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U.S. Geological Survey—Northern Prairie Wildlife Research Center

2019–20 Research Activity Report

Circular 1481

U.S. Department of the Interior
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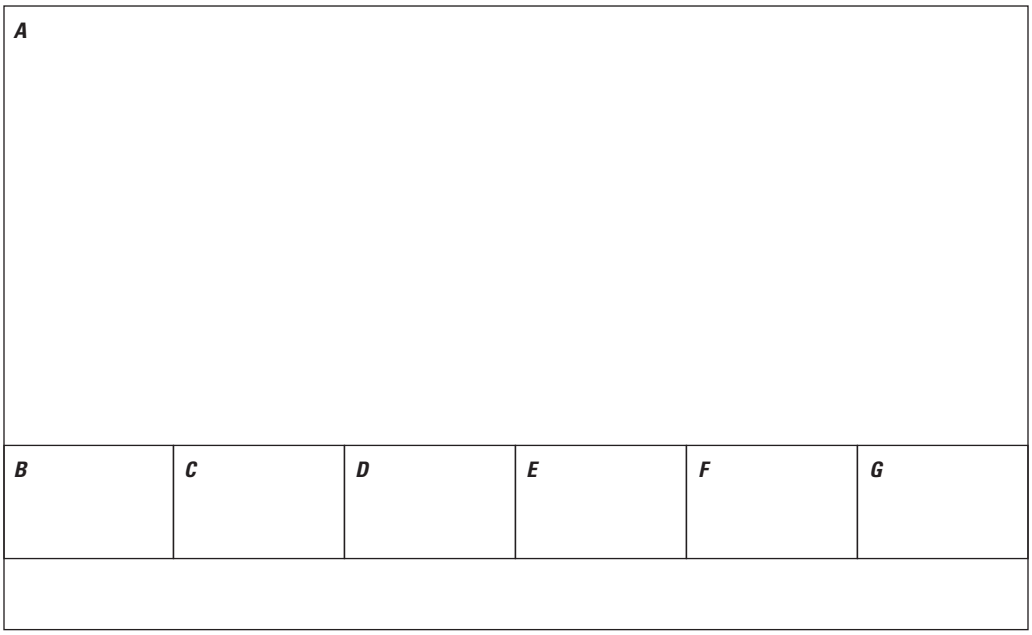

Front cover: *A*, Prairie grassland habitat. Photograph by U.S. Geological Survey (USGS). *B*, Beetle on prairie rose. Photograph by Stacy Simanonok, USGS. *C*, Lark bunting nest. Photograph by Katy Anderson, Northern Prairie Wildlife Research Center. *D*, Common tern in flight. Photograph by USGS. *E*, Radio-collared white tailed deer. Photograph by Shannon Barber-Meyer, USGS. *F*, Yellow-headed blackbird in semipermanent wetland. Photograph by Lawrence D. Igl, USGS. *G*, Bumble bee on Echinacea species. Photo by Stacy Simanonok, USGS.

Back cover: Prairie grassland habitat. Photograph by USGS.

U.S. Geological Survey—Northern Prairie Wildlife Research Center 2019–20 Research Activity Report

Edited by Mark H. Sherfy

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U.S. Department of the Interior
U.S. Geological Survey

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Acknowledgments

This report is a compilation of narratives on the current science portfolio of Northern Prairie Wildlife Research Center. This work reflects our long and proud history of working with many partners and collaborators who have made much of the science presented here possible, and we thank each of them for their support of our research.

The content of this report was written by the scientific staff at the Northern Prairie Wildlife Research Center, whose devotion of time to preparing the content, and more importantly, to completing the underlying research, is greatly appreciated. Michael J. Anteau, David M. Mushet, and Max Post van der Burg provided critical reviews of earlier drafts and made many valuable suggestions about how best to organize and present Northern Prairie's science portfolio. Mona Khalil provided advice on the structure and display of the report.

Contents

Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
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	
square meter (m^2)	0.0002471	acre
hectare (ha)	2.471	acre
square kilometer (km^2)	247.1	acre
square meter (m^2)	10.76	square foot (ft^2)
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	0.3861	square mile (mi^2)

Abbreviations

AIOM	avian-impact offset method
ABAM	Annual Brome Adaptive Management
AMF	arbuscular mycorrhizal fungi
CRP	Conservation Reserve Program
CWD	chronic wasting disease
DNA	deoxyribonucleic acid
DOI	Department of the Interior
FWS	U.S. Fish and Wildlife Service
GHG	greenhouse gas
GPS	Global Positioning System
HAPET	Habitat and Population Evaluation Team
NPAM	Native Prairie Adaptive Management
NPWRC	Northern Prairie Wildlife Research Center
PHyLiSS	Pothole Hydrology Linked System Simulator
PPJV	Prairie Pothole Joint Venture
PRRIP	Platte River Recovery Implementation Program
RWBJV	Rainwater Basin Joint Venture
UAS	unmanned aircraft systems
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

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Northern Prairie Wildlife Research Center History and Science Focus

The Department of the Interior (DOI) conserves and manages the Nation's natural resources and cultural heritage, including public lands and minerals, national parks, national wildlife refuges, and western water resources. The DOI also is responsible for migratory wildlife conservation, historical preservation, endangered species conservation, and surface-mined land restoration. To meet these responsibilities, the DOI provides scientific information about natural resources and natural hazards to other Federal agencies and the public. The breadth of the DOI's science mission requires expertise in several disciplines to support informed and defensible management decisions on behalf of the American public. Much of this expertise is provided by way of the U.S. Geological Survey (USGS), the Nation's premier earth and biological science agency. Specifically, USGS biological and ecological research is completed through a network of 16 science centers throughout the Nation, each representing a distinct component of the USGS mission and a unique focal area of expertise in natural resource science.

The Northern Prairie Wildlife Research Center (NPWRC) was established in 1965 to address key information needs for managing nationally significant waterfowl populations and habitats. In the heart of the Nation's prairie wetland and grassland resources, NPWRC is ideally positioned for interdisciplinary research on migratory birds, land-use change, and wetland and grassland wildlife. NPWRC also is ideally positioned for quantifying ecosystem services as affected by land management, conservation programs, and climate variability. During its more than 50-year history, NPWRC has produced a wealth of information on applied management issues, focusing on the priorities and footprint of the DOI. NPWRC also has developed long-standing and productive partnerships with a variety of land-management agencies, nonprofit organizations, and universities; fostering opportunities for creative and cost-effective solutions to management and conservation issues.

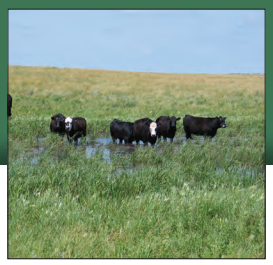
Today (2019–20), the NPWRC's science program is organized around the following five themes: (1) wildlife science, (2) ecosystem science, (3) climate-change science, (4) land-use change science, and (5) analytics and decision support. Together, research under these five themes addresses the primary information needs of land managers and policymakers across a vast part of the central United States and is strategically linked through NPWRC's organizational structure to facilitate interdisciplinary collaboration to address complex issues.

DOI Mission.—The DOI protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to Native Americans, Alaska Natives, and affiliated island communities.

USGS Mission.—The USGS provides science about the natural hazards that threaten lives and livelihoods; the water, energy, minerals, and other natural resources we rely on; the health of our ecosystems and environment; and the effects of climate and land-use change. USGS scientists develop new methods and tools to supply timely, relevant, and useful information about the Earth and its processes.

NPWRC Mission.—The NPWRC provides scientific information needed to conserve and manage the Nation's natural capital for current and future generations, with an emphasis on migratory birds, DOI trust resources, and ecosystems of the Nation's interior.

The NPWRC celebrated its 50-year anniversary in 2015 and published a report describing the first 50 years of biological research at the NPWRC (Austin and others, 2017) along with a bibliography of scientific products (U.S. Geological Survey, 2017). The scientific foundation developed at the NPWRC during this timeframe provides the base for applied research and enables the NPWRC to quickly respond to emerging issues in the Northern Great Plains and beyond. The NPWRC has since published annual research activity reports (Sherfy, 2019; Sherfy, 2020) that provide details on the studies that constituted the NPWRC's 2016–18 science portfolio. This report updates Sherfy (2020) by describing NPWRC's 2019–20 science portfolio.

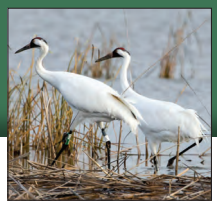

Lines of Work

The NPWRC's science portfolio is built around a diverse suite of management questions, partnerships, and funding sources. The USGS Ecosystems Mission Area accounts for most of NPWRC's appropriated funding and has developed a hierarchical system to classify biological science portfolios into Lines of Work. The highest level of the hierarchy contains three Programs, each containing two Lines of Work that, in turn, contain many science subjects, or Sub-Lines of Work, as summarized parenthetically below:

The Species Management Program encompasses research on *Species Biology* (research into life history, successful conservation, and recovery of threatened and endangered species listed under the Endangered Species Act; trust species that are protected by law; sensitive species that are declining, rare, or uncommon and are identified as candidates for future listing consideration; and species of management concern that warrant management or conservation attention as identified by a natural resource management agency) and *Species Stressors* (research into the cause and mitigation of environmental and anthropogenic stressors that potentially affect the health and reproductive capacity of species of management concern).

The Landscape Management Program encompasses research on *Management and Restoration* (understanding how ecosystems work and how chemical, geological, hydrological, and biological processes interact and change with human and natural alterations) and *Priority Landscapes* (place-based research to understand the biological and physical processes that affect change and management options across large geographic areas of management concern).

The Biological Threats Program encompasses research on *Invasive Species* (research, monitoring, and technology development for containing or eradicating nonindigenous species with potential to cause significant ecologic or economic damage or affect human health) and *Fish and Wildlife Disease* (ecology of fish and wildlife diseases, effect of diseases on wild populations with emphasis on federally listed species; development of surveillance, control, and risk-assessment tools; and decision support science for management agencies).





This hierarchical system has become a standard mechanism for organizing and communicating NPWRC's science research program within the Ecosystems Mission Area. Accordingly, NPWRC has adopted this system's principles for this report. Narratives describing each study are organized according to their principal alignment with Programs, Lines of Work, and Sub-Lines of Work. Each study also is associated with additional Sub-Lines of Work as needed to represent the subject area(s) of the study. These additional Sub-Lines of Work are indicated graphically by icons in each narrative. A cross-reference of active NPWRC studies to these hierarchical levels and definitions of the icons are provided in table 1.

Grassland Ecosystems.—Temperate grasslands are one of the most imperiled ecosystems globally, facing threats including conversion to crop production, invasion by nonnative species, and loss of disturbance factors that favor diverse native plant communities.

Northern Forests.—Northern hardwood and conifer forest communities from the upper Midwest to the Rocky Mountains support ungulate and carnivore populations that are Federal management priorities owing to their population status and occurrence on Federal lands.

Prairie Pothole Region.—Known as "the duck factory of North America" because it supports the core breeding population of many migratory waterfowl species, the Prairie Pothole Region contains millions of depressional, glacially derived wetlands with dynamic and variable hydroperiods that generate periodic pulses of productivity.

Midcontinent River Systems.—Large river systems, such as the Missouri, Platte, and Mississippi Rivers, are major landscape features that provide ecosystem services, support populations of priority species, and provide linkages between terrestrial and aquatic habitats.

Table 1. Alignment with studies constituting the science portfolio at Northern Prairie Wildlife Research Center with Research Programs, Lines of Work, and Sub-Lines of Work. Each study is represented by its index number (table 2) and has a primary alignment with one Sub-Line of Work and secondary alignment with one, two, or three Sub-Lines of Work.

[Icons from https://www.flaticon.com/, Creative Commons 3.0 license. T&E, threatened and endangered; --, not applicable; SMC, species of management concern]

Program	Program icon	Primary alignment (index number)	Secondary alignment (index number)
Species Management Program—Species Biology Line of Work			
T&E: listed birds		15, 16, 17, 18, 19, 20, 21	44
T&E: listed insects		35	32, 33
T&E: whooping crane		22, 23, 24, 25	--
T&E: wolves		36, 37, 38	--
SMC: migratory birds		1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 41, 43, 44, 46, 49, 50, 51, 68
SMC: pollinators		26, 27, 28, 29, 30, 31, 32, 33, 34	35, 42, 64
SMC: ungulate ecology		39, 40	36, 72, 73
SMC: waterbird management		--	1, 2, 3, 4, 5, 11, 13, 17, 49, 51, 61, 62
Population dynamics		--	2, 3, 4, 5, 6, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 36, 37, 38, 39, 73
Species Management Program—Species Stressors Line of Work			
Agriculture		--	26, 27, 42, 47, 48, 49, 50
Biofuels		42	--
Contaminants		43	--
Cumulative stressors		--	7, 23
Habitat loss/degradation		44	8, 26, 30, 41, 52, 53, 61, 62
Hydropower		--	16
Oil and gas		--	7
Wind energy		41	22

Table 1. Alignment with studies constituting the science portfolio at Northern Prairie Wildlife Research Center with Research Programs, Lines of Work, and Sub-Lines of Work. Each study is represented by its index number (table 2) and has a primary alignment with one Sub-Line of Work and secondary alignment with one, two, or three Sub-Lines of Work.—Continued

[Icons from https://www.flaticon.com/, Creative Commons 3.0 license. T&E, threatened and endangered; --, not applicable; SMC, species of management concern]

Program	Program icon	Primary alignment (index number)	Secondary alignment (index number)
Landscape Management Program—Management and Restoration Line of Work			
Climate change		60, 61, 62	14, 45, 47, 52, 53
Decision analysis frameworks		58, 59	1, 31, 45, 67, 68, 70
Ecosystem health		63	30, 35, 46, 54, 55
Ecosystem services		56, 57	--
Fire		--	64, 69
Land management practices		45	1, 2, 6, 8, 10, 26, 27, 28, 30, 34, 39, 40, 42, 43, 46, 48, 50, 51, 56, 57, 58, 61, 62, 63, 64, 68, 71
Landscape ecology		--	20, 52, 53
Remediation/revitalization		--	10, 11, 48
Riparian/wetland		46, 47, 48, 49, 50, 51, 52, 53, 54, 55	3, 10, 11, 20, 43, 56, 57, 60, 61, 62, 63
River		--	15, 19, 54
Biological Threats Program—Invasive Species Line of Work			
Ecology and impacts		64, 65, 66, 67	47, 60, 70
Management and control tools		68, 69, 70, 71	29, 65, 66, 67
Risk assessment, decision science, forecasting		72	29, 39, 59, 67, 71
Biological Threats Program—Fish and Wildlife Disease Line of Work			
Ecology and impacts		73	9, 37

List of Projects

The 2019–20 science portfolio at NPWRC consisted of 73 studies covering a diverse suite of biological subjects and management applications. These studies are listed in table 2 and are organized by primary alignment with Research Programs, Lines of Work, and Sub-Lines of Work.

Pollinator plots at the Northern Prairie Wildlife Research Center. Photograph by U.S. Geological Survey.

Table 2. Index number, lead principal investigator, and title of research study constituting the 2019–20 science portfolio at Northern Prairie Wildlife Research Center.

[SMC, species of management concern; T&E, threatened and endangered; NPAM, Native Prairie Adaptive Management; ABAM, Annual Brome Adaptive Management]

Index number	Lead principal investigator	Title of research study
		Species Management Program—Species Biology Line Of Work—SMC: migratory birds
1	Anteau	Provide support to the U.S. Fish and Wildlife Service and Prairie Pothole Joint Venture for monitoring and management of migratory bird populations.
2	Pearse	An evaluation of waterfowl breeding ecology in the context of their predator community in eastern South Dakota.
3	Anteau	Demographic analysis of waterfowl populations.
4	Pearse	Reconciling competing models of temporospatial variation in duck nest survival.
5	Igl	Developing techniques to census and monitor American white pelicans and other colonial waterbirds at Chase Lake National Wildlife Refuge in North Dakota.
6	Igl	Breeding bird use of grasslands enrolled in the Conservation Reserve Program in the northern Great Plains.
7	Igl	Response of grassland birds to habitat characteristics, oil wells, and roads in managed grasslands in the Little Missouri National Grassland in North Dakota.
8	Igl/J. Shaffer	The effects of management on grassland birds—Literature reviews.
9	Igl	Immune components in eggs of New World blackbirds.
10	Pearse	Ecology and management of midcontinent sandhill cranes.
11	Pearse	Development of survey methods for spring-migrating waterfowl in the Rainwater Basin.
12	Shaffer	Investigating roadside bias in point-count surveys of grassland passerines.
13	Pearse	Postfledging movement and habitat selection by mallards in the fall and their effect on spring recruitment.
		Species Management Program—Species Biology Line Of Work—SMC: listed birds
14	Swift	Identifying population limiting factors of Hudsonian Godwits.
15	Anteau	Demographic response of least terns and piping plovers to the 2011 Missouri River Flood.
16	Anteau	Metapopulation dynamics of piping plovers in the Northern Great Plains.
17	Anteau	Breeding ecology and demographics of least terns and piping plovers at the Central Platte River, Nebraska.
18	Anteau	Population demographics of least terns and piping plovers in Colorado.
19	Sherfy	Improving monitoring techniques for nests of interior least terns and piping plovers.
20	Anteau	Identifying important habitat, developing inexpensive habitat monitoring, and developing habitat-based abundance estimates for piping plovers at wetland habitats in the Prairie Pothole Region.
21	Anteau/Ellis	Impacts of extreme disturbances at wintering areas on piping plover survival and migratory connectivity.
		Species Management Program—Species Biology Line Of Work—SMC: whooping crane
22	Pearse	Migration and winter ecology of the Aransas-Wood Buffalo population of whooping cranes.
23	Pearse	Cumulative impacts of energy development and other anthropogenic stressors for migrating whooping cranes.
24	Pearse	Identifying potential whooping crane migration habitat for assessing risk of disturbance.
25	Pearse	Whooping crane flight behavior to support aircraft-bird collision risk assessments at U.S. Air Force installations.
		Species Management Program—Species Biology Line Of Work—SMC: pollinators
26	Otto	Understanding how land-use change in the Northern Great Plains affects pollinator health and pollination services.
27	Otto	Improving forage for honey bees and native pollinators on Federal conservation lands.

Table 2. Index number, lead principal investigator, and title of research study constituting the 2019–20 science portfolio at Northern Prairie Wildlife Research Center.—Continued

[SMC, species of management concern; T&E, threatened and endangered; NPAM, Native Prairie Adaptive Management; ABAM, Annual Brome Adaptive Management]

Index number	Lead principal investigator	Title of research study
28	Igl	Long-term changes in pollinator resources (alfalfa, sweetclover, and milkweed) and monarch butterfly populations in Conservation Reserve Program grasslands.
29	Larson	To control or not to control—Response of pollinator communities to invasive plant management.
30	Larson	Below-ground mutualisms to support pollination mutualisms—Improving pollinator habitat using mycorrhizal inoculum.
31	Otto	The pollinator library—A decision-support tool for improving national pollinator conservation efforts.
32	Otto	Determining the dietary preferences and population genetics of an endangered bumble bee, *Bombus affinis*, by maximizing the use of museum specimens.
33	Otto	Float like a butterfly—Employing unmanned aircraft systems technology to quantify milkweed for monarch butterflies.
34	Otto	Native bee response to warm and cool-season grassland management at National Park Service historical sites in the Mid-Atlantic region, United States.
35	Post van der Burg	Understanding spatiotemporal patterns of threatened and endangered butterflies in the Great Plains.
		Species Management Program—Species Biology Line Of Work—T&E: wolves
36	Mech	Superior National Forest wolf and lynx populations.
37	Mech	Yellowstone wolf restoration.
38	Mech	Ellesmere wolf movements.
		Species Management Program—Species Biology Line Of Work—SMC: ungulate ecology
39	Sargeant	Integrated conservation of bison and native prairie at Badlands National Park, South Dakota.
40	Symstad	Support the development of a National Park Service Midwest Region Bison Stewardship Strategy.
		Species Management Program—Species Stressors Line of Work—Wind energy
41	Shaffer, J	A method for mitigating the behavioral effects of energy development and other anthropogenic disturbances on grassland birds and waterfowl.
		Species Management Program—Species Stressors Line of Work—Biofuels
42	Otto	Quantifying the effects of land-use change and bioenergy crop production on ecosystem services in the Northern Great Plains.
		Species Management Program—Species Stressors Line of Work—Contaminants
43	Anteau	Can wetland water-management influence mercury bioaccumulation in songbirds and ducks at National Wildlife Refuges with mercury problems?
		Species Management Program—Species Stressors Line of Work—Habitat loss/degradation
44	Post van der Burg	Inventory, mapping, estimation, and monitoring of least tern and piping plover habitats on the upper Missouri River using satellite imagery.
		Landscape Management Program—Management and Restoration Line of Work—Land management practices
45	Symstad	Integrating climate change scenario planning into National Park Service resource management.
		Landscape Management Program—Management and Restoration Line of Work—Riparian/wetland
46	Anteau	Evaluating wetland ecosystem health using real-time nutrient dynamics of ducks.
47	Anteau	Interactions of consolidation drainage and climate on water-level dynamics, wetland productivity, and waterbirds.
48	Anteau	Restoration of wetland invertebrates to improve wildlife habitat in Minnesota.
49	Anteau	Importance of wetlands in intensively farmed landscapes to duck production.
50	Anteau	Understanding consequences of management strategies for farmed wetlands to ecosystem services in the Prairie Pothole Region.

Table 2. Index number, lead principal investigator, and title of research study constituting the 2019–20 science portfolio at Northern Prairie Wildlife Research Center.—Continued

[SMC, species of management concern; T&E, threatened and endangered; NPAM, Native Prairie Adaptive Management; ABAM, Annual Brome Adaptive Management]

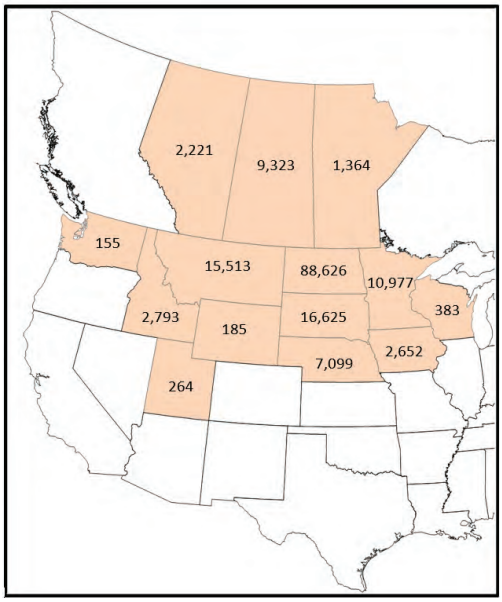
Index number	Lead principal investigator	Title of research study
51	Anteau	Evaluating dynamics of habitat resource availability for diving ducks at Pools 13 and 19 of the Mississippi River.
52	Mushet	A systems approach to modeling effects of climate and land-use change on prairie wetland ecosystems.
53	Mushet	Application and refinement of a systems model for prairie-pothole wetlands.
54	Mushet	Development and validation of wetland connectivity indicators in the U.S. Prairie Pothole Region.
55	Tangen	Description of aquatic vegetation and invertebrate communities at Big Stone National Wildlife Refuge.
		Landscape Management Program—Management and Restoration Line of Work—Ecosystem services
56	Mushet	Quantify the multiple services performed by wetland ecosystems in the Prairie Pothole Region.
57	Mushet	Development of a Conservation Reserve Enhancement Program (CREP) reporting and analysis template.
		Landscape Management Program—Management and Restoration Line of Work—Decision analysis frameworks
58	Post van der Burg	Decision analysis and support.
59	Post van der Burg	Decision analysis of options for controlling Asian carp invasion in the Tennessee River.
		Landscape Management Program—Management and Restoration Line of Work—Climate change
60	Bansal	Mechanisms, models, and management of invasive species and soil biogeochemical process in prairie pothole wetlands.
61	McKenna	The impact of future changes in climate on breeding waterfowl pairs in the U.S. Prairie Pothole Region.
62	McKenna	The impact of future climate on wetland habitat in a critical migratory waterfowl corridor of the Prairie Pothole Region.
63	Bansal	Fish and Wildlife seasonal and temporary wetland assessment.
		Biological Threats Program—Invasive Species Line of Work—Ecology and impacts
64	Larson	Evaluation of conservation grazing compared to prescribed fire to manage tallgrass prairie remnants for plant and pollinator species diversity.
65	Larson	Effects of invasive plant species on reproduction of the rare endemic plant Dakota buckwheat (*Eriogonum visheri)* at Badlands National Park.
66	Larson	Evaluation of tallgrass prairie restoration methods to improve resistance to invasive species and maintenance of plant species diversity with time.
67	Larson	Developing evaluation and monitoring frameworks for tallgrass prairie reconstruction.
		Biological Threats Program—Invasive Species Line of Work—Management and control tools
68	Shaffer	Improving wildlife habitat through management and restoration of native prairies on lands under U.S. Fish and Wildlife Service ownership (NPAM).
69	Symstad	What role does prescribed fire play in managing annual bromes in Northern Great Plains grasslands?
70	Symstad	An adaptive management framework to control invasive annual brome grasses in Northern Great Plains Parks (ABAM).
71	Larson	Sourcing plants for conservation and restoration—Developing a risk assessment framework.
		Biological Threats Program—Invasive Species Line of Work—Risk assessment, decision science, forecasting
72	Symstad	Grazing resources for integrated conservation of bison and native prairie at Badlands National Park, South Dakota.
		Biological Threats Program—Fish and Wildlife Disease Line of Work—Ecology and impacts
73	Sargeant	Effects of population density on prevalence of chronic wasting disease, physical condition, and vital rates of elk at Wind Cave National Park, South Dakota.

