark (*Sturnella neglecta*), Savannah sparrow (*Passerculus sandwichensis*), bobolink (*Dolichonyx oryzivorous*), grasshopper sparrow (*Ammodramus savannarum*), upland sandpiper (*Bartramia longicauda*), and clay-colored sparrow (*Spizella pallida*) as calculated from Niemuth and others (2017).

NDGrasslandBirdConservationAreaType3—Raster of Type III Grassland Bird Conservation Areas (55 acres), developed using methods described in Johnson and others (2010).

GrasslandHabitat_UplandsOnly—Raster of only the grassland cover class used with other cover classes to create Type III Grassland Bird Conservation Areas defined in table 2 of Johnson and others (2010).

WaterfowlBiologicalBenefits—There are two attributes relative to duck pairs in this feature class.

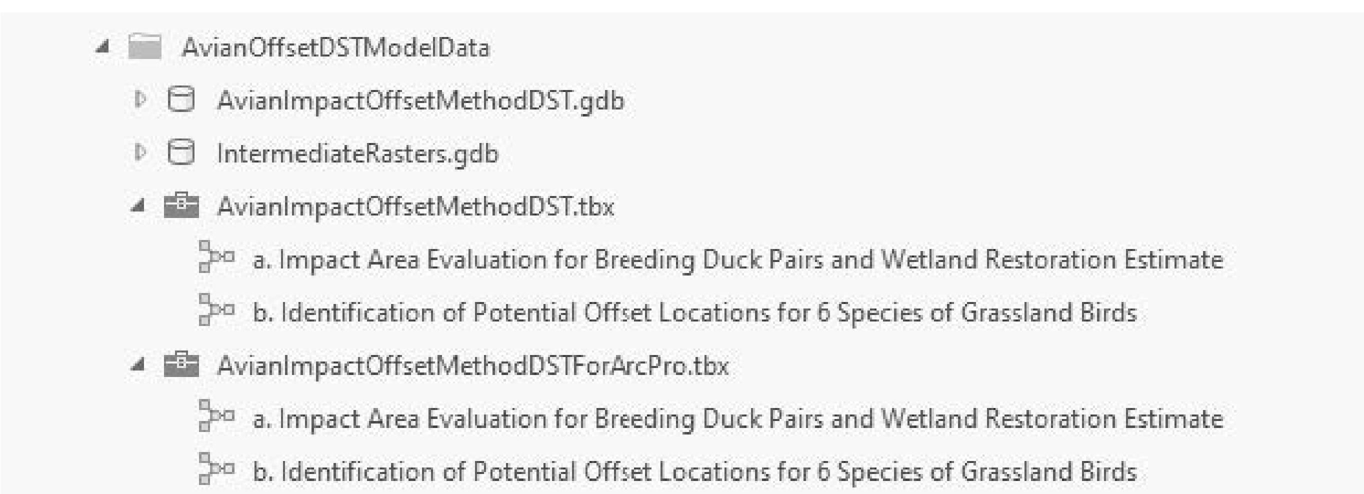


Figure 3.1. Representation of the organization of the installation folder containing the geodatabases, tool boxes, and models that support the geospatial tools for the Avian-Impact Offset Method.

The first attribute contains the number of breeding duck pairs of northern pintail (*Anas acuta*), blue-winged teal (*Spatula discors*), northern shoveler (*Spatula clypeata*), gadwall (*Mareca strepera*), and mallard (*Anas platyrhynchos*) predicted for each of the wetlands existing within a 390 x 390 meter fishnet.

The second attribute contains an estimate of the number of breeding pairs that were modeled for a single, restored 2.2-acre seasonal wetland in each fishnet cell. Note that 2.2 acres represents the average size of seasonal wetlands restored in North Dakota and South Dakota by the Partners for Fish and Wildlife Program, administered by the U.S. Fish and Wildlife Service. The estimates were averaged for each county, and the county average was stored in each fishnet cell within the respective county.

IntermediateRasters.gdb—Storage location for temporary rasters generated when running the AIOM tools.