Study Narratives

Species Biology

1. Provide Support to the U.S. Fish and Wildlife Service and Prairie Pothole Joint Venture for Monitoring and Management of Migratory Bird Populations

Sound management of migratory-bird breeding populations in the Prairie Pothole Region hinges on effective monitoring programs and comprehensive analyses of long-term survey data. To this end, the NPWRC provides support to the U.S. Fish and Wildlife Service (FWS) in several important areas. The Four-Square-Mile Breeding Duck and Habitat Survey was developed by the NPWRC in the mid-1980s and has been completed annually by FWS refuge personnel under leadership by their Habitat and Population Evaluation Team (HAPET) since the late 1980s. A concurrent effort to assemble and archive information on duck nest survival from studies completed by the NPWRC and dozens of partners has resulted in a database of more than 158,000 nest records spanning 66 years, 11 States, and 3 Provinces. The NPWRC, in cooperation with HAPET, periodically analyzes these two long-term datasets to improve understanding of duck settling ecology and to update estimates of duck nest survival. These and other analyses fuel decision support tools used by Prairie Pothole Joint Venture (PPJV) partners to prioritize and target conservation efforts.



Spatial distribution and count of nest records (1954–2020) that have been compiled and archived in the nest record file maintained at the Northern Prairie Wildlife Research Center.

Contact: Mike Anteau, manteau@usgs.gov

Collaborators: FWS, HAPET, National Wildlife Refuge System; PPJV

Timeline: Ongoing

2. An Evaluation of Waterfowl Breeding Ecology in the Context of Their Predator Community in Eastern South Dakota

Population growth in upland-nesting ducks is highly affected by spatial and temporal variation in nest survival, and mammalian predators are the major cause of nest failure. Beginning in spring 2018, a graduate student from South Dakota State University, coadvised by a NPWRC scientist, has been studying predator communities and their movements in landscapes with varying grassland patch composition, while concurrently investigating nest-site selection and survival of upland duck nests. We anticipate that findings from this study will increase understanding of how grassland patches and vegetation composition, diversity, and structural heterogeneity affect predator habitat use and movements and survival of upland duck nests. We will use results to evaluate comprehensive management strategies for remnant grasslands, restoration efforts, and management programs that aim to modify grassland regimes to improve nesting habitat.

Contact: Aaron T. Pearse, apearse@usgs.gov

Collaborators: USGS South Dakota Cooperative Fish and Wildlife Research Unit (lead agency); South Dakota State University; South Dakota Department of Game, Fish, and Parks

Timeline: Fiscal years 2018–22

Products:

Fino, S., Stafford, J.D., Pearse, A.T., and Jenks, J.A., 2019, Incidental captures of plains spotted skunks in central South Dakota: Prairie Naturalist, v. 51, p. 33–36.

3. Demographic Analysis of Waterfowl Populations

The NPWRC has a history of broad-scale demographic analyses on available waterfowl. Our current efforts are collaborative with a variety of partners. Current studies include (1) analysis of midcontinent waterfowl harvest information to identify predictable drivers of recruitment and (2) evaluation of the North American survey for sources of changing bias in survey methods. The NPWRC recognizes the cultural and socioeconomic importance of waterfowl in North America, and each of these analyses are completed to inform pressing conservation decisions that are made by partners.

Contact: Michael J. Anteau, manteau@usgs.gov

Collaborators: FWS, HAPET and Division of Migratory Bird Management; North Dakota Game and Fish Department; Duke University

Timeline: Fiscal years 2016–Ongoing

The annual economic footprint of waterfowl hunting is more than $3 billion. Photograph by Glen Sargeant, U.S. Geological Survey.

4. Reconciling Competing Models of Temporospatial Variation in Duck Nest Survival

Conservation planning and management activities for upland-nesting ducks during the breeding season are based on decades of research. The results from the research have been distilled into various principles used to direct activities. The principle that abundant perennial-grassland cover increases nest survival has been brought into question by research proposing that nest survival is influenced by spatiotemporal variation in gross primary productivity. These conflicting models have expansive implications to allocation of conservation resources. To resolve uncertainty of which model best reflects current conditions in nest survival across the PPJV, we are comparing two competing models of nest survival by using nest-fate data from other independent studies. Determining which model, or in which context each model, has the best performance will give managers an updated and expanded understanding of where to promote conservation actions and which actions would best meet long-standing objectives.

Contact: Aaron T. Pearse, apearse@usgs.gov

Collaborators: PPJV, FWS

Timeline: Fiscal years 2019–21

A blue-winged teal nest in grassland in the Sand Lake Wetland Management District. Photograph by Tom Koerner, U.S. Fish and Wildlife Service.

5. Developing Techniques to Census and Monitor American White Pelicans and Other Colonial Waterbirds at Chase Lake National Wildlife Refuge in North Dakota

Monitoring is essential to detect colonial waterbirds and to provide insights about changes in waterbird distribution and abundance. For colonial waterbirds, major population fluctuations often go undetected because surveys are not completed regularly, inventory methods are inconsistent, or estimates have unknown reliability. The waterbird colony at Chase Lake National Wildlife Refuge in North Dakota is one of the largest nesting colonies in the region. Abundance and species diversity of birds nesting at this refuge have generally increased but annually fluctuate. The NPWRC is assessing methods to estimate breeding populations of ground- and shrub-nesting waterbirds at Chase Lake. The goal is to identify reliable methods for estimating abundance of different waterbird species and to provide protocols for monitoring colonial species at Chase Lake National Wildlife Refuge. The results from this study will increase our knowledge of waterbird abundance at this refuge and provide techniques for long-term monitoring of colonial waterbirds. The methods also will be applicable to other island-nesting waterbird colonies with similar attributes in the region and elsewhere.

Great egret at a multispecies waterbird nesting colony at Chase Lake National Wildlife Refuge. Photograph by Alisa Bartos, U.S. Fish and Wildlife Service.

Contact: Lawrence D. Igl, ligl@usgs.gov

Collaborators: FWS, Chase Lake Wetland Management District, Chase Lake National Wildlife Refuge, Arrowwood National Wildlife Refuge Complex

Timeline: Fiscal years 2011–21

Products:

Igl, L.D., Bartos, A.J., Woodward, R.O., Scherr, P., and Sovada, M.A., 2020, Evaluation of survey methods for colonial waterbirds at Chase Lake National Wildlife Refuge, North Dakota: U.S. Geological Survey Open-File Report 2020–1008, 44 p. [Also available at https://doi.org/10.3133/ofr20201008.]

6. Breeding Bird Use of Grasslands Enrolled in the Conservation Reserve Program in the Northern Great Plains

Agriculture is the dominant land use on privately owned lands in the Northern Great Plains of the United States. Management decisions on agricultural lands are heavily affected by a variety of policies and programs established by the Federal Government in periodic Farm Bills. In 1985, Congress passed the Food Security Act. Title XII of the Act established the Conservation Reserve Program (CRP), a voluntary, long-term, cropland retirement program that is available to agricultural producers to help safeguard environmentally sensitive land. From 1990 to 2017, the NPWRC evaluated breeding-bird use of several hundred grasslands enrolled in the CRP in four States (North Dakota, South Dakota, Minnesota, and Montana) in the Northern Great Plains, in collaboration with the U.S. Department of Agriculture (USDA). This study is the longest evaluation of CRP grasslands for their contribution to breeding birds. Results from this study have been used by stakeholders to generate support for renewal of the CRP in subsequent Farm Bills and to make the Prairie Pothole Region a high-priority area for CRP in the United States. The results from this study also have served to inform private landowners, managers, and policy makers on program improvements for

Biological science technician surveying breeding birds on idle and hayed portions of a Conservation Reserve Program grassland in Sheridan County, Montana. Photograph by Lawrence D. Igl, U.S. Geological Survey.

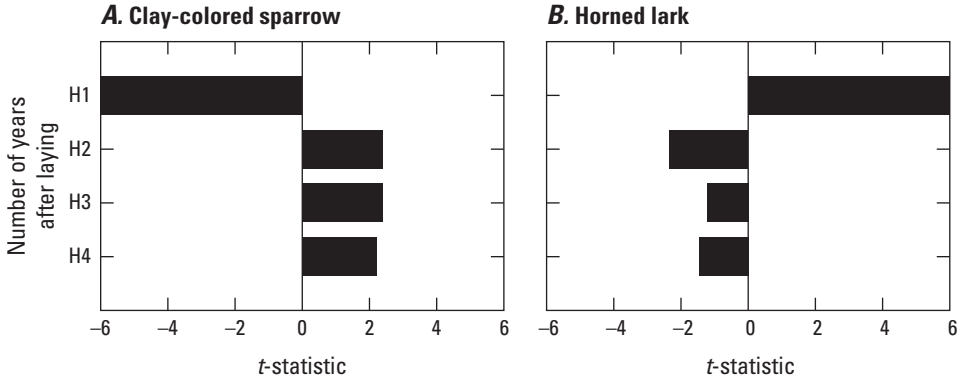
grassland birds related to CRP management (for example, haying and grazing), grassland patch size, and seeding mixtures (native compared to exotic).

Contact: Lawrence D. Igl, ligl@usgs.gov

Collaborators: Private landowners; USDA, Farm Service Agency and Natural Resources Conservation Service; FWS

Timeline: Fiscal years 1990–Ongoing

Products:



The strength and direction of a bird species' response to emergency or managed haying in Conservation Reserve Program grasslands varies. The *t*-statistics or *t*-values show comparisons between idle and 1, 2, 3, and 4 years after haying (modified from Igl and Johnson, 2016).

Elliott, L.H., Igl, L.D., Johnson, D.H., 2020, The relative importance of wetland area versus habitat heterogeneity for promoting species richness and abundance of wetland birds in the Prairie Pothole Region, USA: The Condor, v. 122, no. 1, 21 p. [Also available at https://doi.org/10.1093/condor/duz060.]

7. Response of Grassland Birds to Habitat Characteristics, Oil Wells, and Roads in Managed Grasslands in the Little Missouri National Grassland in North Dakota

Little Missouri National Grasslands in western North Dakota (inset: livestock and Baird's sparrow). Photographs by Brian Chepulis, U.S. Geological Survey (grassland and livestock) and David O. Lambeth (Baird's sparrow).

In collaboration with the U.S. Forest Service and North Dakota State University, the NPWRC is evaluating the effects of landscape-level (for example, oil development and roads) and site-specific (for example, vegetation structure and composition) factors on populations of Sprague's pipits, Baird's sparrows, and other declining grassland birds in the Little Missouri National Grassland in western North Dakota. The Sprague's pipit and Baird's sparrow are listed as sensitive species in the Northern Region of the U.S. Forest Service, meaning these species need special management to maintain and improve their status on National Forests and Grasslands and to prevent a need for listing under the Endangered Species Act. These species are thought to require large patches of native grass cover throughout their life cycles. Large-scale losses and degradation of critical grassland habitat highlight the importance of appropriate management and conservation measures for remaining native grasslands. The results from this study will contribute to understanding grassland songbird responses to local and landscape factors and identify specific mechanisms by which conservation measures for declining grassland bird populations can be improved.

Contact: Lawrence D. Igl, ligl@usgs.gov

Collaborators: U.S. Forest Service; North Dakota State University

Timeline: Ongoing

8. The Effects of Management on Grassland Birds—Literature Reviews

The ongoing decline of North American grassland bird populations has highlighted the need to better understand the habitat requirements of grassland birds and how management practices affect them. The demand for this information led to the writing of a compendium on "The Effects of Management Practices on Grassland Birds," in which more than 6,000 publications were consulted and several thousand publications were synthesized. The compendium consists of an introductory chapter, 40 species accounts, a chapter summarizing rates of cowbird parasitism for each species, and a concluding chapter. The species represent a taxonomically diverse group that includes grouse, shorebirds, owls, diurnal raptors, and songbirds. The species accounts include information on species' range, breeding habitat, area requirements, landscape associations, breeding-season phenology, brood parasitism, responses to habitat management, and management recommendations from the literature.

Adult male bobolink in a grazed grassland. Photographs by Lawrence D. Igl, U.S. Geological Survey.

Contact: Lawrence D. Igl, ligl@usgs.gov; Jill A. Shaffer, jshaffer@usgs.gov

Collaborators: PPJV; FWS, Migratory Bird Program, Denver, Colo.; U.S. Forest Service, Dakota Prairie Grasslands, Bismarck, N. Dak.; The Nature Conservancy; Plains and Prairie Potholes Landscape Conservation Cooperative

Timeline: Fiscal years 1996–2022

Products:

Johnson, D.H., Igl, L.D., Shaffer, J.A., and DeLong, J.P., eds., 2019, The effects of management practices on grassland birds: U.S. Geological Survey Professional Paper 1842, [variously paged]. [Also available at https://doi.org/10.3133/pp1842.]

Shaffer, J.A., and DeLong, J.P., 2019, The effects of management practices on grassland birds—An introduction to North American grasslands and the practices used to manage grasslands and grassland birds, chap. A *of* Johnson, D.H., Igl, L.D., Shaffer, J.A., and DeLong, J.P., eds., The effects of management practices on grassland birds: U.S. Geological Survey Professional Paper 1842, 63 p. [Also available at https://doi.org/10.3133/pp1842A.]

Male lark bunting. Drawing by Christopher Goldade, U.S. Geological Survey.

The following is a list of species accounts that have been published as chapters of Johnson and others (2019); full citations are provided in the "References" section at the back of this report.

American Bittern (*Botaurus lentiginosus*); Shaffer and others (2019a), https://doi.org/10.3133/pp1842K.
Baird's Sparrow (*Centronyx bairdii*); Shaffer and others (2020a), https://doi.org/10.3133/pp1842HH.
Brewer's Sparrow (*Spizella breweri breweri*); Walker and others (2020), https://doi.org/10.3133/pp1842AA.
Brown-headed Cowbird (*Molothrus ater*) nest parasitism rates; Shaffer and others (2019b), https://doi.org/10.3133/pp1842PP.
Chestnut-collared Longspur (*Calcarius ornatus*);Shaffer and others (2020b), https://doi.org/10.3133/pp1842X.

Eastern Meadowlark (*Sturnella magna*);Hull and others (2019), https://doi.org/10.3133/pp1842MM.
Ferruginous Hawk (*Buteo regalis*); Shaffer and others (2019c), https://doi.org/10.3133/pp1842N.
Greater Sage-Grouse (*Centrocercus urophasianus* Rowland (2019), https://doi.org/10.3133/pp1842B.
Horned Lark (*Eremophila alpestris*); Dinkins and others (2019), https://doi.org/10.3133/pp1842U.
Henslow's Sparrow (*Centronyx henslowii*); Herkert (2019), https://doi.org/10.3133/pp1842II.
Lark Bunting (Calamospiza *melanocorys*); Shaffer and others (2020c), https://doi.org/10.3133/pp1842EE.
LeConte's Sparrow (*Ammospiza leconteii*); Shaffer and others (2020d), https://doi.org/10.3133/pp1842JJ.
Lesser Prairie-Chicken (*Tympanuchus pallidicinctus*); Jamison and others (2020), https://doi.org/10.3133/pp1842D.
Long-billed Curlew (*Numenius americanus*); Shaffer and others (2019d), https://doi.org/10.3133/pp1842G.
Marbled Godwit (*Limosa fedoa*), Shaffer and others (2019e), https://doi.org/10.3133/pp1842H.
McCown's Longspur (*Rhynchophanes mccownii*); Shaffer and others (2019f), https://doi.org/10.3133/pp1842Y.
Merlin (*Falco columbarius*); Konrad and others (2020), https://doi.org/10.3133/pp1842R.
Mountain Plover (*Charadrius montanus*); Shaffer and others (2019g), https://doi.org/10.3133/pp1842E.
Nelson's Sparrow (*Ammospiza nelsoni nelsoni*); Shaffer and others (2020e), https://doi.org/10.3133/pp1842KK.
Northern Harrier (*Circus hudsonius*); Shaffer and others (2019h), https://doi.org/10.3133/pp1842L.
Prairie Falcon (*Falco mexicanus*); DeLong and Steenhof (2020), https://doi.org/10.3133/pp1842S.
Savannah Sparrow (*Passerculus sandwichensis*); Swanson and others (2020), https://doi.org/10.3133/pp1842FF.
Sedge Wren (*Cistothorus platensis*); Shaffer and others (2020f), https://doi.org/10.3133/pp1842V.
Sprague's Pipit (*Anthus spragueii*); Shaffer and others (2020g), https://doi.org/10.3133/pp1842W.
Swainson's Hawk (*Buteo swainsoni*); Shaffer and others (2019i), https://doi.org/10.3133/pp1842M.
Upland Sandpiper (*Bartramia longicauda*); Shaffer and others (2019j), https://doi.org/10.3133/pp1842F.
Willet (*Tringa semipalmata inornata*); Shaffer and others (2019k), https://doi.org/10.3133/pp1842I.
Wilson's Phalarope (*Phalaropus tricolor*); Shaffer and others (2019l), https://doi.org/10.3133/pp1842J.

9. Immune Components in Eggs of New World Blackbirds

Interest in the immune systems of wild birds has increased as public health authorities have recognized that many emerging infectious diseases of wildlife can be transmitted to humans (that is, zoonoses). Eco-immunology is an emerging field that characterizes how immune adaptations of wild species vary as a result of evolution in different habitats and niches. Present understanding of the effect of specific life-history traits and habitat on wild bird immune investment is rudimentary, and few studies have compared multiple immunological parameters of related wild bird species. A NPWRC scientist is a collaborator on this study and compares passive immune components of six songbird species in a single taxonomic family, New World blackbirds (Icteridae), including two obligate brood parasites. Information from this research will be used to evaluate how the observed differences in immune components in eggs of different species may be related to divergence in life-history traits and ecological niches. This comparative approach contrasts variation in immunity components of several closely related species and will provide a baseline for the degree of between-species variability. Results from this study also will provide information that will help answer broader questions related to the effectiveness of the immune system in resisting infection in species of conservation concern and closely related nonthreatened taxa.

Candling a red-winged blackbird egg to determine incubation stage (inset: parasitized red-winged blackbird nest). Photograph by Lawrence D. Igl, U.S. Geological Survey.

Contact: Lawrence D. Igl, ligl@usgs.gov

Collaborators: USGS, Patuxent Wildlife Research Center; Creighton University; Departamento de Recursos Naturales y Ambientales de Puerto Rico

Timeline: Fiscal years 2009–20

Products:

Fassbinder-Orth, C.A., Igl, L.D., Hahn, D.C., Watts, K.M., Wilcoxen, T.E., and Ramos-Álvarez, K.R., 2019, Do life history traits influence patterns of maternal immune elements in New World blackbirds (Icteridae)?: Integrative Organismal Biology, v. 1, no. 1, 12 p. [Also available at https://doi.org/10.1093/iob/oby011.]

Yellow-headed blackbird in semipermanent wetland. Photograph by Lawrence D. Igl, U.S. Geological Survey.

10. Ecology and Management of Midcontinent Sandhill Cranes

Midcontinent sandhill cranes occupy a large geographic area of central and western North America and northeastern Asia during breeding, winter, and migration. Sandhill cranes are a species with a unique convergence of user groups that have a unified interest in the continued health of this population. Tens of thousands of people view cranes during spring staging at the Platte River Valley in Nebraska, and hunters pursue and harvest cranes annually in most of their fall and winter range. The overall goal of this project is to provide information that will improve crane management. This research includes the following multiple objectives: (1) determination of geographic distribution, migration chronology, and spring-staging ecology in the Platte River Valley; (2) evaluation of survey methods; (3) estimation of survival and recruitment; and (4) modeling of population dynamics. Work completed will provide better information regarding harvest management strategies, opportunities for increased international conservation collaboration, conservation of crane habitats at multiple spring stopover sites, and insight into long-term monitoring of habitats and cranes.

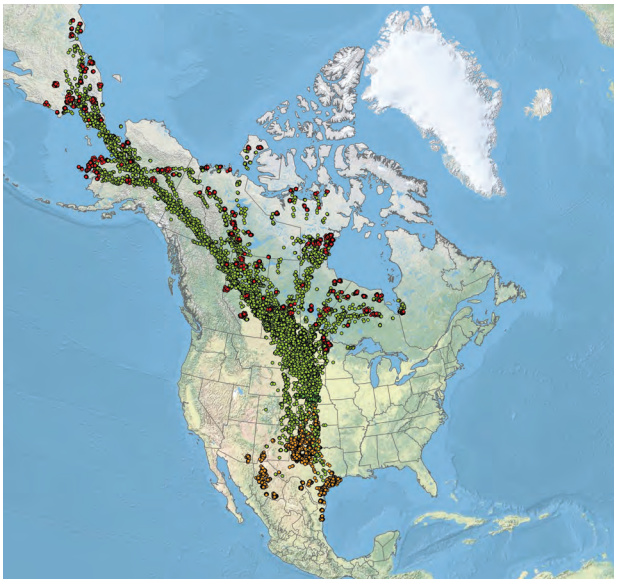
Contact: Aaron T. Pearse, apearse@usgs.gov

Collaborators: FWS, Ecological Services Nebraska Field Office, Rainwater Basin Joint Venture (RWBJV); State and Provincial game and fish agencies of Colorado, Texas, Oklahoma, Kansas, Nebraska, South Dakota, North Dakota, Wyoming, Montana, New Mexico, Saskatchewan, and Alberta; International Crane Foundation; The Crane Trust; Playa Lakes Joint Venture; Russian Academy of Science–Sakha Division; Central Flyway Council; Texas Tech University; Texas A&M University

Timeline: Fiscal years 2010–Ongoing

Products:

Caven, A.J., Brinley Buckley, E.M., King, K.C., Wiese, J.D., Baasch, D.M., Wright, G.D., Harner, M.J., Pearse, A.T., Rabbe, M., Varner, D.M., Krohn, B., Aricilla, M., Schroeder, K.D., and Dinan, K.F., 2019, Temporospatial shifts in sandhill crane staging in the Central Platte River Valley in response to climactic variation and habitat change: Monographs of the Western North American Naturalist, v. 11, no. 4, p. 33–76. [Also available at https://scholarsarchive.byu.edu/mwnan/vol11/iss1/4.]



Geographic distribution of midcontinent sandhill cranes as determined by satellite telemetry from cranes marked at the Platte River, Nebraska, United States. This project identified breeding areas (red circles), migration (green circles), and wintering locations (orange circles) that occurred over a broad area within North America and portions of Asia.

Pearse, A.T., Sargeant, G.A., Krapu, G.L., and Brandt, D.A., 2020, Population and harvest dynamics of midcontinent sandhill cranes: The Journal of Wildlife Management, v. 84, no. 5, p. 902–910. [Also available at https://doi.org/10.1002/jwmg.21865.]

Varner, D.M., Pearse, A.T., Bishop, A.A., Davis, J., Denton, J., Grosse, R., Johnson, H., Munter, E., Schroeder, K.D., Spangler, R., Vrtiska, M., and Wright, A., 2020, Roosting habitat use by sandhill cranes and waterfowl on the North and South Platte Rivers in Nebraska: Journal of Fish and Wildlife Management, v. 11, no. 1, p. 56–67. [Also available at https://doi.org/10.3996/042019-JFWM-030.]

VonBank, J.A., Brandt, D.A., Pearse, A.T., Wester, D.B., and Ballard, B.M., 2019, Using morphological measurements to predict subspecies of midcontinent sandhill cranes: Wildlife Society Bulletin v. 43, no. 4, p. 737–744. [Also available at https://doi.org/10.1002/wsb.1020.]

11. Development of Survey Methods for Spring-Migrating Waterfowl in the Rainwater Basin

The Rainwater Basin of Central Nebraska is a midlatitude focal point of spring migration for many species of birds in the Great Plains. The RWBJV and partners desire geospatial models to identify characteristics of wetland complexes and understand local and landscape-level factors that affect habitat selection of migrating waterfowl. To support this effort, NPWRC scientists developed a monitoring strategy that incorporates the complexities of large spatial and temporal variation in ponded water during spring survey periods. Our strategy relies on the more than 10 years of surface-water data that the RWBJV has collected during spring. Development of these types of models and conservation planning tools requires long-term study; thus, the sampling strategy, which was initiated in 2017, will be completed annually for the next 10 years to collect data needed to develop models and describe habitat relationships.

Wetlands within the Rainwater Basin in south central Nebraska are randomly selected and visited multiple times each spring to count numbers of ducks and geese. Wetland and landscape characteristics corresponding to these counts will form basis of future conservation planning tools.

Contact: Aaron T. Pearse, apearse@usgs.gov

Collaborators: RWBJV; Nebraska Game and Parks Commission; Ducks Unlimited, Inc.

Timeline: Fiscal years 2017–Ongoing

12. Investigating Roadside Bias in Point-Count Surveys of Grassland Passerines

The North American Breeding Bird Survey provides essential information for assessing bird populations, but how inherent assumptions of the Breeding Bird Survey apply to grassland birds in the Northern Great Plains is unknown. Understanding the effects of these assumptions on our understanding of grassland bird populations is essential given widespread declines of grassland birds as well as recent and impending petitions to list some species under the Endangered Species Act. The NPWRC is assessing how occurrence and detection of grassland birds are affected by roadside sampling, seasonal timing of surveys, and fine-grained habitat features such as fences and utility lines that are often associated with roads. Our study also will allow better interpretation of Breeding Bird Survey results, improve understanding of population trends, and inform future population monitoring in the Northern Great Plains. Ultimately, we expect this information will improve inferences made from spatial models

used to guide grassland bird conservation and increase confidence in population data used for listing decisions.

Contact: Thomas K. Buhl, tbuhl@usgs.gov and Terry L. Shaffer, tshaffer@usgs.gov

Collaborators: FWS, HAPET, National Wildlife Refuge System, Inventory and Monitoring Program

Timeline: Fiscal years 2015–19

A Northern Prairie Wildlife Research Center seasonal technician conducting a bird survey at a road site following Breeding Bird Survey procedures. Comparable off-road sites were 200–1,500 meters from any road (U.S. Geological Survey photograph).

13. Postfledging Movement and Habitat Selection by Mallards in the Fall and Their Effect on Spring Recruitment

Although most aspects of the annual cycle of North American mallards have received considerable scientific research, the period between when juveniles are capable of flight to their first southward migration remains an understudied period for all waterfowl species. This period can have implications to population recruitment and availability of birds to hunters. Beginning in 2018, a graduate student from South Dakota State University, coadvised by a NPWRC scientist, quantified movements during the postfledge period of juvenal mallards hatched in North and South Dakota. Using internally implanted transmitters that collect Global Positioning System (GPS) coordinates, we are investigating potential causes for movements of postfledging mallards, including the role of key landscape parameters in influencing habitat selection and space use. A research goal is to draw inferences of observed postbreeding movements and habitat use with respect to waterfowl hunters to assist State game agencies for conservation planning and management.

Contact: Aaron T. Pearse, apearse@usgs.gov

Collaborators: USGS South Dakota Cooperative Fish and Wildlife Research Unit (lead agency); North Dakota Game and Fish Department; South Dakota Department of Game, Fish, and Parks; South Dakota State University

Timeline: Fiscal years 2018–21

South Dakota State University graduate student, Cynthia Anchor, inspects a captured flightless mallard before implantation of transmitter. Photograph by Aaron Pearse, U.S. Geological Survey.

14. Identifying Population Limiting Factors of Hudsonian Godwits

Migratory species are among the most threatened on the planet and are predicted to be especially sensitive to rapid environmental change. Because of the immense scale of the movements by many migrants and the difficulty in tracking individual organisms across these large spatial scales, analyses are needed throughout the annual cycle to identify population limiting factors. This project will provide detailed answers that are relevant to our model species, the Hudsonian Godwit (*Limosa haemastica*), and to migratory species more generally. The Hudsonian Godwit is among the most impressive migratory shorebirds, traveling nearly the length of North and South America. Current research topics include (1) how choices throughout the annual cycle affect survival, condition, and performance; (2) how density-dependent heterospecific interactions and phenological mismatches affect populations; and (3) climate impacts on the network of migratory stopover sites. This study will inform conservation decisions that are made by partners throughout the annual cycle and identify conservation priorities related to changes in climate conditions, habitat quality, and species interactions.

Contact: Rose Swift, rswift@usgs.gov

Collaborators: University of South Carolina; USGS Alaska Science Center; FWS Migratory Bird Division; Cornell Lab of Ornithology

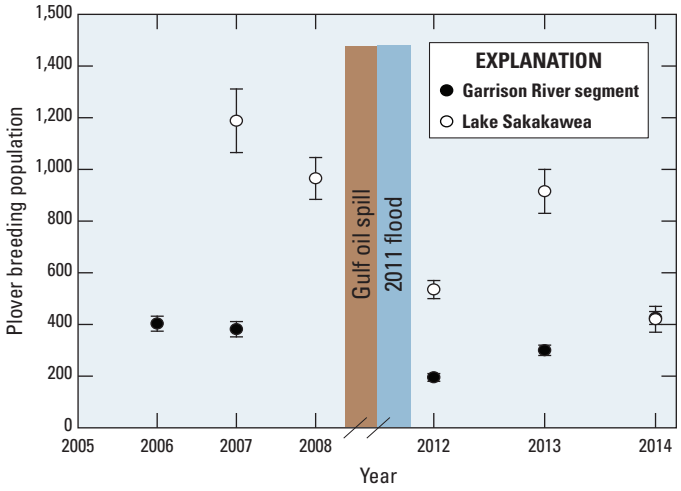
Timeline: Fiscal years 2019–23

Products:

Swift, R.J., Rodewald, A.D., Johnson, J.A., Andres, B.A., and Senner, N.R., 2020, Seasonal survival and reversible state effects in a long-distance migratory shorebird: Journal of Animal Ecology, v. 89, no. 9, p. 2043–2055. [Also available at https://doi.org/10.1111/1365-2656.13246.]

15. Demographic Response of Least Terns and Piping Plovers to the 2011 Missouri River Flood

The largest recorded flood event on the Missouri River occurred during 2011. In 2014, NPWRC concluded a study that evaluated effects of the 2011 flood on least tern and piping plover breeding populations. These federally listed species nest on riverine sandbars and reservoir shorelines. Since construction of the dams on the Missouri River, there have been few floods of a magnitude great enough to create sandbar habitat for these species. We collected breeding productivity data of least terns and piping plovers during 2012–14. We compared estimates of breeding population, nest success, and chick survival at the Garrison River segment and Lake Sakakawea to estimates from data we collected in the same area during 2006–08. These comparisons provided the U.S. Army Corps of Engineers (USACE) with information about how quickly newly created habitat is used and about how long quality habitat persists.



Plot of the piping plover breeding population estimates for the Garrison River segment and Lake Sakakawea before and after the 2011 Missouri River flood (Anteau and others, 2019).

Contact: Michael J. Anteau, manteau@usgs.gov

Collaborators: USACE, Omaha District, Threatened and Endangered Species Section; FWS, North Dakota Ecological Services Field Office

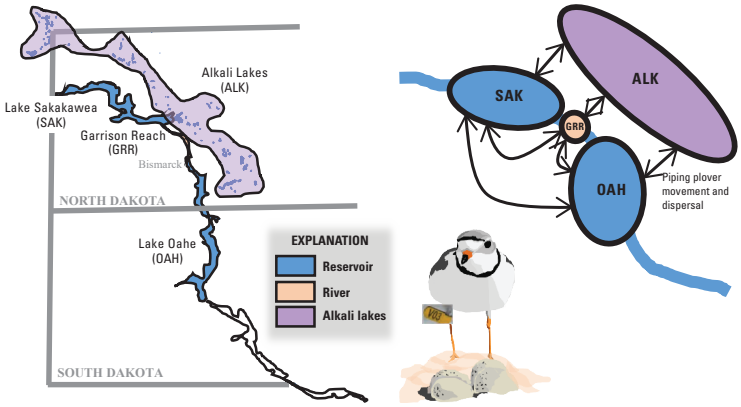
Timeline: Fiscal years 2012–19

Products:

Anteau, M.J., Sherfy, M.H., Shaffer, T.L., Swift, R.J., Toy, D.L., and Dovichin, C.D., 2019, Demographic responses of least terns and piping plovers to the 2011 Missouri River flood—A large-scale case study: U.S. Geological Survey Open-File Report 2018–1176, 33 p. [Also available at https://doi.org/10.3133/ofr20181176.]

Swift, R.J., Anteau, M.J., Roche, E.A., Sherfy, M.H., Toy, D.L., and Ring, M.M., 2020, Asymmetric benefits of a heterospecific breeding association vary with habitat, conspecific abundance and breeding stage: Oikos, v. 129, no. 10, p. 1504–1520. [Also available at https://doi.org/10.1111/oik.07256.]

16. Metapopulation Dynamics of Piping Plovers in the Northern Great Plains



Study areas within the Northern Great Plains (left) and a graphic representation of movements and dispersal between the project-defined study areas (right).

The NPWRC is leading a multiagency regional study to understand metapopulation dynamics of piping plovers in the Northern Great Plains. Piping plovers are a federally listed species that nests on riverine sandbars and shorelines of wetlands and reservoirs. These habitats are dynamic in response to climate and water-management regimes of the Missouri River. The USACE manages the Missouri River for hydropower, recreation, water supply, navigation, flood control, and fish and wildlife. That management strategy puts piping plovers in jeopardy. Accordingly, the USACE has prepared to spend more than 10 million U.S. dollars a year for the foreseeable future to create breeding habitat for plovers on the Missouri River. Additionally, the other key areas where plovers breed, wetlands in the Prairie Pothole Region, are under threat from changing climate and land-use practices. During 2020, NPWRC completed the final year of an 8-year study that involves marking adults and chicks with alphanumeric color bands and resighting them at breeding areas throughout the Northern Great Plains. This study will provide population demographic and dispersal information that will inform decisions about management, conservation, and recovery of this species, as well as informing management of the Missouri River.

Contact: Michael J. Anteau, manteau@usgs.gov

Collaborators: USACE, Omaha District, Threatened and Endangered Species Section; Missouri River Recovery Implementation Committee; FWS, North Dakota Ecological Services Field Office and Region 6 Refuge System; The Nature Conservancy

Timeline: Fiscal years 2014–20

Products:

Swift, R.J., Anteau, M.J., Ellis, K.S., Ring, M.M., Sherfy, M.H., Toy, D.L., and Koons, D.N., 2021, Spatial variation in population dynamics of northern great plains piping plovers: U.S. Geological Survey Open-File Report 2020–1152, 211 p. [Also available at https://doi.org/10.3133/ofr20201152.]

Swift, R.J., Anteau, M.J., Ring, M.M., Toy, D.L., and Sherfy, M.H., 2020, Low renesting propensity and reproductive success make renesting unproductive for the threatened Piping Plover (*Charadrius melodus*): The Condor, v. 122, no. 2, 18 p. [Also available at https://doi.org/10.1093/condor/duz066.]

Swift, R.J., Anteau, M.J., Roche, E.A., Sherfy, M.H., Toy, D.L., and Ring, M.M., 2020, Asymmetric benefits of a heterospecific breeding association vary with habitat, conspecific abundance and breeding stage: Oikos, v. 129, no. 10, p. 1504–1520. [Also available at https://doi.org/10.1111/oik.07256.]

17. Breeding Ecology and Demographics of Least Terns and Piping Plovers at the Central Platte River, Nebraska

U.S. Geological Survey field crew members nest searching for piping plover and least tern nests on a sandpit near the Central Platte River (U.S. Geological Survey photograph).

The Platte River Recovery Implementation Program (PRRIP) partnered with the NPWRC to study demographics of least terns and piping plovers at the Central Platte River in Nebraska. Because of water management and other alterations, riverine habitat for least terns and piping plovers has become degraded. Least terns and piping plovers, however, have begun breeding on sandpits that are immediately adjacent to the river. The NPWRC marked adults and chicks and resighted them to provide additional data for the PRRIP's monitoring practices. The NPWRC also analyzed data to provide information on dispersal, fidelity, and use of newly constructed or managed habitats that will be useful to make decisions to aid in the conservation and recovery of these species. In addition, results from the banding efforts along the Central Platte River have contributed to information for the NPWRC metapopulation study of piping plovers of the Northern Great Plains.

Contact: Michael J. Anteau, manteau@usgs.gov

Collaborators: PRRIP; Nebraska Public Power District; Nebraska Game and Parks Commission; Central Platte Natural Resources District; Crane Trust

Timeline: Fiscal years 2010–21

18. Population Demographics of Least Terns and Piping Plovers in Colorado

Least tern and piping plover monitoring staff and U.S. Army Corps of Engineers staff observe piping plover nest on John Martin Reservoir. Photograph by Dustin Toy, U.S. Geological Survey.

The NPWRC is helping to improve the monitoring of federally listed least terns and piping plovers by the USACE at John Martin Reservoir in southeastern Colorado. The NPWRC is providing information to the USACE to improve their habitat management and productivity monitoring. The NPWRC also is providing the capability to mark adults and chicks with alphanumeric color bands during a 5-year period that began in 2017. The USACE's monitoring program will benefit from having the population of least terns and piping plovers that use this area uniquely marked because the information will help to estimate recruitment and fidelity to breeding areas. The monitoring of marked birds at John Martin Reservoir as well as marked birds in other areas will answer broader questions about how isolated these populations are from other breeding areas. In addition, these banding efforts will contribute information for the NPWRC metapopulation study of piping plovers of the Northern Great Plains.

Contact: Michael J. Anteau, manteau@usgs.gov

Collaborators: USACE, Albuquerque District; Colorado Parks and Wildlife

Timeline: Fiscal years 2016–21

19. Improving Monitoring Techniques for Nests of Interior Least Terns and Piping Plovers

Nocturnal image of a great-horned owl depredating a least tern nest on the Missouri River. Photograph by Alicia Andes, University of North Dakota.

Federally listed least terns and piping plovers are the subject of numerous large-scale population monitoring efforts that are used to assess needs and outcomes of management actions. Population monitoring requires periodic researcher visits to nesting areas to count and assess breeding status of the birds. At higher visit frequencies, detection of nests and chicks improves as does ability to determine outcomes of nesting attempts, resulting in more complete and accurate information about productivity. However, frequent visits may affect productivity of the birds by altering nest attendance or behavioral patterns. A University of North Dakota graduate student, coadvised by a NPWRC scientist, used concealed miniature video cameras to (1) observe responses of nesting Missouri River least terns and piping plovers to human activities typically associated with population monitoring (that is, nest visits, adult trapping, and chick banding), (2) evaluate accuracy of nest fate (success compared to failure) determined by field evidence obtained at various visitation frequencies, and (3) describe composition of the nest predator community on the Missouri River. Results from this study will aid management agencies in designing accurate population monitoring programs that minimize effects on the birds, thereby improving quality of monitoring datasets and contributing to species recovery.

Contact: Mark H. Sherfy, msherfy@usgs.gov

Collaborators: FWS, North Dakota Ecological Services Field Office; USACE, Omaha District, Threatened and Endangered Species Section; University of North Dakota

Timeline: Fiscal years 2015–21

Products:

Andes, A.K., Shaffer, T.L., Sherfy, M.H., Hofer, C.M., Dovichin, C.M., and Ellis-Felege, S.N., 2019, Accuracy of nest fate classification and predator identification from evidence and nests of least terns and piping plovers: The Ibis, v. 161, no. 2, p. 286–300. [Also available at https://doi.org/10.1111/ibi.12629.]

Andes, A.K., Sherfy, M.H., Shaffer, T.L., and Ellis-Felege, S.N., 2020, Plasticity of least tern and piping plover nesting behaviors in response to sand temperature: Journal of Thermal Biology, v. 91, 9 p. [Also available at https://doi.org/10.1016/j.jtherbio.2020.102579.]

20. Identifying Important Habitat, Developing Inexpensive Habitat Monitoring, and Developing Habitat-Based Abundance Estimates for Piping Plovers at Wetland Habitats in the Prairie Pothole Region

The NPWRC is leading a multiagency regional study to understand habitat features used by piping plovers at wetlands across the U.S. Prairie Pothole Region. Piping plovers are a federally listed species that nest throughout the Prairie Pothole Region on shorelines of wetlands. Recent research suggests that climate and land changes are decreasing the amount of available habitat for piping plovers at wetlands of the Prairie Pothole Region. A complete inventory of plover habitat for the wetlands of the Prairie Pothole Region is a component of the species recovery plan; but, the inventory has not been completed. The objectives of this project are to (1) define nesting habitat for piping plovers at prairie wetlands considering fine- and broad-spatial scale habitat features, (2) develop procedures for monitoring piping plover nesting habitat using remote sensing, (3) apply monitoring procedures to existing datasets to produce Prairie Pothole Region habitat maps for 2006–21, (4) evaluate habitat features that influence nesting density and evaluate annual nesting density variability, and (5) examine temporal trends in habitat

abundance during 2006–2021. Ultimately, having a model that can annually predict the abundance and location of plover habitat and the distribution of breeding piping plovers in the Prairie Pothole Region during early summer would (1) allow for predictions of breeding piping plover distribution, (2) improve efficiency of existing demographic monitoring of this population, (3) allow for evaluation of temporal trends in habitat abundance, (4) provide annual habitat abundance estimates that could be used to evaluate progress toward species recovery benchmarks, (5) provide the means to evaluate underlying mechanisms driving plover movement between Missouri River breeding areas and prairie wetland breeding areas, and (6) improve the ability of the FWS to rapidly respond to development requests (for example, oil, gas, or wind-energy development) in areas that may impact breeding plovers.

Alkaline wetland in the Prairie Pothole Region featuring bare shorelines where piping plovers nest (U.S. Geological Survey photograph).

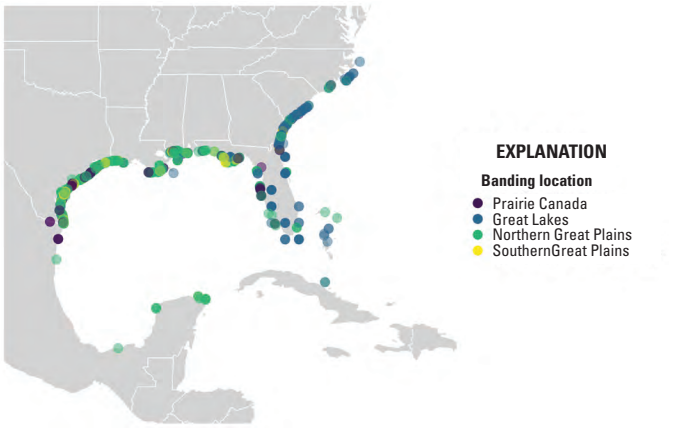
Contact: Michael J. Anteau, manteau@usgs.gov

Collaborators: FWS, North Dakota Ecological Services Field Office and Region 6 Refuge System; The Nature Conservancy

Timeline: Fiscal years 2020–22

21. Impacts of Extreme Disturbances at Wintering Areas on Piping Plover Survival and Migratory Connectivity

The NPWRC initiated a collaborative study to assess the influence of the wintering season on piping plovers that breed across the Great Plains of the United States and Canada and the Great Lakes of the United States. Piping plovers primarily spend the nonbreeding season along the Gulf of Mexico and Atlantic coasts of North America. In these nonbreeding areas, piping plovers can periodically experience extreme environmental disturbances, including oil spills, harmful algal blooms, and hurricanes. Recent evidence has suggested that these environmental disturbances, particularly hurricanes and harmful algal blooms, are increasing in frequency in part because of climate change. The objectives of this project are to (1) evaluate how extreme environmental disturbances impact adult survival, (2) identify potential carry-over effects on survival between seasons, and (3) quantify migratory connectivity for piping plovers breeding within the midcontinent of North America. We analyzed coastal mark-resight data collected by NPWRC, collaborators, and community members on piping plovers from 2002 to 2020. Information gained from this analysis will provide seasonal insights into the population dynamics of piping plovers and lead to better-informed conservation strategies for the species.



Winter season locations of piping plovers on the Atlantic and Gulf of Mexico coasts between 2002 and 2019. Dot colors indicate breeding areas where individuals were first banded.

Contact: Kristen Ellis, kellis@usgs.gov; Michael J. Anteau, manteau@usgs.gov

Collaborators: Environment Canada; University of Minnesota; Nebraska Game and Parks Commission; Colorado State University; Coastal Bend Bays and Estuaries Program; University of Nebraska-Lincoln

Timeline: Fiscal years 2020–21

22. Migration and Winter Ecology of the Aransas-Wood Buffalo Population of Whooping Cranes

A pair of whooping cranes walking along the edge of a wetland in central Kansas. The lead crane was marked with a satellite transmitter that collects multiple Global Positioning System (GPS) locations per day. Photograph by Travis Wooten, U.S. Geological Survey.

The only self-sustaining population of endangered whooping cranes nests within and near Wood Buffalo National Park, Canada; migrates through the Great Plains; and winters primarily along the Texas Gulf Coast. The objectives of this collaborative project are to address the annual life cycle of this species by advancing knowledge of breeding, wintering, and migration ecology, including threats to survival and population persistence. This research will allow researchers to identify potential barriers to species recovery. To complete this work, we have deployed and monitored more than 100 GPS-enabled satellite transmitters during 2010–20. Through coordination of international capture teams and development of innovative trapping techniques, our efforts represent the first time adult whooping cranes have been successfully captured and marked. We also are characterizing stopover sites used by whooping cranes to document surrounding habitat characteristics and land-management practices to better define habitat criteria required by the species at stopover sites like the Platte River. Results from this project will inform recovery and management of whooping cranes into the foreseeable future.

Contact: Aaron T. Pearse, apearse@usgs.gov

Collaborators: FWS, Regions 2 and 6; Canadian Wildlife Service; Crane Trust; PRRIP; International Crane Foundation; Parks Canada

Timeline: Fiscal years 2010–Ongoing

Products:

Baasch, D.M., Farrell, P.D., Howlin, S., Pearse, A.T., Farnsworth, J.M., and Smith, C.B., 2019, Whooping crane use of riverine stopover sites: PLoS One, v. 14, no. 1, 20 p. [Also available at https://doi.org/10.1371/journal.pone.0209612.]