ArcMap and ArcPro Toolboxes

AvianImpactOffsetMethodDSTForArcMap.tbx—This toolbox was created in ArcMap version 10.6.1 and contains two tools:

a. *Identification of Potential Offset Locations for 6 Species of Grassland Birds*—Generates three layers that include the buffer of the disturbance features, the compatible habitat within the buffer area, and potential offset sites with equal or higher biological value than was estimated for the impact area.

b. *Impact Area Evaluation for Breeding Duck Pairs and Wetland Restoration Estimate*—Generates a table with estimates of the number of breeding duck pairs within the impact area, number of displaced pairs, number of 2.2-acre wetlands necessary to support displaced pairs, and an estimate of the number of acres of seasonal wetlands necessary to support displaced pairs.

AvianImpactOffsetMethodDSTForArcPro.tbx—This toolbox was created in ArcPro version 2.7.4 and contains two tools:

a. *Identification of Potential Offset Locations for 6 Species of Grassland Birds*—Generates three layers that include the buffer of the disturbance features, the compatible habitat within the buffer area, and potential offset sites with equal or higher biological value than was estimated for the impact area.

b. *Impact Area Evaluation for Breeding Duck Pairs and Wetland Restoration Estimate*—Generates a table with estimates of the number of breeding duck pairs within the impact area, number of displaced pairs, number of 2.2-acre wetlands necessary to support displaced pairs, and an estimate of the number of acres of seasonal wetlands necessary to support displaced pairs.

Instructions for Installing ArcMap and ArcPro Toolboxes

To install the appropriate tools for the user's software, follow these directions:

Before using the AvianImpactOffsetMethodDST, the correct toolbox must be added to ArcTools.

1. For ArcMap
   a. Open an ArcMap session.
   b. Open the ArcTools tab, and add by right-clicking on ArcToolBox heading and selecting "Add Toolbox."
   c. Navigate to where the toolboxes are stored during the unzip process. Select the AvianImpactOffsetMethodDSTforArcMap.tbx. Select the toolbox and select "Open." The toolbox should show up in the list of tools.
   d. Installation is complete.
2. For ArcPro
   a. Open an ArcPro session.
   b. Select the Catalog tab, and navigate to the "C:\AvianOffsetDSTModelData" folder. The AvianImpactOffsetMethodDSTForArcPro.tbx should be present.
   c. The tools should be accessible in the toolbox.
   d. Installation is complete.

Instructions for Running ArcMap and ArcPro Tools for Breeding Grassland Birds

To use the "Identification of Potential Offset Locations for 6 Species of Grassland Birds" tool, follow these directions:

1. Run tool "b. Identification of Potential Offset Locations for 6 Species of Grassland Birds" by either double-clicking the tool in either software toolset (fig. 3.1) or by right-clicking on the tool name and selecting "Open." Although the dialog boxes look slightly different, the inputs for both software versions are the same.
2. In the dialog box that appears (figs. 3.2 and 3.3), use the dropdown or navigate to the requested file and select it, then identify the location and name of new files created by the tool:
   a. Identify and select the anthropogenic disturbance feature class by either using the dropdown if the feature class is loaded in the ArcPro map, or navigate to the feature class.
   b. Enter the zone of influence or disturbance distance. The default is 300 meters (Shaffer and others, 2019).