Baasch, D.M., Farrell, P.D., Pearse, A.T., Brandt, D.A., Caven, A.J., Harner, M.J., Wright, G.D., and Metzger, K.L., 2019, Diurnal habitat selection of migrating whooping cranes in the Great Plains: Avian Conservation & Ecology, v. 14, no. 1. [Also available at https://doi.org/10.5751/ACE-01317-140106.]

Metzger, K.L., Lehnen, S.E., Sesnie, S.E., Butler, M.J., Pearse, A.T., and Harris, G., 2020, Identifying sustainable winter habitat for whooping cranes: Journal for Nature Conservation, v. 57, 4 p. [Also available at https://doi.org/10.1016/j.jnc.2020.125892.]

Pearse, A.T., Metzger, K.L., Brandt, D.A., Bidwell, M.T., Harner, M.J., Baasch, D.M., and Harrell, W., 2020, Heterogeneity in migration strategies of whooping cranes: The Condor, v. 122, no. 1, 15 p. [Also available at https://doi.org/10.1093/condor/duz056.]

23. Cumulative Impacts of Energy Development and Other Anthropogenic Stressors for Migrating Whooping Cranes

Whooping cranes encounter many human and natural disturbances during migration, including roads, development, agricultural activities, recreational activities, energy extraction, and predators. However, the level of exposure to potential disturbances and the relative magnitude of their effects, individually and collectively, are unknown. Understanding how disturbances influence whooping crane distribution during migration will provide insights for managers on how to determine potential effects to the population when consulting with developers under the Endangered Species Act.

Contact: Aaron T. Pearse, apearse@usgs.gov

Collaborators: Environment and Climate Change Canada, FWS

Timeline: Fiscal years 2020–22

Whooping cranes foraging in a harvested agricultural field in South Dakota. Photograph by Chris Bailey.

24. Identifying Potential Whooping Crane Migration Habitat for Assessing Risk of Disturbance

Whooping cranes encounter many human and natural disturbances during migration, including roads, development, agricultural activities, recreational activities, energy infrastructure, and predators. However, the level of exposure to potential disturbances and the relative magnitude of their effects, individually and collectively, are unknown. The Nebraska Army National Guard conducts year-round training and operational missions across Nebraska and other States in the whooping crane migration corridor. Of these operations, helicopter flights, primarily those at lower altitudes, constitute potential disturbances to whooping cranes during spring and autumn migrations. We are developing predictive maps representing relative probability of locations used by migrating whooping cranes to allow managers to assess potential exposure to disturbances related to National Guard activities and make more informed management plans.

Contact: Aaron T. Pearse, apearse@usgs.gov

Collaborators: Nebraska Army National Guard, U.S. Army Engineer R&D Center

Timeline: Fiscal years 2020–21

25. Whooping Crane Flight Behavior to Support Aircraft-Bird Collision Risk Assessments at U.S. Air Force Installations

Interactions between whooping cranes and military aircraft constitute risk for the U.S. Air Force and the recovery of whooping cranes, and little is known regarding whooping crane use of areas surrounding U.S. Air Force bases in the Great Plains. The Kegelman airfield is within 6 kilometers of Salt Plains National Wildlife Refuge in northern Oklahoma, and the refuge has been designated as critical habitat for whooping cranes. Twenty-seven percent of marked whooping cranes stopped in this refuge each migration from 2010 to 2016. Information on migration timing, crane flight altitudes, and crane flight pathways can assist the U.S. Air Force in assessing potential risk to aircraft and pilots. The FWS also can use this information in developing appropriate avoidance and minimization measures that would reduce the risk of incidental take of this endangered species and, thus, support the recovery of whooping cranes.

Contact: Aaron T. Pearse, apearse@usgs.gov, 701–253–5509

Collaborators: U.S. Air Force; FWS Texas Ecological Services Field Office, Salt Plains National Wildlife Refuge

Timeline: Fiscal years 2020–23

26. Understanding How Land-Use Change in the Northern Great Plains Affects Pollinator Health and Pollination Services

A researcher conducts a health assessment on a honey bee colony in North Dakota. Photograph by Katie Lee, U.S. Geological Survey.

Societal dependence on insects for pollination of agricultural crops has risen amidst concerns about global pollinator declines. Habitat loss and lack of forage have been implicated in the decline of managed and native pollinators in the United States. The NPWRC is leading a regional research project to understand how land use affects honey bee colony health and economic revenues received by beekeepers during the subsequent pollination season. Specifically, we are investigating how land use affects honey bee colony population size during the growing season (May–September) and if these effects have subsequent effect on colony population size and survival for almond pollination in central California the following February. Our work highlights the "downstream" effects of factors driving land-use decisions on the ability of beekeepers to provide robust honey bee colonies to support the pollination industry on a national scale. The work also demonstrates the direct linkages among grassland habitat in the Northern Great Plains, bee health, and pollination services rendered elsewhere in the United States.

Contact: Clint R.V. Otto, cotto@usgs.gov

Collaborators: USDA, Farm Service Agency and Natural Resources Conservation Service; Bee and Butterfly Habitat Fund; Keystone Institute; Project Apis m.

Timeline: Fiscal years 2015–21

Products:

Simanonok, M.P., Otto, C.R.V., and Smart, M.D., 2020, Do the quality and quantity of honey bee-collected pollen vary across an agricultural land-use gradient?: Environmental Entomology, v. 49, no. 1, p. 189–196. [Also available at https://doi.org/10.1093/ee/nvz139.]

Smart, M.D., Otto, C.R.V., Carlson, B.L., and Roth, C.L., 2018, The influence of spatiotemporally decoupled land use on honey bee colony health and pollination service delivery: Environmental Research Letters, v. 13, no. 8. [Also available at https://iopscience.iop.org/article/10.1088/1748-9326/aad4eb.]

Smart, M.D., Otto, C.R.V., and Lundgren, J.G., 2019, Nutritional status of honey bee (*Apis mellifera* L.) workers across an agricultural land-use gradient: Scientific Reports, v. 9, p. 1–10. [Also available at https://doi.org/10.1038/s41598-019-52485-y.]

27. Improving Forage for Honey Bees and Native Pollinators on Federal Conservation Lands

Honey bee laden with pollen. The Northern Prairie Wildlife Research Center has developed a genetic sequencing strategy to identify bee-collected pollen. Photograph by Sarah Scott, U.S. Geological Survey.

Since its inception in 1933, the U.S. Farm Bill has been one of the most influential Federal policies for agriculture and food production. Provisions within the Farm Bill have profound influence on global trade, nutrition programs, commodity crop programs, rural communities, and land conservation. The NPWRC's research quantifies the effect on pollinator forage and health of USDA conservation programs provisioned through the Farm Bill. The NPWRC is working with USDA partners to evaluate conservation seeding mixes with potential to improve pollinator health in the Great Plains and upper Midwest, if included in programs such as the CRP. To address partner research needs, a novel technique has been developed using genetic sequencing to identify pollen collected from the bodies of foraging bees. The work is designed to inform national policy decisions and assist with conservation planning across multiple States in the central United States.

Contact: Clint R.V. Otto, cotto@usgs.gov

Collaborators: USDA, Farm Service Agency, Natural Resources Conservation Service, and Agricultural Research Service

Timeline: Fiscal years 2015–21

Products:

Darby, B., Bryant, R., Keller, A., Jochim, M., Moe, J., Schreiner, Z., Pratt, C., Euliss, N.H., Jr., Park, M., Simmons, R., and Otto, C.R.V., 2020, Molecular sequencing and morphological identification reveal similar patterns in native bee communities across public and private grasslands of eastern North Dakota: PLoS One, v. 15, no. 1, 22 p. [Also available at https://doi.org/10.1371/journal.pone.0227918.]

Otto, C.R.V., 2019, Assessing the impact of the Conservation Reserve Program on honey bee health: U.S. Geological Survey Fact Sheet 2018–3082, 2 p. [Also available at https://pubs.er.usgs.gov/publication/fs20183082.]

Otto, C.R.V., Smart, A., Cornman, R.S., Simanonok, M., and Iwanowicz, D.D., 2020, Forage and habitat for pollinators in the northern Great Plains—Implications for U.S. Department of Agriculture conservation programs: U.S. Geological Survey Open-File Report 2020–1037, 64 p. [Also available at https://pubs.er.usgs.gov/publication/ofr20201037.]

Otto, C.R.V., Zheng, H., Gallant, A.L., Iovanna, R., Carlson, B.L., Smart, M.D., and Hyberg, S., 2018, Past role and future outlook of the Conservation Reserve Program for supporting honey bees in the Great Plains: Proceedings of the National Academy of Sciences of the United States of America, v. 115, no. 29, p. 7629–7634. [Also available at https://www.ncbi.nlm.nih.gov/pubmed/29967144.]

Simanonok, S., and Otto, C.R.V., 2020, Flowering plants preferred by bees of the Prairie Pothole Region: U.S. Geological Survey Fact Sheet 2020–3038, 2 p. [Also available at https://pubs.er.usgs.gov/publication/fs20203038.]

28. Long-Term Changes in Pollinator Resources (Alfalfa, Sweetclover, and Milkweed) and Monarch Butterfly Populations in Conservation Reserve Program Grasslands

Federal cropland retirement programs are increasingly being used to provide resources for pollinators (for example, nectar, pollen, and host plants). Pollinator-friendly plant species (for example, alfalfa and sweetclover) were readily included in seed mixes in CRP grasslands since the CRP inception in the 1985 Farm Bill. Through time, some native plant species (for example, milkweeds) also colonized CRP grasslands. Since 1997, the NPWRC has quantified changes in pollinator resources (alfalfa, sweetclover, and milkweed) and monarch butterfly abundance in several hundred CRP grasslands in nine counties in the Northern Great Plains. Understanding the long-term persistence, increase, or decline of monarchs and pollinator resources in CRP grasslands will help managers with the design and management of current and future long-term cropland retirement programs.

Adult monarch butterfly feeding on an alfalfa plant in a Conservation Reserve Program grassland in Grant County, Minnesota. Photograph by Lawrence D. Igl, U.S. Geological Survey.

Contact: Lawrence D. Igl, ligl@usgs.gov

Collaborators: Private Landowners; USDA, Farm Service Agency and Natural Resources Conservation Service

Timeline: Fiscal years 1997–2022

29. To Control or Not to Control—Response of Pollinator Communities to Invasive Plant Management

If invasive plants are producing pollen and nectar used by native pollinators, what happens when a manager decides to control the invasive plant? The NPWRC is addressing this question and has determined that pollinators are adept at changing their resource acquisition strategies as abundantly flowering invasive species decline. In addition, the invasive species in some cases seems to be drawing in additional pollinators, which then visit native plants as the invasive senesces. From the pollinators' perspective, the key consideration is that alternative resources are available, and from the manager's perspective, those resources should be the desired plant community. Information gained from this effort will allow land managers to be more fully informed when faced with the need to make decisions related to the control of invasive plants. When considering pollination services, the range of insects that provide those services should be recognized; pollen transport networks developed from these studies have illustrated the importance of diverse taxa, including bees, beetles, flies, and wasps, that are important pollen vectors.

A Sphecid wasp nectaring on Canada thistle. Photograph by Diane Larson, U.S. Geological Survey.

Contact: Diane L. Larson, dlarson@usgs.gov

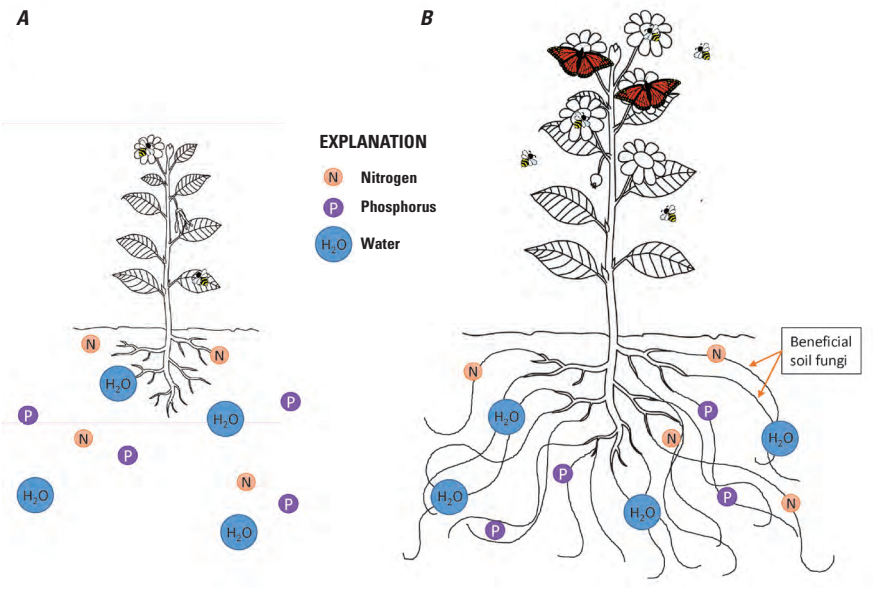
Collaborators: National Park Service, Badlands National Park

Timeline: Fiscal years 2010–19

Products:

Larson, D.L., Larson, J.L., and Buhl, D.A., 2018, Conserving all the pollinators—Variation in probability of pollen transport among insect taxa: Natural Areas Journal, v. 38, no. 5, p. 393–401. [Also available at https://doi.org/10.3375/043.038.0508.]

30. Below-Ground Mutualisms to Support Pollination Mutualisms—Improving Pollinator Habitat Using Mycorrhizal Inoculum



Water and nutrients that are beyond the reach of a plant's roots can *A*, be captured by mutualistic fungi and *B*, be made available to the plant in exchange for sugars derived from plant photosynthesis. (Graphic created by Jennifer Larson, U.S. Geological Survey).

Reconstructed prairies provide critical reservoirs of habitat for species dependent on this rare ecosystem, including the imperiled monarch butterfly and declining pollinators. Outcomes of reconstruction, however, often are disappointing and fail to achieve the desired plant species richness. The objective of this study is to assess how belowground mutualists help plant species thrive. For example, arbuscular mycorrhizal fungi (AMF) provide plants greater access to water and nutrients. To accomplish this objective, we are determining if plant species that establish poorly or decline over time in reconstructions consistently have AMF communities that differ from those of the same species that thrive in remnant prairies. This information will help us understand which plant species are most likely to be helped by AMF inoculum. In addition, the similarities among AMF associated with the same species in geographically separate locations are being assessed to determine how local inoculum must be to provide benefits. Ultimately, the goal of this study is to develop practical methods by which land managers can improve establishment and resilience of prairie reconstructions by improving availability of appropriate AMF to planted species.

Contact: Diane L. Larson, dlarson@usgs.gov

Collaborators: FWS, Region 3; Neal Smith National Wildlife Refuge, Morris Wetland Management District, Litchfield Wetland Management District, Fergus Falls Wetland Management District, Department of Agronomy and Plant Genetics, University of Minnesota, Department of Biological Sciences, North Dakota State University, Groningen Institute for Evolutionary Life Sciences, University of Groningen, The Netherlands.

Timeline: Fiscal years 2019–21

31. The Pollinator Library—A Decision-Support Tool for Improving National Pollinator Conservation Efforts

A native brown-belted bumble bee (*Bombus griseocollis*) visiting leadplant (*Amorpha canescens*). This photograph and other plant-pollinator interaction photographs are available on the Pollinator Library website. Photograph by Russ Bryant, U.S. Geological Survey.

Pollinator declines have emphasized the need for a greater understanding of plant-pollinator networks and land-management activities that improve pollinator habitat. At the request of USDA and FWS partners, the NPWRC created the Pollinator Library for managers and researchers interested in improving pollinator forage on Federal and private lands. The aim of the Pollinator Library, which was created and is managed at the NPWRC, is to support management and research of plant-pollinator systems by documenting, synthesizing, and disseminating information on flowers that are used by pollinators and other insects. By providing free access to essential information, the Pollinator Library facilitates a better understanding of the foraging and habitat needs of flower-visiting insects and plant-pollinator systems. Currently, the Pollinator Library hosts records of about 27,000

pollinator and host plant interactions, including records from 13 States. The Pollinator Library (former URL https://www.npwrc.usgs.gov/pollinator/) is in need of an update in fiscal year 2021 to conform to new USGS standards and to make the search features operate more efficiently. Accordingly, the website may appear down while upgrades are being implemented.

Contact: Clint R.V. Otto, cotto@usgs.gov

Collaborators: FWS; USDA, Farm Service Agency and Natural Resources Conservation Service; Bee and Butterfly Habitat Fund

Timeline: Fiscal years 2015–Ongoing

Products:

Corby-Harris, V., Bowsher, J.H., Carr-Markell, M., Carroll, M.J., Centrella, M., Cook, S.C., Couvillon, M., DeGrandi-Hoffman, G., Dolezal, A., Jones, J.C., Mogren, C.L., Otto, C.R.V., Lau, P., Rangel, J., Schürch, R., and St. Clari, A., 2018, Emerging themes from the ESA Symposium entitled "Pollinator Nutrition—Lessons from bees at individual to landscape levels": Bee World, v. 96, no. 1, p. 3–9. [Also available at https://doi.org/10.1080/0005772X.2018.1535951.]

U.S. Geological Survey, 2018, The pollinator library: U.S. Geological Survey database, https://www.npwrc.usgs.gov/pollinator/.

32. Determining the Dietary Preferences and Population Genetics of an Endangered Bumble Bee, *Bombus affinis*, by Maximizing the Use of Museum Specimens

Museum specimens of rusty-patched bumble bees. Photograph by Clint Otto, U.S. Geological Survey.

The rusty patched bumble bee was federally listed as an endangered species in 2017 and has been identified as a top priority species for recovery nationally. Shortly after listing the species, the FWS and other partners prioritized research needed to prevent extinction of the rusty-patched bumble bee. Among the top research needs that were identified were determining the floral resource needs of the species and understanding genetic population structure between extant and extinct populations. In 2018, the NPWRC partnered with the FWS and the Agricultural Research Service to (1) quantify floral preferences of the rusty-patched bumble bee throughout its historical range and (2) map areas within the United States that support the highest richness of preferred forage plants. We are using novel genetic analyses and pollen samples collected from preserved museum specimens to accomplish these objectives. As of February 2019, we have performed genetic analyses on pollen from 94 *B. affinis* museum specimens representing entomological collections from 7 States during 1913–2013. Results suggest the decline of the rusty patched bumble bee is unlikely due to long-term changes in the floral resource community. The analysis identifies known forage plants that could be included in conservation plantings for rusty patched bumble bee habitat. In fiscal year 2020, we received additional funding from the FWS to quantify pollen stores in two newly discovered rusty-patched bumble colony nests. These two nests are the first known nests of this endangered bumble bee since the 1990s.

Contact: Clint Otto, cotto@usgs.gov; Michael Simanonok, msimanonok@usgs.gov

Collaborators: FWS; USDA, Agricultural Research Service-Logan Bee Lab; Ohio State University; multiple university museums

Timeline: Fiscal years 2019–21

Products:

Simanonok, M.P., Otto, C.R.V., Cornman, R.S., Iwanowicz, D.D., Strange, J.P., and Smith, T., 2021, A century of pollen foraging by the endangered rusty patched bumble bee (*Bombus affinis*)—Inferences from molecular sequencing of museum specimens: Biodiversity and Conservation, v. 30, p. 123–137 [Also available at https://doi.org/10.1007/s10531-020-02081-8.]

33. Float Like a Butterfly—Employing Unmanned Aircraft Systems Technology to Quantify Milkweed for Monarch Butterflies

The annual migration of monarch butterflies in North America represents a biological phenomenon unique to our planet, covering more than 4,000 kilometers and requiring multiple generations of monarchs to complete. The monarch was proposed for listing under the Endangered Species Act in 2014 because of significant population declines and extinction risk. Disappearance of milkweed, the essential host plant for monarch larvae, has been implicated in the decline of the eastern monarch population. The objective of this study is to test the effectiveness of using unmanned aircraft systems (UAS) and artificial neural networks to quantify the density of common and showy milkweed in working grasslands of Minnesota and North Dakota. First, we will develop a machine learning algorithm for detecting milkweeds from UAS-collected aerial images. Second, we will validate our algorithm by comparing plot-level counts of milkweed estimated from UAS images to field count data across a range of milkweed densities. Lastly, we will take steps towards facilitating the integration of this technology into the Integrated Monarch Monitoring Program by estimating the number of spatially independent UAS images required for achieving accurate and precise estimates of milkweed across entire fields. In fiscal year 2019, we completed preliminary UAS flights; however, this project was put on hold because of a DOI ruling that grounded all UAS flights. No USGS UAS flight will be completed until this ruling is changed.

Timeline: Fiscal years 2019–21

Contact: Clint Otto, cotto@usgs.gov

Collaborators: FWS; Sentera Precision Agriculture, Monarch Joint Venture.

34. Native Bee Response to Warm- and Cool-Season Grassland Management at National Park Service Historical Sites in the Mid-Atlantic Region, United States

The National Park Service properties of Antietam National Battlefield, Monocacy National Battlefield, and Chesapeake & Ohio Canal National Historical Park provide ideal locations for studying native bee response to grassland management. These locations are ideal because National Park Service biologists in these parks are managing warm- and cool-season grasslands and have kept detailed records of management strategies (for example, grazing, burning, and spraying) at the field level. The proposed research will provide the National Park Service with a baseline inventory of native bees and their response to grassland management at Antietam, Monocacy, and Chesapeake & Ohio Canal sites. Specifically, the objectives of this research are to (1) inform National Park Service managers about the distribution and relative abundance of native bees throughout the growing season at Antietam, Monocacy, and Chesapeake & Ohio Canal National Park Service properties; (2) quantify native-bee and flowering-plant abundance and richness for three land-management types; and (3) use structural equation modeling to understand how site management, local landscape factors, and soil type affect flowering plant availability and relative abundance of native bees.

Timeline: Fiscal years 2020–21

Collaborators: National Park Service

Contacts: Clint Otto, cotto@usgs.gov; Diane Larson, dlarson@usgs.gov

35. Understanding Spatiotemporal Patterns of Threatened and Endangered Butterflies in the Great Plains

The FWS has currently listed two butterflies (the Dakota skipper and the Poweshiek skipperling) as threatened or endangered and is considering listing other butterflies such as the regal fritillary. To support future monitoring, management and listing decisions for these species, researchers are analyzing existing data from multiple sources. The results from these analyses will allow researchers to make inferences about temporal trends for these species as well as build spatial maps depicting where these species are likely to be on the landscape. These maps will help Federal partners in allocating monitoring efforts and targeting conservation actions.

Contact: Max Post van der Burg, maxpostvanderburg@usgs.gov

Collaborators: FWS

Timeline: Fiscal years 2019–21

Products:

Post van der Burg, M., Austin, J.E., Wiltermuth, M.T., Newton, W., MacDonald, G., 2020, Capturing spatiotemporal patterns in presence–Absence data to inform monitoring and sampling designs for the threatened Dakota skipper (Lepidoptera—Hesperiidae) in the Great Plains of the United States: Environmental Entomology, v. 49, no. 5, p. 1252–1261. [Also available at https://doi.org/10.1093/ee/nvaa081.]

36. Superior National Forest Wolf and Lynx Populations

A radio-collared wolf is captured on a camera trap during March 2019 with a nonradioed packmate in the Superior National Forest, Minnesota (U.S. Geological Survey photograph).