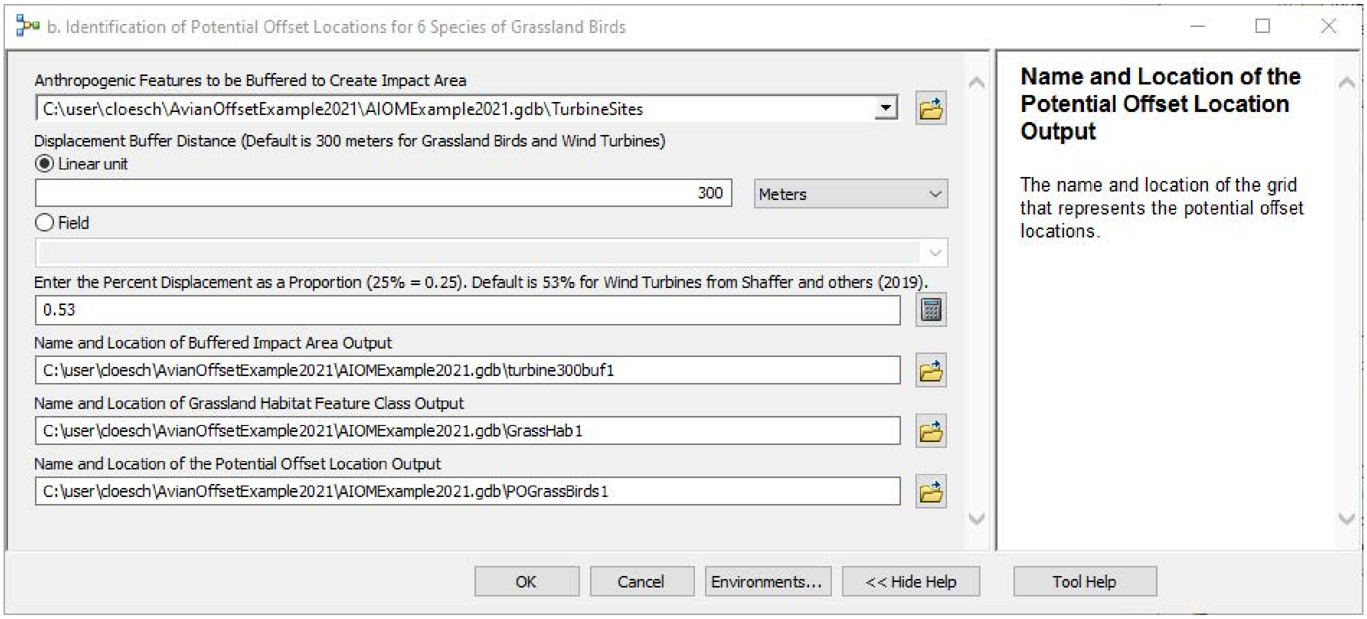


Figure 3.2. Example of a populated ArcMap dialog box that executes the “Potential Offset Locations for 6 Species of Grassland Birds” tool.