When the wolf was listed as endangered, the last remaining mainland wolf population in the lower 48 States was in the Superior National Forest of northeastern Minnesota. Since then, using radio collars and aerial tracking we have studied the wolf population trend; factors influencing the trend; and prey species, white-tailed deer, moose, and beavers affected by wolves. During winters 2018–19 and 2019–20, we initiated noninvasive winter wolf surveys to determine if we could count resident wolves with reasonable precision using camera traps, genetics from scat and snow tracks, snow tracking, and citizen-scientist reports. During 2019, NPWRC researchers, along with international cooperators, commenced noninvasive summer research to determine if wolf howling rates at their homesites were similar across gradients of human impacts on landscapes. To interpret our wolf howling results, we tested the efficacy of the recording device on captive wolves during spring 2019. We also examined howling rates of captive wolves during the breeding season of winter 2020. Knowledge of changes in this natural, protected, wolf population provides insight valuable to State and Federal resource managers charged with managing recovered and recovering wolf populations. During 2020, we assisted the Minnesota Department of Natural Resources with revising the State wolf management plan. During 2019–20, we assisted the FWS with developing a lynx, postdelisting, monitoring planning based on methods and conclusions from the 2018 (and subsequently updated for internal U.S. Forest Service reports) lynx genetics research collaboration.

Contact: L. David Mech, david_mech@usgs.gov; Shannon M. Barber-Meyer, sbarber-meyer@usgs.gov

Collaborators: U.S. Forest Service, Superior National Forest; Minnesota Department of Natural Resources, Northeastern Region; U.S. Forest Service, National Genomics Center for Wildlife and Fish Conservation, Missoula, Montana; International Wolf Center, Ely, Minnesota; Yellowstone National Park; ARCA, People and Nature, Spain; ACNHE, Association for the Conservation of Nature in Human Environments, Spain; University of Minnesota

Timeline: Fiscal years 1968–Ongoing

Products:

Barber-Meyer, S.M., 2019, Comparison of beaver-sign density estimates from aerial surveys of waterways versus transects in varying habitat and harvest pressure: Canadian Wildlife Biology and Management, v. 8, no. 1, p. 9–16. [Also available at https://pubs.er.usgs.gov/publication/70204635.]

Barber-Meyer, S.M., Dysthe, J.C., and Pilgrim, K.L., 2020, Testing environmental DNA from wolf snow tracks for species, sex, and individual identification: Canadian Wildlife Biology and Management, v. 9, no. 1, p. 12–20. [Also available at https://pubs.er.usgs.gov/publication/70214962.]

Barber-Meyer, S.M., Palacios, V., Marti Domken, B., and Schmidt, L.J., 2020, Testing a new passive acoustic recording device to monitor wolves: Wildlife Society Bulletin, v. 44, no. 3, p. 590–598. [Also available at https://doi.org/10.1002/wsb.1117.]

Cronin, M., and Mech, L.D., 2019, E-letter response to "Genomic signatures of extensive inbreeding in Isle Royale wolves, a population on the threshold of extinction," by Robinson and others (2019): Science Advances, v. 5, no. 5, 13 p. [Also available at https://advances.sciencemag.org/content/5/5/eaau0757/tab-e-letters.]

Mech, L.D., 2019, Do indigenous American Peoples' stories inform the study of dog domestication?: Ethnobiological Letters, v. 10, no. 1, p. 69–75. [Also available at https://doi.org/10.14237/ebl.10.1.2019.1474.]

Mech, L.D., 2020, Unexplained patterns of grey wolf *Canis lupus* natal dispersal: Mammal Review, v. 50, no. 3, p. 314–323. [Also available at https://doi.org/10.1111/mam.12198.]

Mech, L.D., and Barber-Meyer, S.M., 2020, Sixty years of white-tailed deer (*Odocoileus virginianus*) yarding in a gray wolf (*Canis lupus*)-deer system: The Canadian Field Naturalist, v. 133, no. 4, p. 343–351. [Also available at https://doi.org/10.22621/cfn.v133i4.2136.]

Mech, L.D., and Breining, G., 2020, Wolf Island—Discovering the secrets of a mythic animal: Minneapolis, University of Minnesota Press, 188 p. [Also available at https://doi.org/10.5749/j.ctv15kxgdk.]

Mech, L.D., and Buhl, D.A., 2020, Seasonal cycles in hematology and body mass in free-ranging gray wolves (*Canis lupus*) from northeastern Minnesota, USA: Journal of Wildlife Diseases, v. 56, no. 1, p. 179–185. [Also available at https://doi.org/10.7589/2018-06-156.]

Mech, L.D., Isbell, F., Krueger, J., and Hart, J., 2019, Gray Wolf (*Canis lupus*) recolonization failure—A Minnesota case study: Canadian Field Naturalist, v. 133, no. 1, p. 60–65. [Also available at https://doi.org/10.22621/cfn.v133i1.2078.]

37. Yellowstone Wolf Restoration

The National Park Service and FWS reintroduced wolves into Yellowstone National Park in 1995 and 1996. This study helps assess that population's recovery and determines factors that affect the population, which include diseases, intraspecific strife, and interactions with prey. The restoration has been successful, and the population of wolves has persisted in Yellowstone National Park for more than 20 years despite being affected by canine distemper, mange, and other diseases. The Yellowstone wolves' primary prey has historically been elk, and we and other researchers have learned much about the interactions between the two species. In collaboration with National Park Service, the NPWRC is addressing remaining questions about wolf and elk ecology such as what factors affect (1) the rate wolves encounter elk, a key

Elk form the primary prey of wolves in Yellowstone. Photograph by L. David Mech, U.S. Geological Survey.

factor in determining wolf hunting success rate and (2) natal dispersal of wolves. Based on 46 wolf-pack study periods from 2004 to 2012, only elk density affected wolf encounter rate of elk, despite evaluating season, snow depth, elk-group density, mean-elk group size, wolf-pack size, and territory size. We are also analyzing how 125 natal dispersals by 229 Yellowstone wolves from 1995 to 2016 were influenced by age, gender, pack breeder status, pack mating system, vacancies in breeding hierarchies, pack size, pack reproduction, population size, population growth rate, geographic range, and season.

Contact: L. David Mech, david_mech@usgs.gov

Collaborators: National Park Service, Yellowstone National Park; University of Minnesota, Department of Fisheries, Wildlife and Conservation Biology

Timeline: Ongoing

38. Ellesmere Wolf Movements

Wolves on Ellesmere Island, just south of the North Pole, survive in extreme cold during 24 hours of darkness per day from November through January and survive in much higher temperatures during 24 hours of light per day from April through September. Partnering with other agencies, the NPWRC use GPS radio collars applied to wolves during summer to examine wolf-pack movements on Ellesmere Island throughout the year. Packs of 20 or more wolves travel more than 6,640 square kilometers within territories during winter darkness and summer total light; kill muskoxen, caribou, and arctic hares throughout the year; and produce litters averaging four pups each May. Sizes of six pack territories during summer varied from 688 to 4,728 square kilometers (95 percent minimum convex polygon). For three packs, winter territory sizes varied from 1,260 to 6,026 square kilometers (95 percent minimum convex polygon). Deoxyribonucleic acid (DNA) from these and other Ellesmere Island packs are being analyzed to determine degree of inbreeding and heterozygosity for this island population at the extreme northern edge of the species' circumpolar distribution.

L. David Mech collars an Ellesmere wolf with a Global Positioning System (GPS) radio-collar. Photograph by Dean Cluff, Department of Environment and Natural Resources, Government of the Northwest Territories.

Contact: L. David Mech, david_mech@usgs.gov

Collaborators: Utah State University, Wildland Resources Department; Wildlife Research Station, Nunavut Department of Environment; Northwest Territories Department of Environment and Natural Resources; Polar Continental Shelf Project; Eureka Weather Station, Environment Canada

Timeline: Ongoing

SCIENTIST SPOTLIGHT

50 Years of Wolf Research

The NPWRC presented Dr. L. David Mech (Dave) with a 50-year length of service award on November 5, 2020, for working with Department of Interior agencies since 1969.

Dave received a B.S. degree from Cornell University in 1958, a Ph.D. from Purdue University in 1962, and an honorary doctorate from Purdue University in 2005. Dave is now a senior research scientist with the USGS and began his government career as a wildlife research biologist for Region 3, FWS studying wolves in northeastern Minnesota; he continues that research today. Dave endured several Federal reorganizations that changed agencies and laboratories administering his research from the FWS through the following agencies: the National Biological Survey, the National Biological Service, and currently the USGS and among the following laboratories: Patuxent Wildlife Research Center, Midcontinent Wildlife Research Center, and currently NPWRC. During most of his tenure, Dave has been headquartered at the University of Minnesota, where he has served as an adjunct professor in the Department of Fisheries, Wildlife, and Conservation Biology and the Department of Ecology, Evolution, and Behavior. As an adjunct professor, Dave has advised 16 M.S. students and 12 Ph.D. students.

Dave's DOI research has centered in Minnesota's Superior National Forest (wolves, deer, and moose) since 1969 and Yellowstone National Park (wolves, elk, and bison) since 1995; with another project (wolves and caribou) in Denali National Park from 1986 through 1995 and one on Ellesmere Island, Canada (wolves, musk-oxen, and arctic hares) during summers 1986–2010. Dave's publications include 12 books, some 400 scientific articles, and more than 100 popular articles. Among the several awards that Dave has received is The Wildlife Society's Aldo Leopold Award for Service to Wildlife Conservation. Dave also holds a patent as coinventor of a remote-controlled capture collar. Dave chaired the World Conservation Union's Wolf Specialist Group from 1978 through 2013 and has been advisor for wolves to the chair of the World Conservation Union's Canid Specialist Group since 2013. In 1985, Dave founded the International Wolf Center (https://www.wolf.org), a nongovernment organization employing 14 staff devoted to educating the public about wolf biology. Since the establishment of the IWC, Dave has been vice chair of the board and the IWC technical editor.

Dave Mech observing wolf on Ellesmere Island, Canada (U.S. Geological Survey photograph).

Dave Mech necropsying wolf-killed moose (U.S. Geological Survey photograph).

Dave Mech radio-collaring Yellowstone wolves (U.S. Geological Survey photograph).

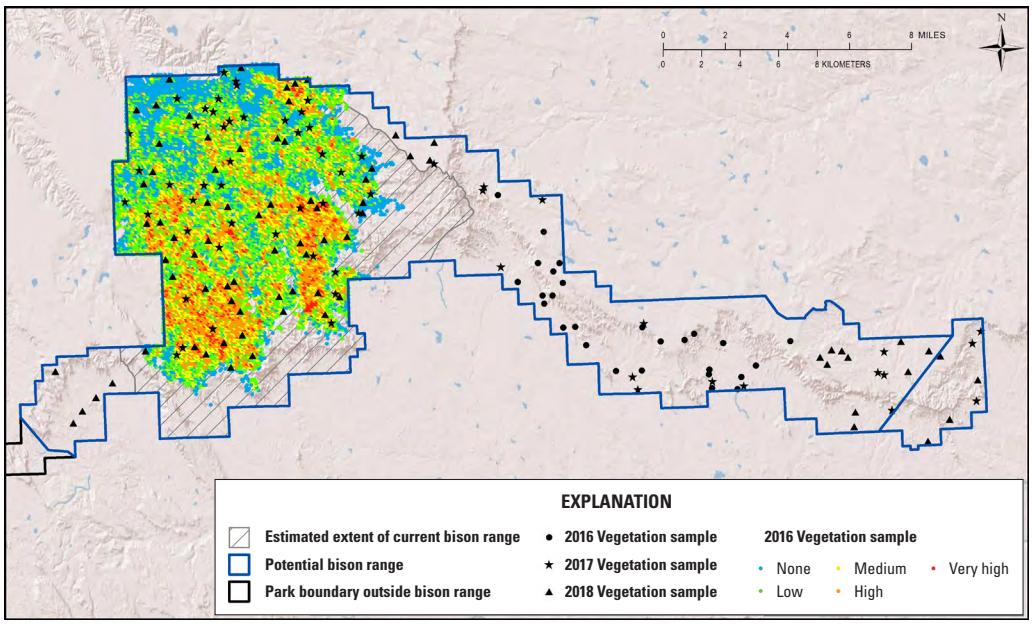
39. Integrated Conservation of Bison and Native Prairie at Badlands National Park, South Dakota

Badlands National Park contains the largest contiguous bison range in the core of the historical bison range on the Northern Great Plains. The park is nevertheless too small to accommodate natural movements of free-ranging bison. As a result, continual grazing by resident bison has supplanted intense-but-ephemeral grazing by nomadic bison. The herd also is currently too small to prevent gradual loss of genetic diversity. Active management of abundance and distribution in the park is, therefore, necessary to conserve bison and their keystone role in natural processes. This research has involved the use of satellite GPS collars to locate marked bison at Badlands National Park at regular intervals since November 2015 and expanded between 2018 and 2020 to also include bison at Theodore Roosevelt and Wind Cave National Parks. Locations are being used to map distributions of bison activity and develop models relating bison use to landscape features, characteristics of vegetation, and proximity to water. Locations also are being used to assess the rate at which bison cows expand their range into areas recently made available after fence removal. A companion project (number 72 in this report) is assessing bison diets and the spatial distribution of productivity, composition, and consumption of park vegetation. Data resulting from these two studies will be used to evaluate potential bison population and vegetation management objectives under various weather scenarios. Results will be used by the National Park Service to refine and implement management strategies that benefit bison and native prairie vegetation in midwestern national parks.

Contact: Glen A. Sargeant, gsargeant@usgs.gov; Amy J. Symstad, asymstad@usgs.gov

Collaborators: National Park Service, Badlands National Park, Wind Cave National Park, and Theodore Roosevelt National Park

Timeline: Fiscal years 2015–Ongoing



Preliminary data from Global Positioning System (GPS)-collared bison showing the bison use of their current range and the locations of vegetation samples. Shaded background is Esri shaded relief.

40. Support the Development of a National Park Service Midwest Region Bison Stewardship Strategy

Bison have played a key role in shaping the grasslands of the Great Plains for millennia. National parks are a major last bastion for wild herds of the national mammal and symbol of the DOI. However, although the National Park Service aims to maintain as natural as possible ecosystem conditions within its parks' boundaries, managers regularly make decisions affecting bison herds to sustain the health of bison populations, plant communities that support bison herds, and other wildlife species. To date, most of those decisions have been made at the park level and have focused on this single species. A new National Park Service initiative to develop a Midwest Region Bison Stewardship Strategy strives to increase managers' consideration of a broader ecological and sociological context when making bison management decisions. We guided players and stakeholders of this strategy through a structured process to determine the strategy's objectives and relevant performance metrics for each objective, consider action elements to achieve those objectives, and construct alternative portfolios of actions into exploratory strategies.

Contact: Amy J. Symstad, asymstad@usgs.gov

Collaborators: National Park Service, Badlands National Park, Tallgrass Prairie National Preserve, Theodore Roosevelt National Park, Wind Cave National Park, Midwest Regional Office, Biological Resources Division; InterTribal Buffalo Council; USGS, North Central Climate Adaptation Science Center, Patuxent Wildlife Research Center

Timeline: Fiscal years 2018–19

Products:

Symstad, A.J., Miller, B.W., Shenk, T.M., Athearn, N.D., and Runge, M.C., 2019, A draft decision framework for the National Park Service Interior Region 5 bison stewardship strategy: National Park Service Natural Resource Report NPS/MWRO/NRR—2019/2046, 43 p. [Also available at http://www.npshistory.com/publications/wildlife/nrr-2019-2046.pdf.]

Decision making by the Midwest Region of the National Park Service units regarding their bison herds currently focuses strongly on this single species. Broadening this focus to include vegetation, ecosystem processes, and Tribal relationships is an impetus for developing a Bison Stewardship Strategy for National Park Service units in the region. Photograph by Amy Symstad, U.S. Geological Survey.

Species Stressors

41. A Method for Mitigating the Behavioral Effects of Energy Development and Other Anthropogenic Disturbances on Grassland Birds and Waterfowl

An aerial view of the Tatanka Wind Farm in Dickey County, North Dakota, and McPherson County, South Dakota. The Tatanka Wind Farm is one of three wind farms included in the Northern Prairie Wildlife Research study evaluating avian displacement to wind infrastructure. Photograph by Chuck Loesch, U.S. Fish and Wildlife Service.

The avian-impact offset method (AIOM) quantifies the amount of habitat needed to provide equivalent biological value for birds displaced by energy and transportation infrastructure. The AIOM is applicable to situations where avian displacement (that is, behavioral avoidance) requires compensatory mitigation. The AIOM is based on the ability to define five metrics—impact distance, impact area, preimpact density, percent displacement, and offset density. Our work provides the following four products: (1) displacement rates from wind-energy facilities for waterfowl and grassland birds; (2) an explanation and demonstration of the AIOM using examples for wind and oil infrastructure, including cases in which the biological value of offset habitat (that is, habitat acquired to fulfill mitigation requirements) is similar to the impacted habitat and when biological value is dissimilar; (3) a worksheet for AIOM users to apply to their own projects; and (4) a geospatial AIOM decision support tool that automates Geographic Information System processes for identifying biologically equivalent habitats for mitigation fulfillment, as well as for forecasting mitigation costs of proposed developments. The AIOM has been adopted by State wildlife agencies, Federal natural-resource agencies, and energy developers, resulting in compensatory mitigation in the form of restoration of grassland and wetland acres.

Contact: Jill A. Shaffer, jshaffer@usgs.gov

Collaborators: FWS, HAPET

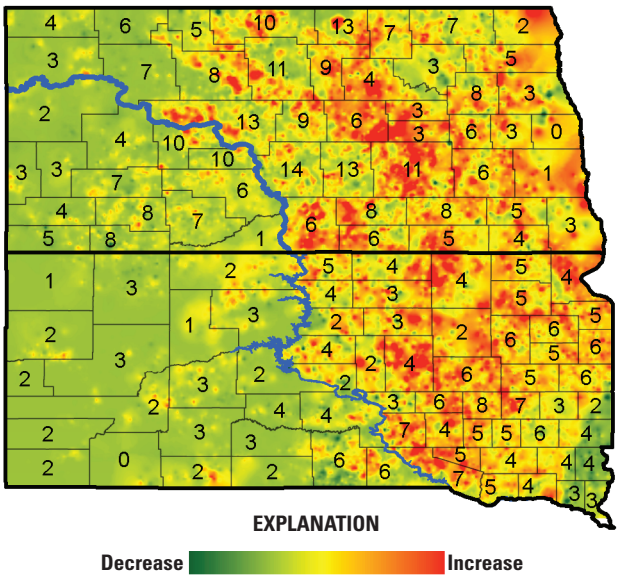
Timeline: Fiscal years 2002–21

Products:

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, 15 p. [Also available at https://doi.org/10.1002/eap.1983.]

42. Quantifying the Effects of Land-Use Change and Bioenergy Crop Production on Ecosystem Services in the Northern Great Plains

Rising commodity-crop prices, increased Federal subsidies for biofuels such as corn-based ethanol and soy-based biodiesel, and reduction in U.S. Farm Bill conservation programs have facilitated rapid land-use changes in the Northern Great Plains. Although renewable biofuels are touted as a mechanism for increasing energy security and potentially reducing greenhouse gas (GHG) emissions, little is known about how rapid expansion of biofuel crops will effect ecosystem services. The objective of this research is to understand how land-use changes and biofuel crop development affect ecosystem services in the Northern Great Plains. For example, the NPWRC biofuels research team studies how land-use change and habitat alteration affect pollinator health and the ability of bees to pollinate agricultural crops. Results from this research will improve societal understanding of the downstream effects of land-use change and the ecological and economic tradeoffs associated with bioenergy crop production. The NPWRC biofuels research has been featured in more than 15 national and international media outlets since 2014.



Heat maps representing the annual rate of change in corn and soybean area around honey bee apiaries from 2006 to 2014. Maps were created using interpolation and data from 18,363 registered apiary locations in North and South Dakota. Red represents regions with the greatest annual increase of corn and soybean area surrounding commercial apiaries. Values within county boundaries represent the average number of registered apiaries per 10,000 hectares (Otto and others, 2016).

Contact: Clint R.V. Otto, cotto@usgs.gov

Collaborators: USDA, Farm Service Agency and Natural Resources Conservation Service

Timeline: Fiscal years 2012–Ongoing

Products:

Durant, J.L., and Otto, C.R.V., 2019, Feeling the sting? Addressing land-use changes can mitigate bee declines: Land Use Policy, v. 87, 8 p. [Also available at https://doi.org/10.1016/j.landusepol.2019.05.024.]

Otto, C.R.V., 2019, Impacts on wildlife of annual crops for biofuel production, *in* Moorman, C.E., Grodsky, S.M., and Rupp, S.P., eds., Renewable Energy and Wildlife Conservation: Baltimore, Md., Johns Hopkins University Press, p 41–63. [Also available at https://jhupbooks.press.jhu.edu/title/renewable-energy-and-wildlife-conservation.]

Smart, M.D., Otto, C.R.V, Carlson, B.L., and Roth, C.L., 2018, The influence of spatiotemporally decoupled land use on honey bee colony health and pollination service delivery: Environmental Research Letters, v. 13, no. 8, 10 p. [Also available at https://doi.org/10.1088/1748-9326/aad4eb.]

43. Can Wetland Water-Management Influence Mercury Bioaccumulation in Songbirds and Ducks at National Wildlife Refuges with Mercury Problems?

During summer 2017, the NPWRC initiated a collaborative research study focused on understanding if water-level management of wetlands at refuges can affect mercury bioaccumulation in wetland-dependent migratory birds. Birds are susceptible to the effects of mercury and can serve as indicators of contamination in ecosystems. We examined mercury concentrations of songbirds and waterfowl using seven different management units at Kellys Slough National Wildlife Refuge near Grand Forks, North Dakota. A mercury hotspot had previously been reported in this area. Our work is designed to investigate if four different water-management regimes potentially can affect mercury bioaccumulation. Preliminary analysis indicates that a wetland's

management regime has profound implications for mercury bioaccumulation in migratory birds. We view this work as a case study that we wish to replicate in other public lands where mercury contamination is a concern. Ultimately, this work could have implications for water-level management of wetlands on public lands in areas where mercury may be a concern.

Contact: Michael J. Anteau, manteau@usgs.gov

Collaborators: USGS, Wisconsin Water Science Center and Western Ecological Research Center; FWS, National Wildlife Health Program and Devils Lake Wetland Management District; Benedictine College

Timeline: Fiscal years 2017–20

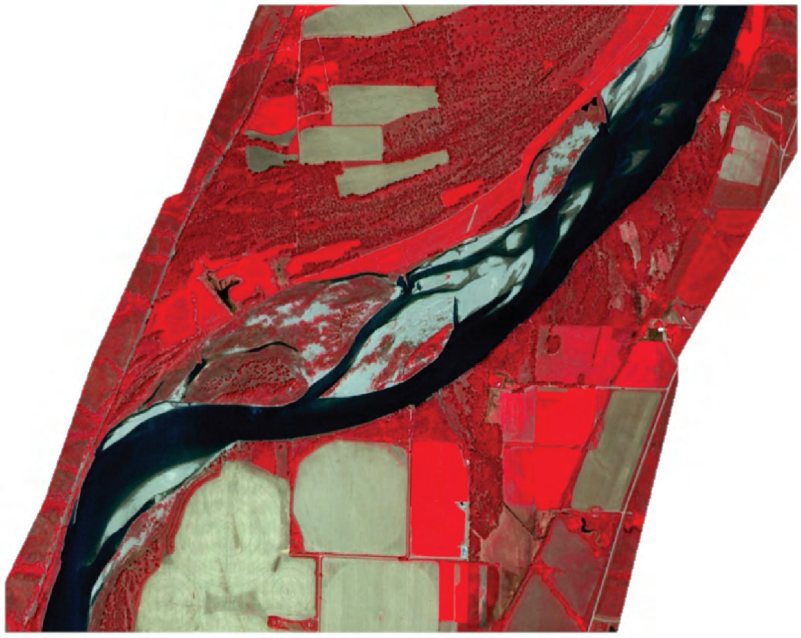
Photograph of Virginia Winder, Benedictine College, holding a common yellowthroat. Wetland-dependent songbirds were captured so a small blood sample could be taken; songbirds were released after being banded, weighed, and measured. Photograph by Michael J. Anteau, U.S. Geological Survey.