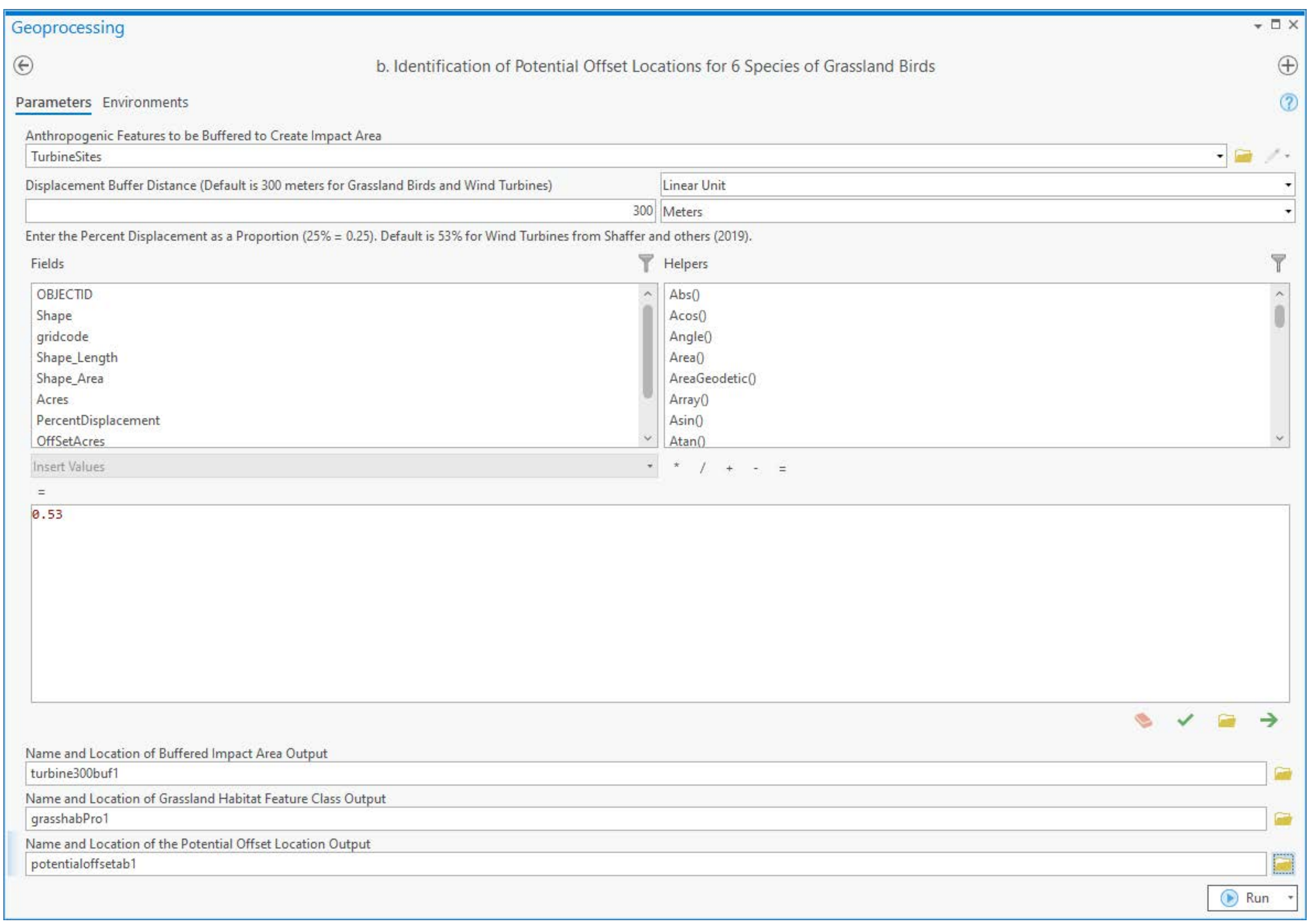


Figure 3.3. Example of a populated ArcPro dialog box that executes the “Potential Offset Locations for 6 Species of Grassland Birds” tool.

c. Enter the percent displacement as a proportion. The default is 0.53 (Shaffer and others, 2019).

d. Enter the name and location in which to store the impact area that will be created from "a." and "b." above.

e. Enter the name and location in which to store the compatible grassland bird habitat within the impact area.

f. Enter the name and location in which to store the raster of potential grassland offset sites.

3. The model produces three geospatial layers:

a. A feature class of the impact area.

b. A feature class of compatible grassland bird habitat within the impact area.

c. A raster where 1=potential offset habitat and 0=unsuitable offset location.

4. A table that provides a summary of the acres of impacted grassland can be found associated with the raster named during the request for "Name and Location of the Potential Offset Location Output." In the example shown in fig. 3.4, the name of the output table is "GrassHab," the grassland acres in the project area are 277, and the offset acres are 146.8.

a. OBJECTID—Ignore

b. Shape—Ignore

c. gridcode—Ignore

d. Shape_Length—Ignore

e. Shape_Areas—Ignore

f. Acres—Grassland acres within the buffer of the impact sites.

g. PercentDisplacement—Percent displacement used in the model run.

h. OffsetAcres—Estimated acres needed to offset the impact.

i. Radius—Radius of a circle if the offset acres were targeted to a single 160-acre circle of habitat.

j. SideLength—Side of a square if offset acres were targeted to a single 160-acre square block of habitat.

Suitable offset habitat is defined as grassland patches that are greater than or equal to 55 acres and contain compatible habitat at locations where the mean grassland bird probability of occurrence is greater than or equal to that of the impact area for the six species of grassland birds listed above (Niemuth and others, 2017). Note that the species composition can be changed to match the important species of the wind facility location if data are available. Patches of existing grassland habitat that are equal to the offset amount, as estimated using the AIOM, are considered an averted-loss type of mitigation. Cropland considered for restoration equal to the offset estimated using the AIOM is considered a net neutral type of mitigation.

Instructions for Running ArcMap and ArcPro Tools for Breeding Waterfowl Pairs

To use the "Impact Area Evaluation for Breeding Duck Pairs and Wetland Restoration Estimate" tool, follow these directions:

1. Run tool "Impact Area Evaluation for Breeding Duck Pairs and Wetland Restoration Estimate" by double-clicking the tool in either of the software toolsets (fig. 3.1) or by right-clicking on the tool name and selecting "Open."

2. In the dialog box that appears, use the dropdown or navigate to the requested file and select it, then identify the location and name of new files created by the tool (figs. 3.5 and 3.6):

a. Identify and select the anthropogenic disturbance feature class by either using the dropdown if the feature class is loaded in the ArcPro map or navigate to the feature class.

b. Enter the zone of influence or disturbance distance. The default is 800 m from Loesch and others (2013).

c. Enter the name and location to store the impact area that will be created from "a." and "b." above.

d. Enter the percent displacement as a proportion. The default is 0.18 from Shaffer and others (2019).

e. Enter the name and location for the summary table of impacts and offsets.

3. The model produces one geospatial layer:

a. A feature class of the impact area.

4. The output table will contain one record with four attributes that summarize the impact and offset estimates that result from the presence of the turbines. In the example shown in fig. 3.7, the name of the output table is "DuckHab2," the number of seasonal wetlands to restore is 8, and the acres of wetlands to restore are 18.

a. OBJECTID—Ignore

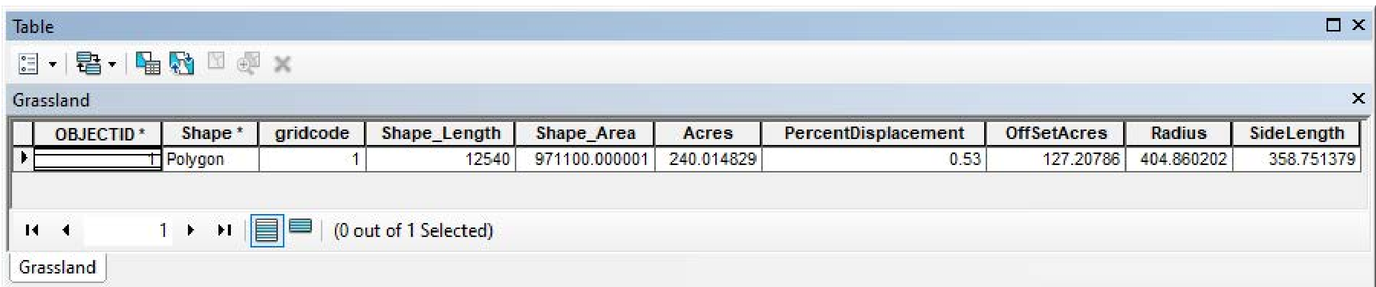
b. FREQUENCY—Ignore

c. SUM_DuckPairs5Species—The number of mallard, blue-winged teal, gadwall, northern pintail, and northern shoveler pairs associated with wetlands within the impact area.

d. SUM_DuckPairsDisplaced—The number of breeding pairs for the five duck species displaced by the disturbance features.

e. NumOfSeasonalWetlandsToRestore—Number of wetlands requiring restoration to offset the displacement of breeding pairs of the five duck species resulting from avoidance.

f. AcresOfSeasonalWetlandsToRestore—Estimate of the number of acres of seasonal wetlands to restore.



Table

Grassland

OBJECTID *	Shape *	gridcode	Shape_Length	Shape_Area	Acres	PercentDisplacement	OffSetAcres	Radius	SideLength
1	Polygon	1	12540	971100.000001	240.014829	0.53	127.20786	404.860202	358.751379

(0 out of 1 Selected)

Grassland

Figure 3.4. Example of an output summary table that is generated from the "Potential Offset Locations for 6 Species of Grassland Birds" tool.