Products:

Winder, V.L., Anteau, M.J., Fisher, M.R., Wilcox, M.K., Igl, L.D., and Ackerman, J.T., 2020, Wetland water-management may influence mercury bioaccumulation in songbirds and ducks at a mercury hotspot: Ecotoxicology (London, England), v. 29, no. 8, p. 1229–1239. [Also available at https://doi.org/10.1007/s10646-019-02143-w.]

44. Inventory, Mapping, Estimation, and Monitoring of Least Tern and Piping Plover Habitats on the Upper Missouri River Using Satellite Imagery

Emergent sandbar maps of the Missouri River produced by the NPWRC continue to be used by the USACE and FWS to monitor and manage critical breeding habitat for the endangered interior population of least terns and the threatened Northern Great Plains population of piping plovers. These maps have been created and refined annually for more than 10 years. Using high spatial resolution satellite imagery, we have developed and continue to refine a database of spectral and spatial properties of potential habitat categories that are classified using a probability-based method. We have focused on increasing automation of these methods to further improve the cost-effectiveness of producing multiple maps during a season that capture temporal variability of available habitat on low-relief emergent sandbars that is related to variation in river discharge.



Satellite image of an area of the Missouri River used to classify potential breeding habitat for least terns and piping plovers on emergent sandbars.

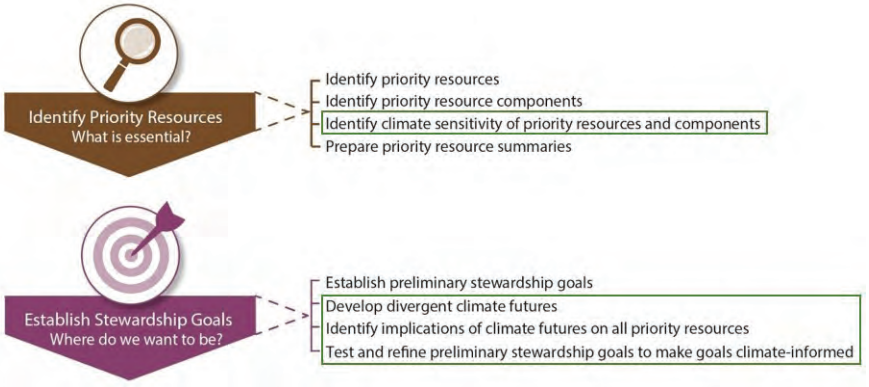
Contact: Max Post van der Burg, maxpostvanderburg@usgs.gov

Collaborators: USACE, Omaha District, Threatened and Endangered Species Section

Timeline: Fiscal years 2005–Ongoing

Management and Restoration

45. Integrating Climate Change Scenario Planning into National Park Service Resource Management



Climate change scenario planning (in green boxes) is incorporated into early steps of the National Park Service's standard Resource Stewardship Strategy development process to improve the robustness of park management actions in the face of a changing climate (National Park Service, 2020).

Resource managers are tasked with managing complex systems with inherent uncertainty around how those systems might change with time and respond to management actions in a changing climate. Scenario planning—often implemented as a qualitative, participatory exercise for exploring multiple possible futures—is a valuable tool for addressing uncertainty. At the same time, quantitative information on projected climate changes and their effects is rapidly growing and evolving, but this information is often not at a scale or in a form that resource managers can use. This project piloted a process for combining qualitative scenario planning and quantitative modeling in a way that would create manager-usable information, largely by emphasizing the coproduction of this information by scientists and managers. Building on this success, we developed a process to incorporate climate-change scenario planning into Resource Stewardship Strategies a planning tool developed and used by the National Park Service across the Nation. Insights gained in the first application of this process at Devils Tower National Monument in Wyoming were used to improve the process when applied at Wind Cave National Park in South Dakota.

Participants in a scenario planning workshop for Wind Cave National Park consider the implications of four future climate scenarios for the park's streams, springs, and groundwater. Photograph provided by National Park Service.

Contact: Amy J. Symstad, asymstad@usgs.gov

Collaborators: DOI North Central Climate Adaptation Science Center; National Park Service, Badlands National Park, Devils Tower National Monument, Wind Cave National Park, Climate Change Response Program, and Denver Service Center Planning Office; U.S. Forest Service, Buffalo Gap National Grassland

Timeline: Fiscal years 2015–20

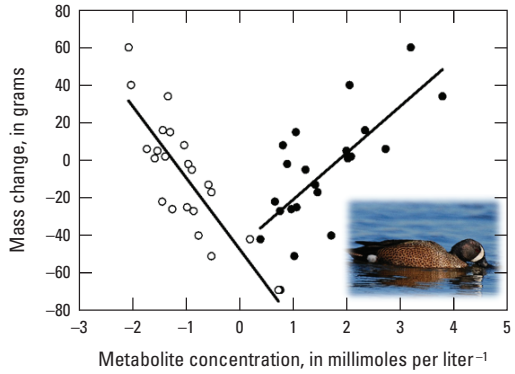
Products:

Miller, B.W., Symstad, A.J., and Schuurman, G.W., 2019, Implications of climate-resource scenarios for Badlands National Park resource management: National Park Service Climate Change Response Program, 5 p. [Also available at https://www.nps.gov/subjects/climatechange/upload/2019-03-26BADLClimateScenariosBrief_508Compliant.pdf.]

National Park Service, 2020, Supplemental guidance—Integration of climate change scenario planning into the resource stewardship strategy process: Denver, Colo., National Park Service, 37 p. [Also available at https://irma.nps.gov/DataStore/Reference/Profile/2267238.]

Schuurman, G.W., Symstad, A.J., Miller, B.W., Runyon, A.N., and Ohms, R., 2019, Climate change scenario planning for resources stewardship—Applying a novel approach in Devils Tower National Monument: Fort Collins, Colo., National Park Service, Natural Resource Report NPS/NRSS/CCRP/NRR—2019/2052, 90 p [Also available at https://irma.nps.gov/DataStore/Reference/Profile/2268255.]

46. Evaluating Wetland-Ecosystem Health Using Real-Time Nutrient Dynamics of Ducks



Relationships of two lipid metabolites (Triglycerides [shaded circles] and Beta-hydroxybutyrate [unshaded circles]) with 1-day mass changes in free living lesser scaup during spring migration (modified from Anteau and Afton, 2008). Photograph by Nick Smith, U.S. Geological Survey.

The NPWRC leads a collaborative effort, spanning several studies, with the objective of improving techniques to assess the quality of spring migration habitat for ducks. Spring is a critical time in the life cycle of migratory ducks because during migration, ducks experience peak energetic needs at a time when food resources are often at their scarcest. Accordingly, ducks must maximize energy acquisition by eating high-lipid forage on spring stopover habitats. Our research is focused on assessing the quality of those stopover habitats and improving the techniques for those efforts. We are using plasma-lipid metabolites of migratory ducks to assess their real-time refueling rates on spring stopover wetland habitats. This work is being done by graduate students that are being coadvised by a NPWRC scientist. The results will improve further research on spring stopover habitats and assess wetland ecosystem health on a broad scale to inform more efficient conservation efforts (for example, restoration and protection of wetland habitats).

Contact: Michael J. Anteau, manteau@usgs.gov

Collaborators: USGS South Dakota Cooperative Fish and Wildlife Research Unit; The Mississippi Flyway Council; Illinois Department of Natural Resources; South Dakota Game, Fish and Parks; South Dakota State University, Western Illinois University; Ducks Unlimited Canada; Forbes Biological Station; Illinois Natural History Survey

Timeline: Fiscal years 2014–Ongoing

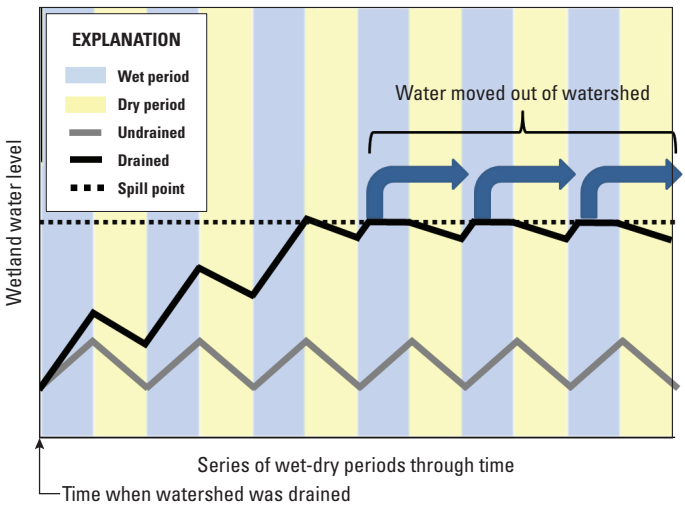
Products:

Janke, A.K., Anteau, M.J., and Stafford, J.D., 2019, Extreme climatic variability during migration invokes physiological and dietary plasticity among spring migrant ducks: Canadian Journal of Zoology, v. 97, no. 4, p. 340–351. [Also available at https://doi.org/10.1139/cjz-2018-0075.]

Janke, A.K., Anteau, M.J., and Stafford, J.D., 2019, Prairie wetlands confer consistent migrant refueling conditions across a gradient of agricultural land use intensities: Biological Conservation, v. 229, p. 99–112. [Also available at https://doi.org/10.1016/j.biocon.2018.11.021.]

47. Interactions of Consolidation Drainage and Climate on Water-Level Dynamics, Wetland Productivity, and Waterbirds

The NPWRC recently completed a project aimed at understanding the effects of wetland drainage on wetlands that receive drainage water. The biological communities of prairie-pothole wetlands evolved in a hydrologically dynamic system because of periodic wet and dry conditions. The NPWRC research



Conceptual model that incorporates observed and theoretical relations that describe the response of wetland water levels to climate variability in landscapes that are undrained landscapes or that have had extensive consolidation drainage (modified from Anteau and others, 2016).

indicates that relative to wetlands in undrained landscapes, wetlands that receive consolidation drainage water drawdown less during dry conditions and progressively get larger and stabilize at their spill point during wet conditions. The implications of this water-level increase and eventual stabilization is that this increase reduces biological productivity and favors invasive species. These results have informed conservation efforts toward watershed-oriented restoration and protection of wetlands in the Prairie Pothole Region.

Contact: Michael J. Anteau, manteau@usgs.gov

Collaborators: FWS, Region 6 Refuges, Wetland Management Districts, and HAPET; Plains and Prairie Potholes Landscape Conservation Cooperative; South Dakota State University

Timeline: Fiscal years 2012–Ongoing

Products:

McKenna, O.W., Kucia, S.R., Mushet, D.M., Anteau, M.J., and Wiltermuth, M.T., 2019, Synergistic interaction of climate and land-use drivers alter the function of North American, prairie-pothole wetlands: Sustainability, v. 11, no. 23, 20 p. [Also available at https://doi.org/10.3390/su11236581.]

48. Restoration of Wetland Invertebrates to Improve Wildlife Habitat in Minnesota

The NPWRC is investigating limitations to restoring abundant aquatic macroinvertebrate populations to Minnesota wetlands and shallow lakes. Recent research on larger, more permanent wetlands in Minnesota indicates that the quality of wetlands used by ducks has decreased. That research also describes a decline in abundance of amphipods, a shrimp-like Crustacean. Amphipods are important forage for ducks during spring migration because amphipods are nutritious and can occur at high densities. This research is focused on understanding what factors limit super abundance of amphipods in Minnesota wetlands. The work will examine limitations of amphipod dispersal and factors that reduce wetland quality (for example, invasive species, agricultural effects, pesticides, and water quality). This study combines a large-scale observational study with laboratory toxicology experiments and a field experiment that involves stocking amphipods.

Amphipods collected during spring when pairs cling together for breeding. Photograph by Michael J. Anteau, U.S. Geological Survey.

Contact: Michael J. Anteau, manteau@usgs.gov

Collaborators: USGS Upper Midwest Environmental Sciences Center; Minnesota Department of Natural Resources (lead agency); Bemidji State University, Environment and Natural Resources Trust Fund; Idaho State University; Legislative-Citizen Commission on Minnesota Resources; Lincoln Bait Landscape Conservation Cooperative

Timeline: Fiscal years 2018–21

49. Importance of Wetlands in Intensively Farmed Landscapes to Duck Production

Mallard brood in a prairie wetland (foreground) and a wetland in an intensively farmed landscape (background). Photographs provided by Ducks Unlimited, Inc.

The NPWRC is collaborating in a partnership to investigate the role of intensively farmed landscapes for production of ducks in the Prairie Pothole Region of the Northern Great Plains. The Prairie Pothole Region annually hosts 50–80 percent of North America's ducks during the breeding season. Accordingly, significant government and private funds go to conservation for the purposes of improving duck production in the Prairie Pothole Region. The Prairie Pothole Region ecosystem has several stressors, and intensive agriculture is chief among them. The current conservation paradigm focuses on protection of habitat in less-farmed landscapes; however, restoration of habitats in intensively farmed landscapes may prove to be an equally valuable approach because areas that are intensively farmed often have a greater baseline capacity for biological productivity. Our research aims to evaluate tradeoffs of baseline productivity with potential negative agricultural effects on duck productivity, while exploring potential avenues to mitigate those negative effects. Our work started with a pilot study in Iowa and Minnesota during summer 2018 and expanded into North and South Dakota during 2019 and 2020. Ultimately, this work will provide information as to where conservation efforts may be most beneficial to ducks, allowing for future work to address social and economic issues associated with where and how conservation is applied to the Prairie Pothole Region landscape.

Contact: Michael J. Anteau, manteau@usgs.gov

Collaborators: PPJV; Ducks Unlimited, Inc. (lead agency); Iowa State University; Louisiana State University

Timeline: Fiscal years 2018–21

50. Understanding Consequences of Management Strategies for Farmed Wetlands to Ecosystem Services in the Prairie Pothole Region

Waterfowl using a partially plowed wetland in an agricultural field. Photograph by Dustin Toy, U.S. Geological Survey.

The NPWRC is leading a partnership with North Dakota State University to examine ecological, social, and financial considerations of farming practices within temporarily ponded wetlands. Farmers strive to maximize crop production on their land and, therefore, may be more successful with more information on costs and benefits of certain management practices. For many years, crops have been planted in prairie-pothole wetlands that are embedded within farm fields. For example, during dry falls, farmers often disturb or remove cattail within seasonal wetlands with hopes of planting crops in the wetlands during the subsequent spring. Wet conditions during spring or summer often prevent a harvestable yield from these areas; however, disturbance of these wetlands may be beneficial because wetlands choked with cattail provide little benefit for wildlife. This study incorporates precision agriculture data (provided by cooperating farmers), field surveys of bird use and wetland characteristics, and opinion surveys of farmers. Our findings will provide insights about ecological implications of

wetland disturbance to migrating birds, profitability of farming wetlands, and farmer motivations in making land-use decisions about wetlands. We anticipate that this work will provide information for future experimental conservation practices whereby farmers may become more profitable and provide management actions to wetlands that benefit wildlife, particularly migratory waterbirds.

Contact: Michael J. Anteau, manteau@usgs.gov

Collaborators: North Dakota State University

Timeline: Fiscal years 2017–21

51. Evaluating Dynamics of Habitat Resource Availability for Diving Ducks at Pools 13 and 19 of the Mississippi River

NPWRC is coleading a partnership with Western Illinois University to understand the dynamics of foods for diving ducks at two important migratory stopover areas on the Mississippi River. Navigational Pools 13 and 19 are crucial refueling sites for migratory waterfowl, especially diving ducks, before reaching these higher latitudes where food shortages have been documented. Pool 19 has had changes in hydrology, traffic, and sedimentation since the installation of the Keokuk lock and dam system in 1913. Unlike other navigational pools of the Mississippi River, few aquatic invertebrate and vegetation evaluations have been conducted on Pool 19 in relation to environmental factors. The objective of this research is to create a spatial and temporal habitat assessment of Navigational Pools 13 and 19 using historical and current data. We will use aquatic surveys to characterize distribution and density of vegetation and macroinvertebrates. We will use waterfowl aerial survey data to evaluate scaup abundance in relation to habitat factors. Lastly, we will conduct true metabolizable energy trials using wild-caught scaup to establish energy values for common diet items.

Contact: Michael J. Anteau, manteau@usgs.gov

Collaborators: Western Illinois University; Illinois Department of Natural Resources; FWS Region 4, Forbs Biological Station; Illinois Natural History Survey.

Timeline: Fiscal years 2018–21

A lesser scaup fitted with an excrement collection harness during a true metabolizable energy trial, April 2019.

52. A Systems Approach to Modeling Effects of Climate and Land-Use Change on Prairie Wetland Ecosystems

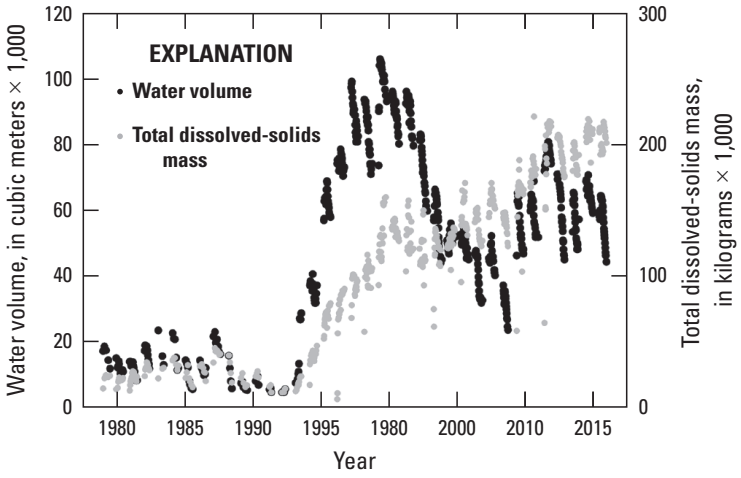
The NPWRC developed an integrated, process-based, systems model for prairie-pothole wetlands to facilitate forecasts of how climate and land-use change will affect wetland processes and biota. The Pothole Hydrology Linked System Simulator (PHyLiSS) model simulates changes in hydrology and water chemistry as a result of altered temperature, precipitation, and other

environmental and land-use inputs. We used extensive biotic and abiotic datasets from the Missouri Coteau Wetland Ecosystem Observatory to parameterize, calibrate, and validate the model. The PHyLiSS model allows researchers to explore important scientific questions related to (1) how changes in climate will affect water levels and hydroperiods of prairie-pothole wetlands, (2) how these hydrological changes will affect chemical characteristics of various wetland types, (3) how alternate land uses will interact with climate to alter wetland processes, and (4) how potential effects of climate change on prairie-wetland ecosystems might be mitigated. The answers to each of these questions will have direct implications to the conservation and management of these nationally important wetland ecosystems.

Contact: David M. Mushet, dmushet@usgs.gov

Collaborators: FWS, Chase Lake Wetland Management District; USDA, Natural Resources Conservation Service; North Dakota State University; University of North Dakota; University of Minnesota; The Ohio State University; Syracuse University

Timeline: Fiscal years 2015–19



Climate-induced shifts in water volume and mass of total dissolved solids that occurred in a semipermanently ponded wetland of the Cottonwood Lake Study Area, Stutsman County, North Dakota, 1979–2015 (modified from McKenna and others, 2017).

Products:

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Levy, Z.F., Mills, C.T., Lu, Z., Goldhaber, M.B., Rosenberry, D.O., Mushet, D.M., Lautz, L.K., Zhou, X., and Siegel, D.I., 2018, Using halogens (Cl, Br, I) to understand the hydrogeochemical evolution of drought-derived saline porewater beneath a prairie wetland: Chemical Geology, v. 476, p. 191–207. [Also available at https://doi.org/10.1016/j.chemgeo.2017.11.017.]

Levy, Z.F., Rosenberry, D.O., Moucha, R., Mushet, D.M., Goldhaber, M.B., LaBaugh, J.W., Fiorentino, A.J., and Siegel, D.I., 2018, Drought-induced recharge promotes long-term storage of porewater salinity beneath a prairie wetland: Journal of Hydrology (Amsterdam), v. 557, p. 391–406. [Also available at https://doi.org/10.1016/j.jhydrol.2017.12.005.]

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McKenna, O.P., Mushet, D.M., Scherff, E.J., McLean, K.I., and Mills, C.T., 2018, The pothole hydrology-linked systems simulator (PHyLiSS)—Development and application of a systems model for prairie-pothole wetlands: U.S. Geological Survey Open-File Report 2018–1165, 21 p. [Also available at https://doi.org/10.3133/ofr20181165.]

Mushet, D.M., McKenna, O.P., LaBaugh, J.W., Euliss, N.H., Jr., and Rosenberry, D.O., 2018, Accommodating state shifts within the conceptual framework of the wetland continuum: Wetlands, v. 38, no. 3, p. 647–651. [Also available at https://doi.org/10.1007/s13157-018-1004-y.]

Mushet, D.M., McKenna, O.P., and McLean, K.I., 2020, Alternative stable states in inherently unstable systems: Ecology and Evolution, v. 10, no. 2, p. 843–850. [Also available at https://doi.org/10.1002/ece3.5944.]

Mushet, D.M., Solensky, M.J., and Erickson, S.F., 2019, Temporal gamma-diversity meets spatial alpha-diversity in dynamically varying ecosystems: Biodiversity and Conservation, v. 28, no. 7, p. 1783–1797. [Also available at https://doi.org/10.1007/s10531-019-01756-1.]

53. Application and Refinement of a Systems Model for Prairie-Pothole Wetlands

In a recently completed effort, the NPWRC developed an integrated, process-based, systems model for prairie-pothole wetlands to facilitate forecasts of how climate and land-use change will affect wetland hydrology and geochemistry. The PHyLiSS model simulates changes in hydrology and water chemistry as a result of altered temperature, precipitation, and other environmental and land-use inputs. In the current effort, the extensive biotic and abiotic datasets from the Missouri Coteau Wetland Ecosystem Observatory are being used to incorporate wetland plant, invertebrate, and vertebrate communities into the PHyLiSS model. We will also be using the model to address a variety of climate change and land-use related questions of interest to managers and policy makers.

Contact: David M. Mushet, dmushet@usgs.gov

Collaborators: FWS, Chase Lake Wetland Management District; North Dakota State University; University of Minnesota

Timeline: Fiscal years 2020–24

Products:

McLean, K.I., Mushet, D.M., Sweetman, J., Anteau, M.J., and Wiltermuth, M.T., 2020, Invertebrate communities of prairie-pothole wetlands in the age of the aquatic homogenocene: Hydrobiologia, v. 847, no. 18, p. 3773–3793. [Also available at https://doi.org/10.1007/s10750-019-04154-4.]

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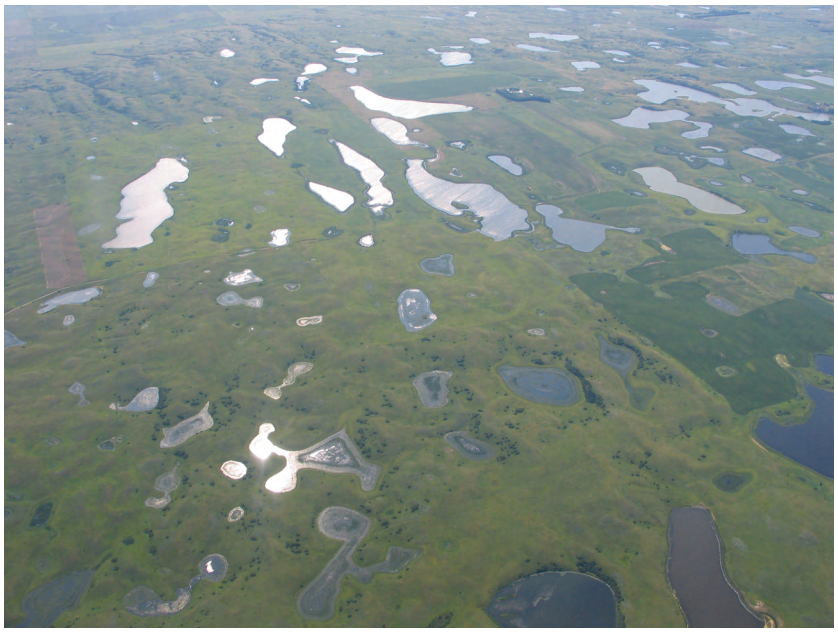
54. Development and Validation of Wetland-Connectivity Indicators in the U.S. Prairie Pothole Region

We worked in partnership with the U.S. Environmental Protection Agency to (1) quantify cumulative effects of prairie-pothole wetlands on stream communities; (2) explore relations between aquatic-system connectivity and genetic-, species-, and ecosystem-scale biological diversity at watershed and landscape scales; (3) develop mapping unit descriptors based on biotic community traits for ongoing hydrologic connectivity mapping efforts; and (4) facilitate data collection efforts associated with quantifications of watershed-scale hydrologic responses to the aggregate effects of prairie-pothole wetlands. This effort is associated with a USGS Powell Center for Analysis and Synthesis effort to develop aquatic system hydrological- and biological-connectivity maps for the Nation. In 2018, we also initiated an exploration into wetland effects on freshwater mussel communities in streams and cascading environmental effects that result when mussel communities and associated “mussel beds” are degraded or lost.