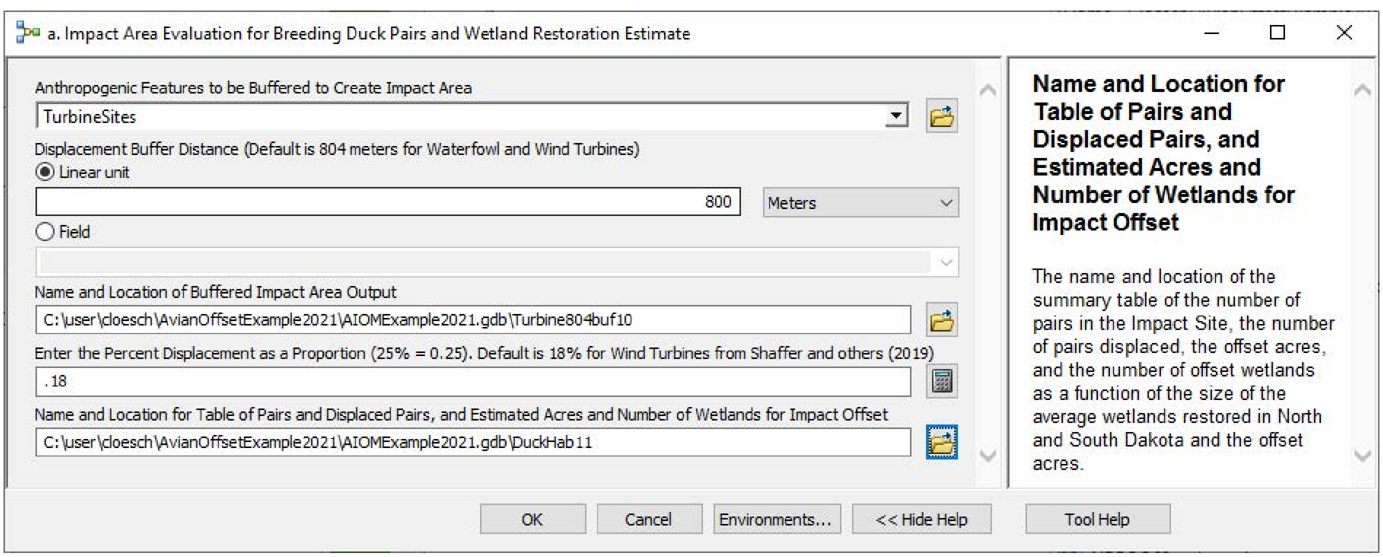


Figure 3.5. Example of a populated ArcMap dialog box that executes the "Impact Area Evaluation for Breeding Duck Pairs and Wetland Restoration Estimate" tool.