Wetlands in the Prairie Pothole Region of North American, although often appearing as isolated from each other, are interconnected through a variety of ways including temporary surface-water flows, long-term groundwater flows, and biotic movements. Photograph by David Mushet, U.S. Geological Survey.

Contact: David M. Mushet, dmushet@usgs.gov

Collaborators: U.S. Environmental Protection Agency, Office of Research and Development

Timeline: Fiscal years 2017–19

Products:

Mushet, D.M., Alexander, L.C., Bennett, M., Schofield, K., Christensen, J.R., Ali, G., Pollard, A., Fritz, K., and Lang, M.W., 2019, Differing modes of biotic connectivity within freshwater ecosystem mosaics: Journal of the American Water Resources Association, v. 55, no. 2, p. 307–317. [Also available at https://doi.org/10.1111/1752-1688.12683.]

Neff, B.P, Rosenberry, D.O., Leibowitz, S.G., Mushet, D.M., Golden, H.E., Rains, M.C., Brooks, J.R., and Lane, C.R., 2019, A hydrologic landscapes perspective on groundwater connectivity of depressional wetlands: Water (Basel), v. 12, no. 1, p. 50. [Also available at https://doi.org/10.3390/w12010050.]

Smith, L.L., Subalusky, A.L., Atkinson, C.L., Earl, J.E., Mushet, D.M., Scott, D.E., Lance, S.L., and Johnson, S.A., 2019, Biological connectivity of seasonally ponded wetlands across spatial and temporal scales: Journal of the American Water Resources Association, v. 55, no. 2, p. 334–353. [Also available at https://doi.org/10.1111/1752-1688.12682.]

Waraniak, J., Fisher, J.D.L., Purcell, K., Mushet, D.M., and Stockwell, C.A., 2019, Landscape genetics reveal broad and fine-scale population structure due to landscape features and climate history in the northern leopard frog (*Rana pipiens*) in North Dakota: Ecology and Evolution, v. 9, no. 3, p. 1041–1060. [Also available at https://doi.org/10.1002/ece3.4745.]

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Zhu, X., Yuan, Y., Mushet, D.M., and Otte, M.L., 2019, Can multi-element fingerprinting of soils inform assessments of chemical connectivity between depressional wetlands?: Wetlands, v. 39, no. 5, p. 1015–1027. [Also available at https://doi.org/10.1007/s13157-019-01154-x.]

55. Description of Aquatic Vegetation and Invertebrate Communities at Big Stone National Wildlife Refuge

Big Stone National Wildlife Refuge is within a riverine system where refuge wetlands receive sediment-laden inflows that have been associated with diminished plant communities and water-quality conditions. Accordingly, improved habitat- and water-quality conditions have been recognized as overall management goals, and the collection of baseline biotic and abiotic data has been identified as a priority to facilitate refuge planning, management, and restoration efforts. To support refuge management, we conducted a study with overall goals of characterizing the aquatic invertebrate and vegetation communities of the refuge and exploring relations between these communities and various water-quality parameters. Information provided by this study will directly support management of the Big Stone National Wildlife Refuge and other refuges.

Collecting aquatic invertebrates at Big Stone National Wildlife Refuge. Photograph by Charles Dahl, U.S. Geological Survey.

Contact: Brian A. Tangen, btangen@usgs.gov

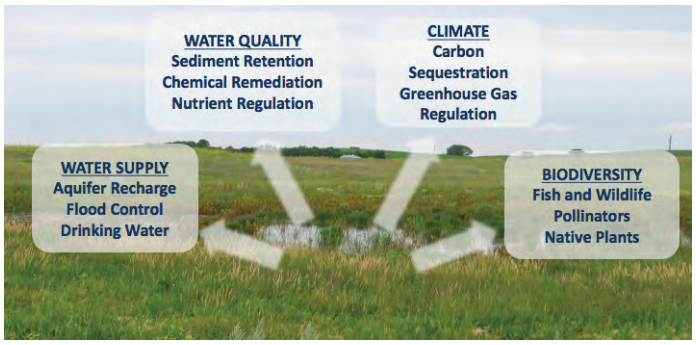
Collaborators: FWS, Big Stone National Wildlife Refuge

Timeline: Fiscal years 2012–19

Products:

Tangen, B.A., Finocchiaro, R.G., Newton, W.E., and Dahl, C.F., 2019, Aquatic vegetation and invertebrate communities of Big Stone National Wildlife Refuge: Journal of Fish and Wildlife Management, v. 10, p. 277–294. [Also available at https://doi.org/10.3996/082018-JFWM-066.]

56. Quantify the Multiple Services Performed by Wetland Ecosystems in the Prairie Pothole Region



Wetlands perform multiple services valued by society that can be affected in various ways by conservation programs and practices. Photograph by David Mushet, U.S. Geological Survey.

In response to the need to quantify wetland-ecosystem services as affected by Federal conservation programs, the NPWRC initiated an effort to develop an integrated landscape model that would facilitate the simultaneous evaluation of multiple services performed by prairie-pothole wetland ecosystems. This effort is focused on incorporating land-use and land-cover change into forecasting models that accounted for variations in agricultural practices and conservation programs. The primary tool being used in this effort is the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) modeling suite. We have parameterized this modeling tool for the Prairie Pothole Region of the United States and developed new components as needed to quantify conservation program and practice effects on wetland carbon stores; water quality; amphibian, waterfowl, and grassland-bird habitat; native-plant communities; and floral resources available to pollinators. We also are using a wetland systems model (PHyLiSS), developed under a separate project, to explore land-use change effects on depressional wetlands and have expanded our reach beyond the Prairie Pothole Region to include work in the upper Mississippi River watershed. Model results provide information used for the implementation of conservation activities, such as practices conducted within the USDA CRP and Wetland Reserve Program and policy making that affect wetland ecosystems throughout the agricultural landscape of the Northern Great Plains.

Contact: David M. Mushet, dmushet@usgs.gov

Collaborators: USDA, Farm Service Agency, Economics and Policy Analysis Staff, and Natural Resources Conservation Service

Timeline: Fiscal years 2012–21

Products:

De Steven, D., and Mushet, D.M., 2018, Estimating the effects of wetland conservation practices in croplands—Approaches for modeling in CEAP–Cropland Assessment: Natural Resources Conservation Service, Conservation Effects Assessment Project, CEAP–Wetlands Science Note, 6 p. [Also available at https://pubs.er.usgs.gov/publication/70196846.]

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Mushet, D.M., and Roth, C.L., 2020, Modeling the multiple ecosystem services of wetlands in agricultural landscapes: Wetlands, v. 40, p. 1061–1069. [Also available at https://doi.org/10.1007/s13157-020-01297-2.]

Shaffer, J.A., Roth, C.L., and Mushet, D.M., 2019, Modeling effects of crop production, energy development, and conservation-grassland loss on avian habitat: PLoS One, v. 14, no. 1, 17 p. [Also available at https://doi.org/10.1371/journal.pone.0198382.]

Williams, A.S., Mushet, D.M., Lang, M., McCarty, G.W., Shaffer, J.A., Kahara, N., Johnson, M.-V.V., and Kiniry, J.R., 2020, Improving the ability to include freshwater wetland plants in process-based models: Journal of Soil and Water Conservation, v. 75, no. 6, p. 704–712. [Also available at https://doi.org/10.2489/jswc.2020.00089.]

57. Development of a Conservation Reserve Enhancement Program (CREP) Reporting and Analysis Template

A glacially formed kettle-wetland landscape in northwest Iowa. Photograph by David Mushet, U.S. Geological Survey.

The NPWRC is working with the USDA Farm Production and Conservation Business Center to improve partner reporting of the Conservation Reserve Enhancement Program (CREP) reporting of annual accomplishments. In the first phase of this effort, we will be working with the USDA Farm Services Agency to develop an online reporting template for partners to use in submitting annual reports. This template will be designed to collect information needed from partners in a standardized form that facilitates subsequent analyses and development of summary reports to Congress. In the second phase, we will be developing mechanisms to facilitate the quantification of multiple ecosystem services from information provided by partners and identify additional information that would lead to more robust quantifications of services currently being reported or that would be required to quantify additional services.

Contact: David M. Mushet, dmushet@usgs.gov

Collaborators: USDA, Farm Production and Conservation Business Center, Economic and Policy Analysis Division

Timeline: Fiscal years 2020–22

58. Decision Analysis and Support

Natural resource decision makers face many challenges in terms of making choices to solve complex management problems. Many of these challenges stem from being overwhelmed by too many choices, uncertain or delayed outcomes, and multiple stakeholders with conflicting desires. Decision analysis (also known as structured decision making) is a set of qualitative and quantitative tools for structuring and analyzing the impediments to decision making, with a focus on overcoming those impediments. At the NPWRC, we use the principles of decision analysis, coupled with our expertise in ecological analysis and numerical optimization, to help our partners make more transparent and defensible management decisions. Projects that the NPWSC has supported have included finding optimal climate adaptation strategies for historical resources in the national parks, helping the FWS find solutions to specific refuge management problems, and helping our partners evaluate which scientific information is most important in their decisions. Our staff also participates in training and mentorship programs associated with the FWS National Conservation Training Center in Shepherdstown, West Virginia.

Contact: Max Post van der Burg, maxpostvanderburg@usgs.gov

Collaborators: FWS; National Park Service; USACE

Timeline: Ongoing

59. Decision Analysis of Options for Controlling Asian Carp Invasion in the Tennessee River

Range expansion of Asian carp along the Tennessee River is a concern because of potential negative impacts to the ecological and economic benefits provided by the river. Fisheries resource managers of Alabama, Mississippi, and Tennessee are urgently looking for management and control actions that will prevent further expansion of Asian carp. Other managers on the Tennessee river also have interest in managing Asian carp expansion. The Tennessee Valley Authority owns the lock and dam infrastructure on the river, and the USACE operates and manages the Tennessee Valley Authority infrastructure. Both organizations are preparing to develop a management framework using deterrent technologies to reduce or prevent fish passage with focus on Asian carp. We are using a quantitative decision analysis approach to help State and Federal decision makers make choices about where to place barriers and remove Asian Carp populations to prevent further expansion within the Tennessee River. The results from this analysis will be used by the Tennessee Valley Authority to draft an Environmental Assessment to support barrier installation.

Contact: Max Post van der Burg, maxpostvanderburg@usgs.gov

Collaborators: USACE; Tennessee Valley Authority; FWS, Tennessee Wildlife Resources Agency; Mississippi Wildlife, Fisheries and Parks; Kentucky Department of Fish and Wildlife

Timeline: Fiscal years 2020–21

60. Mechanisms, Models, and Management of Invasive Species and Soil Biogeochemical Process in Prairie Pothole Wetlands

The ecological integrity of thousands of acres of wetland habitat is being impacted by changes in land cover, land use, climate, and invasive species. Previous work has indicated that Prairie Pothole Region wetlands are hotspots for rapid turnover and transport rates of GHG and storage and sequestration of soil organic carbon. Many of these changes in GHG fluxes are driven by changes in wetland plant communities from invasion of hybrid cattail. However, mechanisms controlling GHG and soil organic carbon fluxes and species invasion are not well understood, leading to high uncertainty in model estimates of these processes. The purpose of this project is to use USGS remotely sensed products, along with experimental and observational field data to develop spatially explicit, landscape-scale models of invasive cattails and soil biogeochemical processes. These models will assist in monitoring wetland habitat, in anticipating changes that may occur under various land-use, land-cover, and climate scenarios, and in choosing management strategies that reduce GHG emissions, facilitate SOC sequestration and storage, and preserve high-quality wetland habitat.

Contact: Sheel Bansal, sbansal@usgs.gov

Collaborators: USGS, Geology, Geophysics, and Geochemistry Science Center, National Research Program, Woods Hole Coastal and Marine Science Center, Wetland and Aquatic Research Center; FWS, Chase Lake Wetland Management District; U.S. Forest Service, Southern Research Station; USDA, Agricultural Research Service; Ducks Unlimited, Inc.; Olympia Circuits

Timeline: Fiscal years 2019–23

Products:

Bansal, S., Johnson, O.F., Meier, J., Zhu, X., 2020, Vegetation affects timing and location of wetland methane emissions: Journal of Geophysical Research, Biogeosciences, v. 125, no. 9, p 1–14. [Also available at https://doi.org/10.1029/2020JG005777.]

Bansal, S., Lishawa, S.C., Newman, S., Tangen, B.A., Wilcox, D., Albert, D., Anteau, M.J., Chimney, M.J., Cressey, R.L., DeKeyser, E., Elgersma, K.J., Finkelstein, S.A., Freeland, J., Grosshans, R., Klug, P.E., Larkin, D.J., Lawrence, B.A., Linz, G., Marburger, J., Noe, G., Otto, C., Reo, N., Richards, J., Richardson, C., Rodgers, L., Schrank, A.J., Svedarsky, D., Travis, S., Tuchman, N., and Windham-Meyer, L., 2019, *Typha* (cattail) invasion in North American wetlands–Biology, regional problems, impacts, ecosystem services, and management: Wetlands, v. 39, no. 4, p. 645–684. [Also available at https://doi.org/10.1007/s13157-019-01174-7.]

Technicians measuring greenhouse gas flux from floating chambers and water chemistry in a prairie pothole wetland at Cottonwood Lake Study Area, North Dakota. Photograph by Sheel Bansal, U.S. Geological Survey.

Bansal, S., and Tangen, B.A., in press, Preserving soil organic carbon in prairie wetlands of central North America *in* Technical manual on soil management for organic carbon sequestration and maintenance: United Nations Food and Agriculture Organization in cooperation with Global Soil Partnership.

Bansal, S., Tangen, B.A., Gleason, R.A., Badiou, P., and Creed, I.F., in press, Land management strategies influence soil organic carbon stocks of prairie potholes, *in* Krauss, K., Zhu, Z., and Stagg, C., eds., Wetland Carbon and Environmental Management: American Geophysical Union Publishing.

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Tangen, B.A., and Bansal, S., in press, Hotspots of soil organic carbon storage and sequestration: Wetlands *in* Technical manual on soil management for organic carbon sequestration and maintenance: United Nations Food and Agriculture Organization in cooperation with Global Soil Partnership.

Tangen, B.A., Bansal, S., 2020, Soil organic carbon stocks and sequestration rates of inland, freshwater wetlands—Sources of variability and uncertainty: Science of the Total Environment, v. 749, article 141444. [Also available at https://doi.org/10.1016/j.scitotenv.2020.141444.]

SCIENCE SPOTLIGHT

Automated Gas Flux Monitoring System

Accurate assessment of greenhouse gas (GHG) fluxes from terrestrial and aquatic ecosystems are necessary to (1) understand how changing environmental conditions affect landscape-scale GHG emissions, (2) meet international GHG emissions objectives, and (3) develop climate-change mitigation strategies. Assessing GHG fluxes is challenging because of the considerable spatial and temporal variation in belowground conditions and processes that control flux rates. Traditional methodologies involve manually placing gas flux chambers on soil or water surfaces and, then, during a 30–60 minute period, collecting 3 to 6 gas samples for analyses on lab-based gas chromatographs. This method involves considerable time and personnel, thus constraining spatial and temporal replication.

Recent advances in high-frequency GHG analyzers have allowed researchers to obtain flux measurements at sub-minute time intervals under field conditions. However, these new analyzers still require personnel to manually place chambers, limiting their potential benefits. Current market products for automated chamber-placement systems are costly, have limited versatility for use in nonagricultural systems, and only work with specific chamber configurations and exclusive models of high-frequency analyzers.

Dr. Sheel Bansal (NPWRC) and his colleague Dr. Peter Gould (Washington Department of Natural Resources) developed a versatile, automated GHG flux monitoring system that allows researchers to continually measure GHG flux rates with user-defined chambers and any GHG analyzer during complete 24-hour cycles for multiple days/weeks without personnel in the field. The product uses robotic arms to raise and lower chambers, a centralized valve controller to cycle between chambers, and nonproprietary software that can be executed on any web browser with a Wi-Fi capable mobile device. The automated system will increase quantity and improve accuracy of GHG flux measurements, especially in understudied ecosystems such as in wetlands. This will improve model estimates of landscape-scale GHG emissions and, therefore, allow researchers to ask novel questions about spatiotemporal mechanisms driving variation in GHG flux rates. In collaboration with the USGS Office of Policy and Analysis, Bansal and Gould were issued the following patent from the U.S. Patent and Trademark Office in 2020 for their automated GHG monitoring system:

Bansal, S., Gould, P., 2020, Remotely monitored greenhouse gas flux testing of wetlands and vegetation: October 27, 2020, U.S. Patent 10,816,442, https://patents.google.com/patent/US10816442B2/en.

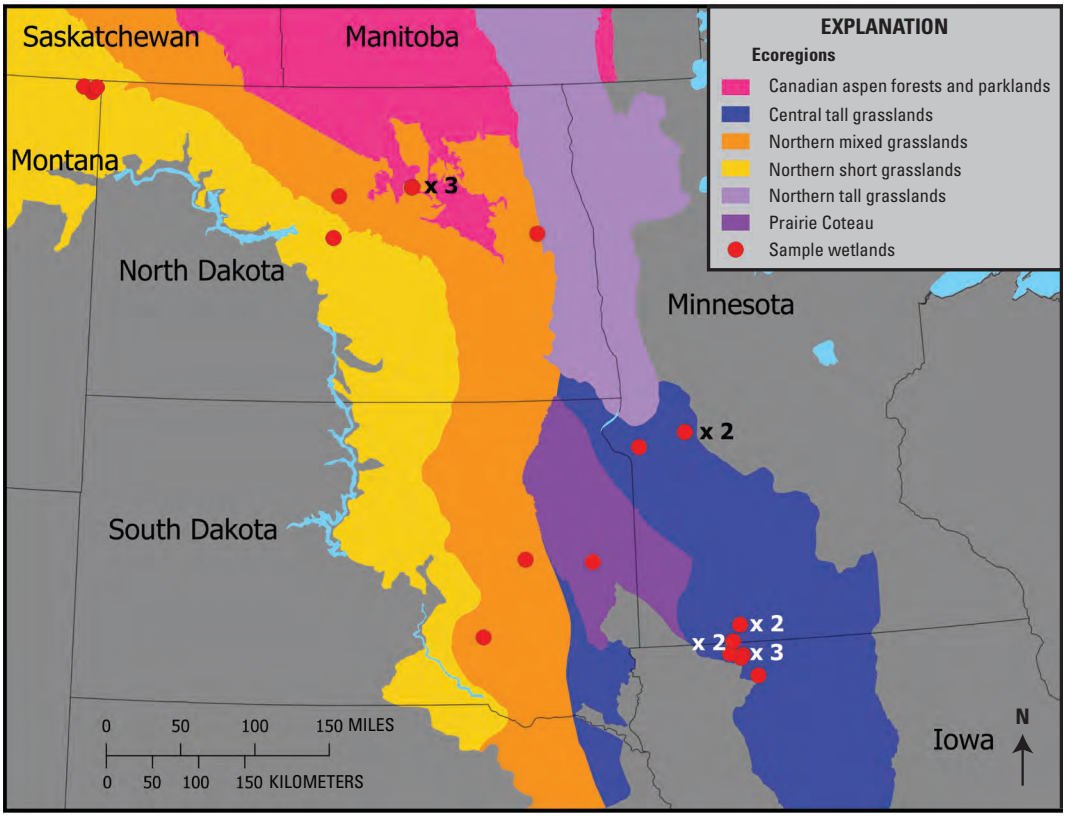
Automated gas flux monitoring system chamber. Photograph by Peter Gould, Washington Department of Natural Resources.

Prairie grassland habitat. Photograph by U.S. Geological Survey.

Sheel Bansal. Photograph by U.S. Geological Survey.

61. The Impact of Future Changes in Climate on Breeding Waterfowl Pairs in the U.S. Prairie Pothole Region

The Prairie Pothole Region is recognized as one of the most productive areas for waterfowl in North America and is used by an estimated 50–80 percent of the continent's breeding duck population. The ongoing acquisition program of the FWS National Wildlife Refuge System has conserved about 1.3 million hectares of critical breeding-waterfowl habitat. A major assumption inherent to the current conservation approach is that past distributions of waterfowl habitat and populations are relatively representative of future distributions. Our goal with this project is to coproduce novel information for land-management agencies to better plan for future impacts of climate change on the wetland habitat for breeding waterfowl pairs in the U.S. Prairie Pothole Region. We are using a mechanistic hydrology model in combination with FWS multidecadal datasets and predictive breeding waterfowl pair statistical models to simulate wetland-waterfowl responses under different climate futures. By working directly with scientists and decision makers at a DOI land management agency, we will ensure delivery of actionable science that can readily provide information to FWS about potential climate-driven impacts to breeding waterfowl pairs on currently monitored wetlands.



Four Square Mile Survey wetlands modeled for this study identified by ecoregion within the U.S. Prairie Pothole Region.

Contact: Owen P. McKenna, omckenna@usgs.gov

Collaborators: FWS, HAPET, Bismarck, N. Dak.; University of Colorado-Boulder

Timeline: Fiscal years 2020–22

62. The Impact of Future Climate on Wetland Habitat in a Critical Migratory Waterfowl Corridor of the Prairie Pothole Region

The Prairie Pothole Region is recognized as one of the most productive areas for waterfowl in North America and supports an estimated 50–80 percent of the continent's duck population. The southeast portion of the Prairie Pothole Region in Minnesota and Iowa has faced some of the greatest challenges in wetland conservation. Although advances have been made to restore these habitats, land managers face new challenges in the form of climate change and continued land-use change pressures. The goal of this research is to provide wetland managers with an assessment of wetland trends and forecasts to better plan and target conservation actions. By combining long-term monitoring and mechanistic modeling with the most up to date climate and land-use change projections, we aim to produce a reproducible workflow for assessing site-specific and regional changes in the hydrological functioning of critical waterfowl habitat. To ensure the most effective application of these results we have brought together a diverse set of wetland managers to provide feedback throughout the research process.

Contact: Owen P. McKenna, omckenna@usgs.gov

Collaborators: FWS, Bloomington, Minn.; FWS, Morris Wetland Management District, Morris, Minn.