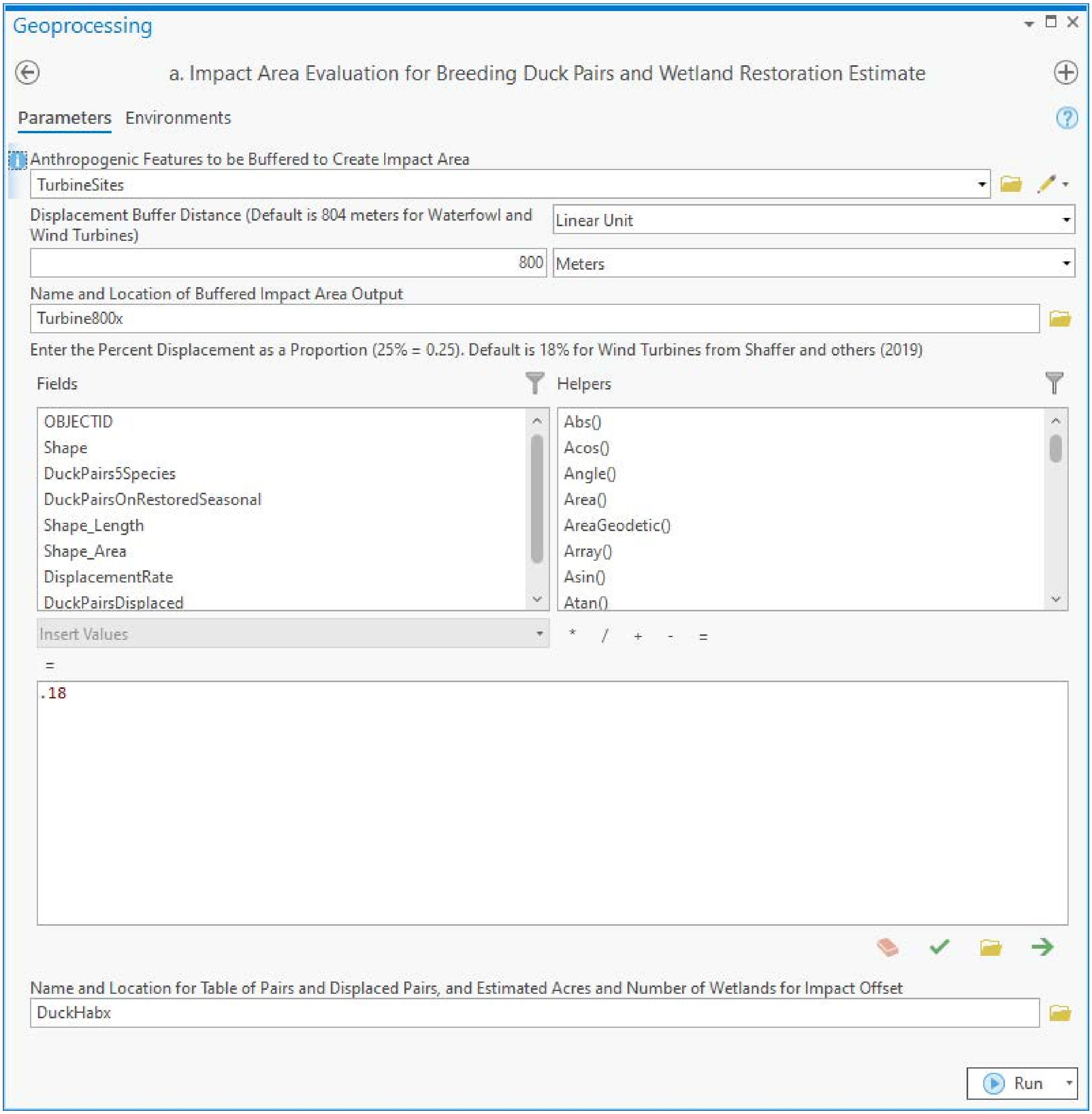


Figure 3.6. Example of a populated ArcPro dialog box that executes the “Impact Area Evaluation for Breeding Duck Pairs and Wetland Restoration Estimate” tool.

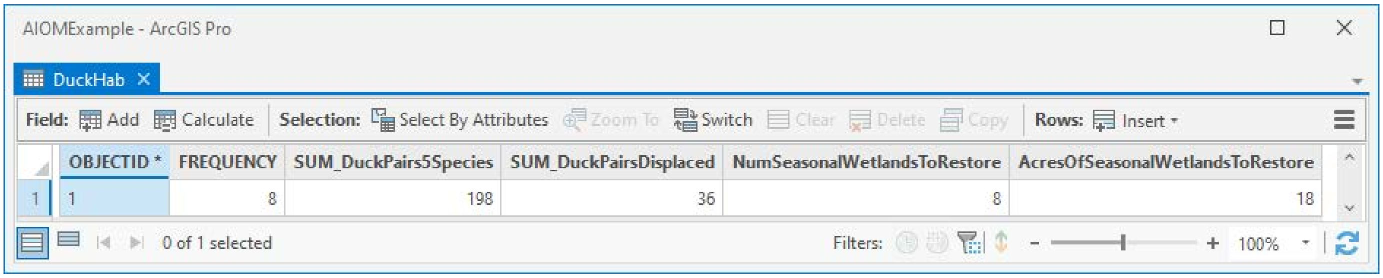


Figure 3.7. Example of an output summary table that is generated from the "Impact Area Evaluation for Breeding Duck Pairs and Wetland Restoration Estimate" tool.

Contact Information

To access the decision-support tools and for assistance, use the following contact information:

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