Timeline: Fiscal years 2020–22

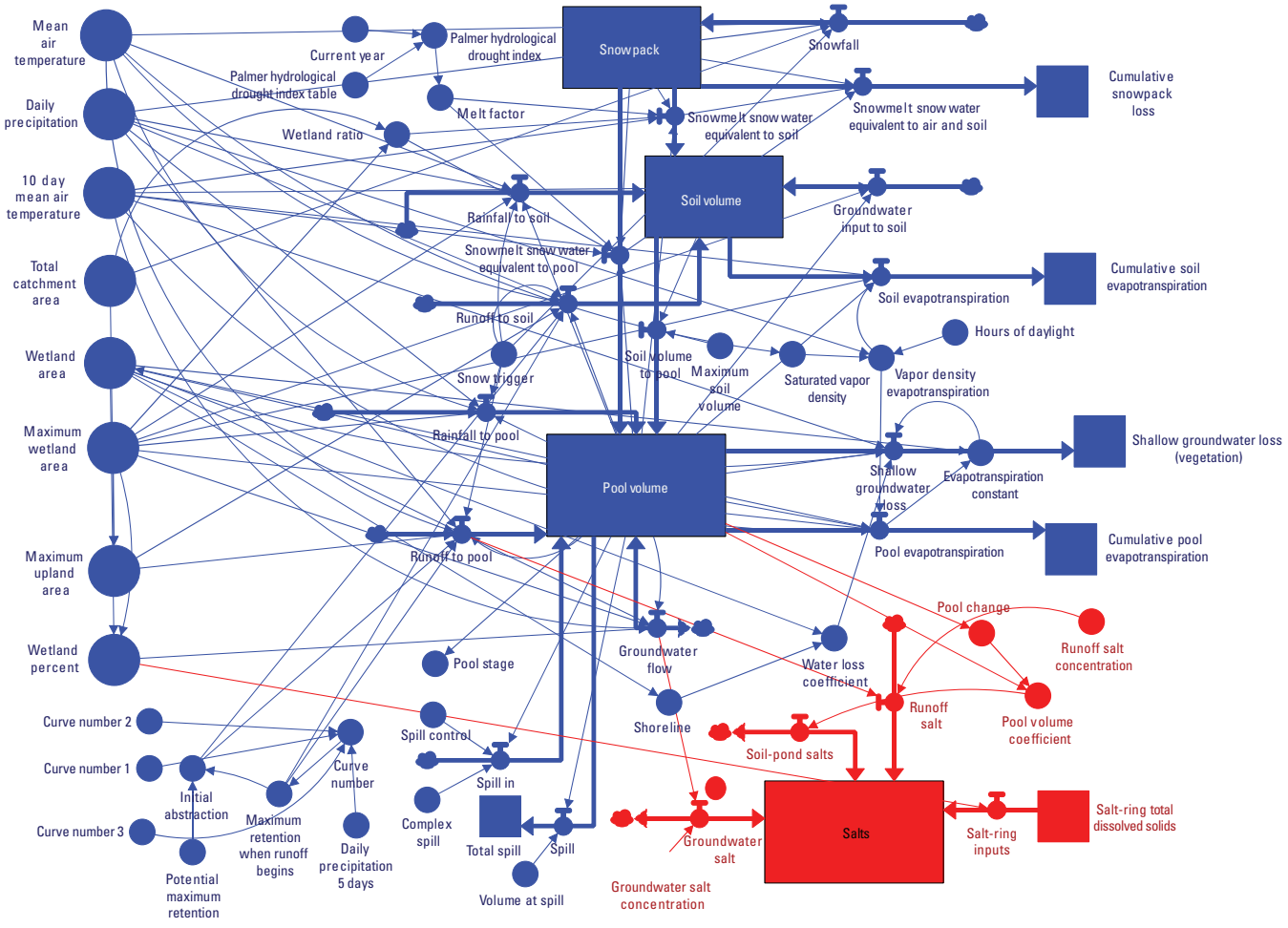


Diagram showing a Stella schematic of the Pothole Hydrology-Linked Systems Simulator (PHyLiSS) model. Red boxes and arrows represent salt stocks and flows, and blue boxes and arrows represent water stocks and flows.

63. Fish and Wildlife Seasonal and Temporary Wetland Assessment

Wetlands of the Prairie Pothole Region are nested within a matrix of grassland and agriculture. Past and current management of Department of Interior lands by the U.S. Fish and Wildlife Service impact wetland habitat quality for wildlife such as migratory waterfowl, especially for smaller, temporary, and seasonal wetlands. Photograph by Ray Finocchiaro, U.S. Geological Survey.

The Prairie Pothole Region supports some of the most productive wetlands in the world for waterfowl. As much as 90 percent of seasonal and temporary wetlands have been lost in areas of the Prairie Pothole Region because of the conversion of grasslands to croplands and the drainage of wetlands. The DOI Waterfowl Production Areas and National Wildlife Refuges in North Dakota, South Dakota, and eastern Montana provide critical, remaining grassland and wetland habitat for nesting waterfowl. However, neighboring agricultural activities combined with invasion of nonnative plants (for example, cattail and reed canary grass) in temporary and seasonal wetlands makes them less attractive to breeding waterfowl. The FWS, USGS, and North Dakota State University are developing a multiphase plan to assess the current state of temporary and seasonal wetlands on Waterfowl Production Areas and National Wildlife Refuges. The first phase involves development of a spatially balanced, wetland-sampling design across the region, followed by a field campaign during the second phase. The third phase will use these data to develop models to predict wetland quality on the landscape. These findings will help to inform management decisions to effectively and efficiently protect wetland habitat.

Contact: Sheel Bansal, sbansal@usgs.gov

Collaborators: FWS, Chase Lake Wetland Management District; North Dakota State University

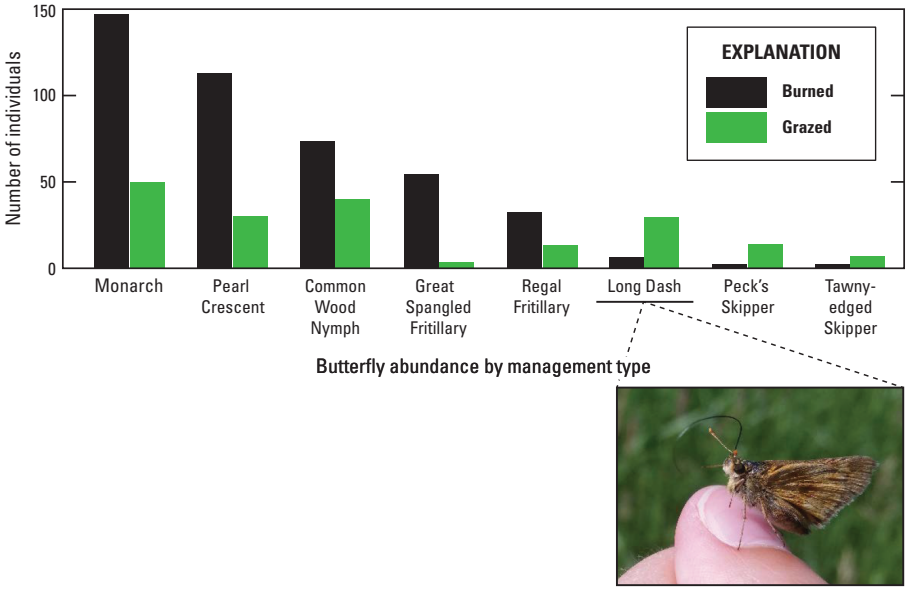
Timeline: Fiscal years 2019–23

Products:

Tangen, B.A., Bansal, S., Fern, R.R., DeKeyser, E.S., Hargiss, C.L.M., Mushet, D.M., and Dixon, C.S., 2019, Study design and methods for a wetland condition assessment on U.S. Fish and Wildlife Service fee-title lands in the Prairie Pothole Region of North Dakota, South Dakota, and Montana, USA: U.S. Geological Survey Open-File Report 2019–1118, 24 p. [Also available at https://doi.org/10.3133/ofr20191118.]

Invasive Species

64. Evaluation of Conservation Grazing Compared to Prescribed Fire to Manage Tallgrass Prairie Remnants for Plant and Pollinator Species Diversity



Several species of butterflies varied in abundance between burned (black bars) and grazed (green bars) sites. Some of the least commonly encountered butterflies were only on grazed sites (pooled 2016 and 2017 counts).

With scarcely 2 percent of native tallgrass prairie remaining today, wisely managing what little remains is imperative to conserve prairie-dependent plants, pollinators, and other animals and ecosystem processes. Two commonly used methods of prairie management are prescribed fire and conservation grazing. Both of these methods may present tradeoffs with respect to conservation of vulnerable plant, bee, or butterfly species, but currently those tradeoffs are not well described, and resource managers do not have all the information necessary to develop optimal management plans for their goals. With this study, funded by the Minnesota Environment and Natural Resources Trust Fund, we aim to fill that knowledge gap by characterizing effects on bees and butterflies that are related to the management practice alone compared to those effects mediated by management-caused changes in vegetation. Further, we will relate bee and butterfly life history traits to their responses to fire and grazing to clarify if results can be generalized or are species-specific.

Contact: Diane L. Larson, dlarson@usgs.gov

Collaborators: FWS, Morris Wetland Management District; Minnesota Department of Natural Resources, Division of Parks and Trails, Prairie Conservation Plan; University of Minnesota Department of Entomology and Graduate Program in Conservation Sciences; The Nature Conservancy; Minnesota Environment and Natural Resources Trust Fund; and private landowners in western Minnesota

Timeline: Fiscal years 2016–21

Products:

Larson, D.L., Hernández, D.L., Larson, J.L., Leone, J.B., and Pennarola, N.P., 2020, Management of remnant tallgrass prairie by grazing or fire—Effects on plant communities and soil properties: Ecosphere, v. 11, no. 8, 17 p. [Also available at https://doi.org/10.1002/ecs2.3213.]

Leone, J.B., Larson, D.L., Larson, J.L., Pennarola, N.P., and Oberhauser, K., 2019, Adult monarch (*Danaus plexippus*) abundance is higher in burned sites than in grazed sites: Frontiers in Ecology and Evolution, v. 7, p. 435. [Also available at https://doi.org/10.3389/fevo.2019.00435.]

65. Effects of Invasive Plant Species on Reproduction of the Rare Endemic Plant Dakota Buckwheat (*Eriogonum visheri*) at Badlands National Park

Our study system is at Badlands National Park. *A*, yellow sweetclover dominating the landscape; *B*, bumblebees visiting yellow sweetclover flowers; *C*, Dakota buckwheat, preferred by smaller bees, such as sweat bees; and *D*, Russian thistle flowers, also preferred by smaller bees. Photographs by Milt Haar (*A*) and Diane Larson (*B–D*), U.S. Geological Survey

Endemism in plants is uncommon in the Great Plains. Dakota buckwheat (*Eriogonum visheri*) is a rare, endemic plant present in only a few locations at Badlands National Park and at sites with similar soils outside the park. In an earlier study, the NPWRC inferred that of two common, coflowering invasive plants, Russian thistle (*Salsola tragus*) was more likely than yellow sweetclover (*Melilotus officinalis*) to interfere with Dakota buckwheat pollination. This inference was based on an analysis that grouped pollinating insects and flowering plants into groups, called "modules," in which pollinators and plants were statistically more likely to interact with each other than with those outside their module. In this study, we explicitly test the effect of these two invasive plants on visitation, pollen limitation, and seed set of Dakota buckwheat. By doing the meticulous work this study requires, we have been able to better interpret other studies that only investigate visitation without assessing seed set and provide managers with information needed to manage invasive plants near this rare endemic plant. Germination tests, pollen counts on stigmas of *E. visheri* flowers, and insect visitor identification were completed during fiscal year 2019; we completed analyses and manuscript submission in fiscal year 2020.

Contact: Diane L. Larson, dlarson@usgs.gov

Collaborators: National Park Service, Badlands National Park

Timeline: Fiscal years 2014–20

66. Evaluation of Tallgrass Prairie Restoration Methods to Improve Resistance to Invasive Species and Maintenance of Plant Species Diversity With Time

Typical early establishing species in a prairie reconstruction planted with a low-diversity seed mix. Photograph by Diane Larson, U.S. Geological Survey.

Patience is necessary when reconstructing native tallgrass prairie from abandoned farmland. In this research effort, we observed that as reconstructions matured, Canada thistle (*Cirsium arvense*) cover declined even though herbicides were not applied. There is no single best planting method for all situations. Ten years after planting, cover of planted, native nonplanted, and exotic species varied little among three planting methods (dormant-season broadcast, growing-season broadcast, and growing-season drill) used in this study. Planting a seed mix with more species did result in reconstructions that harbored more species, but at the cost of lower proportional success. Exotic cool-season grasses may be the biggest threat to these reconstructions. None of the planting methods or seed mix richness levels slowed their increase. Knowledge gained from this research effort is useful to land managers aiming to improve invasion resistance in tallgrass prairie restorations. We also worked with restoration ecologists in other ecosystems to synthesize recommendations for using ecological restoration to curb biotic invasions.

Contact: Diane L. Larson, dlarson@usgs.gov

Collaborators: FWS, Neal Smith National Wildlife Refuge, Litchfield Wetland Management District, Fergus Falls Wetland Management District, and Morris Wetland Management District; U.S. Forest Service, Eastern Forest Environmental Threat Assessment Center

Timeline: Fiscal years 2005–21

Products:

Drobney, P., Larson, D.L., Larson, J.L., and Viste-Sparkman, K., 2020, Toward improving pollinator habitat—Reconstructing prairies with high forb diversity: Natural Areas Journal, v. 40, no. 3, p. 252–261 [Also available at https://doi.org/10.3375/043.040.0322.]

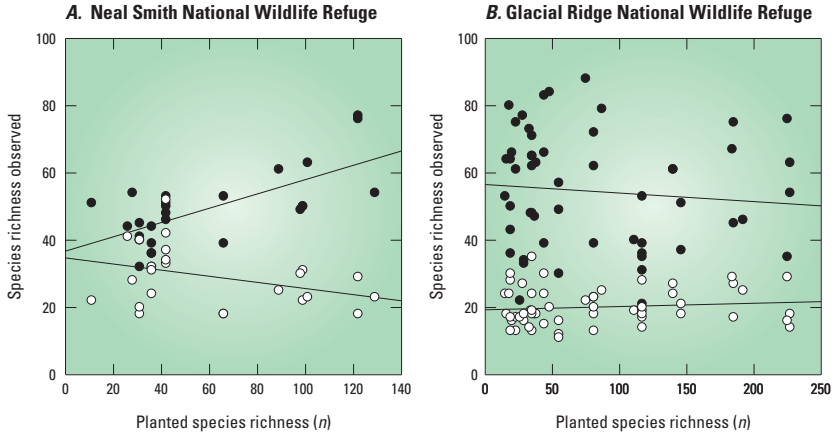
Guo, Q., Brockway, D.G., Larson, D.L., Wang, D., and Ren, H., 2018, Improving ecological restoration to curb biotic invasion—A practical guide: Invasive Plant Science and Management, v. 11, no. 4, p. 163–174. [Also available at https://doi.org/10.1017/inp.2018.29.]

Larson, D.L., Bright, J.B., Drobney, P., Larson, J.L., and Vacek, S., 2017, Persistence of native and exotic plants 10 years after prairie reconstruction: Restoration Ecology, v. 25, no. 6, p. 953–961. [Also available at https://doi.org/10.1111/rec.12521.]

Perkins, L.B., Ahlering, M., Larson, D.L. 2019, Looking to the Future—Key points for sustainable management of Northern Great Plains grasslands. Restoration Ecology, v. 27 no. 6, p. 1212–1219. [Also available at https://doi.org/10.1111/rec.13050.]

67. Developing Evaluation and Monitoring Frameworks for Tallgrass Prairie Reconstruction

Tallgrass prairie species are planted on thousands of hectares of retired farmland each year. If the methods used and resulting characteristics of these prairies are recorded, compiled, and analyzed, the data can provide a valuable resource for evaluating seed mixes, planting methods, and postplanting management. Toward this end, collaborators in the Prairie Reconstruction Initiative, funded by the FWS, developed a database to make data such as these available to researchers and the public. To begin this effort and to illustrate what can be learned by keeping good records of reconstructions, we gathered data from two refuges consisting of reconstructed prairies and evaluated the utility of retrospective information on planting methods, seed mix characteristics, and postplanting management in predicting reconstruction outcomes. Information gained from this effort will be useful for tallgrass-prairie evaluation and monitoring efforts in the Northern Great Plains. Further, in collaboration with researchers at North Dakota State University, we have assessed the overall likelihood of unsuccessful tallgrass prairie reconstructions.



Ideally, we would see an increase in observed native species richness and a decline in introduced species richness as a greater number of species are planted. Such a pattern was evident at *A*, Neal Smith National Wildlife Refuge but not at *B*, Glacial Ridge National Wildlife Refuge. Open circles represent introduced species and closed circles represent native species.

Contact: Diane L. Larson, dlarson@usgs.gov

Collaborators: FWS, Region 6, Neal Smith National Wildlife Refuge, and Glacial Ridge National Wildlife Refuge; North Dakota State University; The Nature Conservancy; The Prairie Reconstruction Initiative

Timeline: Fiscal years 2017–19

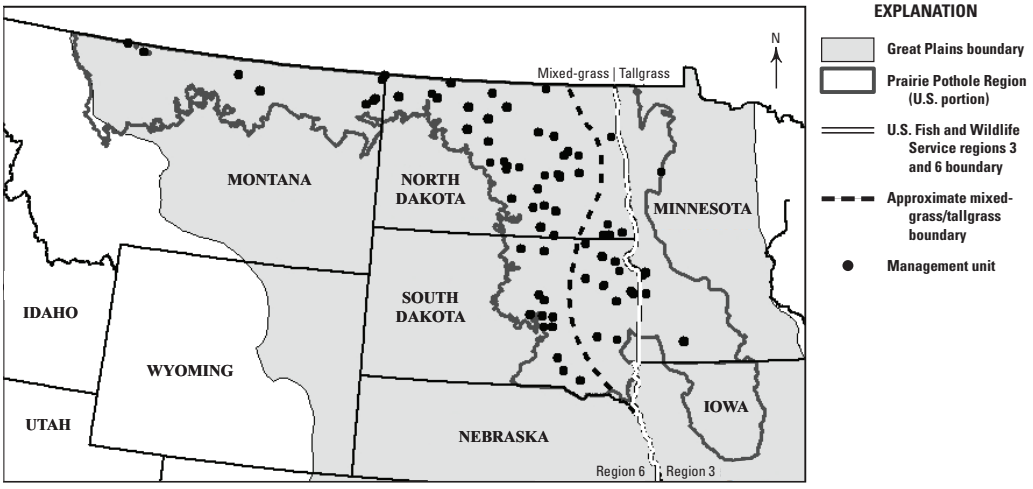
Products:

Larson, D.L., Ahlering, M., Drobney, P., Esser, R., Larson, J.L., and Viste-Sparkman, K., 2018, Developing a framework for evaluating tallgrass prairie reconstruction methods and management: Ecological Restoration, v. 36, no. 1, p. 6–18. [Also available at https://doi.org/10.3368/er.36.1.6.]

McColpin, A.C., Drobney, P.M., Larson, D.L., Ahlering, M.A., Buhl, D.A., Dixon, C.S., Vacek, S.C., and Walker, B.A., 2019, National protocol framework for monitoring vegetation in prairie reconstructions: U.S. Fish and Wildlife Service Catalog. [Also available at https://ecos.fws.gov/ServCat/Reference/Profile/113970.]

Norland, J.E., Dixon, C.S., Larson, D.L., Askerooth, K.L., and Geaumont, B.A., 2018, Prairie reconstruction unpredictability and complexity—What is the rate of reconstruction failures?: Ecological Restoration, v. 36, no. 4, p. 263–266. [Also available at https://doi.org/10.3368/er.36.4.263.]

68. Improving Wildlife Habitat Through Management and Restoration of Native Prairies on Lands Under U.S. Fish and Wildlife Service Ownership (NPAM)



Extent of the mixed-grass and tallgrass prairies in the Great Plains of the northern United States. The U.S. Fish and Wildlife Service (FWS) management units enrolled in the Native Prairie Adaptive Management (NPAM) program are contained within the U.S. portion of the Prairie Pothole Region, an ecoregion of soils and topography formed by glacial activity. The dashed line is the approximate demarcation of the mixed-grass (westerly) and tallgrass prairie (easterly) systems. Refuges from two FWS regions (3 and 6) participate in the NPAM program. Graphic from Moore and others (2020).

The extent of native prairie throughout the north-central United States has sharply declined since European settlement, and much of the native prairie that remains has been invaded by introduced cool-season grasses, reducing floristic diversity and quality. On lands under its ownership, the FWS is working to restore native prairie integrity by reducing introduced species under the Native Prairie Adaptive Management (NPAM) program. Restoration actions consist of forms and timing of defoliation, including burning and grazing. Each year, managers face a difficult decision about whether to defoliate a prairie or not and, if so, which defoliation treatment to apply given the current type and degree of invasion and recent history of defoliation. Managers desire to learn about effectiveness and efficiency of these approaches through the decision-making and implementation process. The NPAM program provides real-time decision support to managers with the objective of increasing the cover of native grasses and forbs.

Contact: Terry Shaffer, tshaffer@usgs.gov

Collaborators: FWS (lead agency), National Wildlife Refuge System, Refuge Cooperative Research Program, and Inventory and Monitoring Program; USGS; Georgia Cooperative Fish and Wildlife Research Unit

Timeline: Fiscal years 2010–20

Products:

Grant, T.A., Shaffer, T.L., and Flanders, B., 2020, Patterns of smooth brome, Kentucky bluegrass, and shrub invasion in the Northern Great Plains vary with temperature and precipitation: Natural Areas Journal, v. 40, no. 1, p. 11–22. [Also available at https://doi.org/10.3375/043.040.0103.]

Grant, T.A., Shaffer, T.L., and Flanders, B., 2020, Resiliency of native prairies to invasion by Kentucky bluegrass, smooth brome, and woody vegetation: Rangeland Ecology & Management, v. 73, no. 2, p. 321–328. [Also available at https://doi.org/10.1016/j.rama.2019.10.013.]

SCIENTIST SPOTLIGHT

NPWRC News—Terry L. Shaffer Earns the Meritorious Service Award during May 2020

For more than 30 years, Terry Shaffer has provided outstanding leadership through statistical and scientific innovation at the NPWRC. Shaffer has authored or coauthored more than 80 peer-reviewed research products that have impacted research, monitoring plans, and conservation actions. Shaffer's most notable paper, the sole-authored publication, "A unified approach to analyzing nest success" provided a powerful, flexible approach to analyzing nest success that is still used today, as evidenced by more than 850 citations.

Shaffer's strength is collaboration with partners within and outside DOI. These collaborations have resulted in major contributions to conservation science and development of long-standing partnerships. The following three examples are noteworthy.

1. Shaffer codeveloped a hybrid field survey—a remote-sensing system for estimating wetland habitat and breeding duck numbers. The survey, known as the "4-square-mile survey," has been completed annually since 1987, and the survey now covers a 5-State area. This effort expanded knowledge of relations among duck numbers, habitat, and landscape features and lead to the FWS organizing a Habitat and Population Evaluation Team. The information from this effort has greatly influenced siting and focus of millions in conservation dollars, and the information was pivotal to understanding the importance of the Conservation Reserve Program (CRP) for supporting waterfowl populations.

2. Shaffer developed an early example of a collaborative multirefuge adaptive management system for invasive plant control on FWS-owned native prairies. This work demonstrated extensive degradation by invasive species and developed a truly adaptive system for learning from management actions. The project introduced several technical innovations and has served as a template for other conservation efforts.

3. Shaffer led a study focusing on evaluating procedures for monitoring numbers and productivity of Federally listed least terns and piping plovers. This study identified many biases in the USACE's monitoring program, and the new system Shaffer designed was adopted as the proposed future monitoring program. Shaffer was a valued collaborator on other tern and plover studies and often is sought out by partners for input on management priorities.

A common thread through Shaffer's collaborative work, which is particularly valued among his teams and partners, is his ability to face contested topics with a steady, rational, and information-driven approach.

Terry Shaffer. Photograph by Terry Shaffer, U.S. Geological Survey.

Prairie pothole wetlands. Photograph by U.S. Fish and Wildlife Service.

Banded piping plovers on the Missouri River. Photograph by Rose Swift, U.S. Geological Survey.

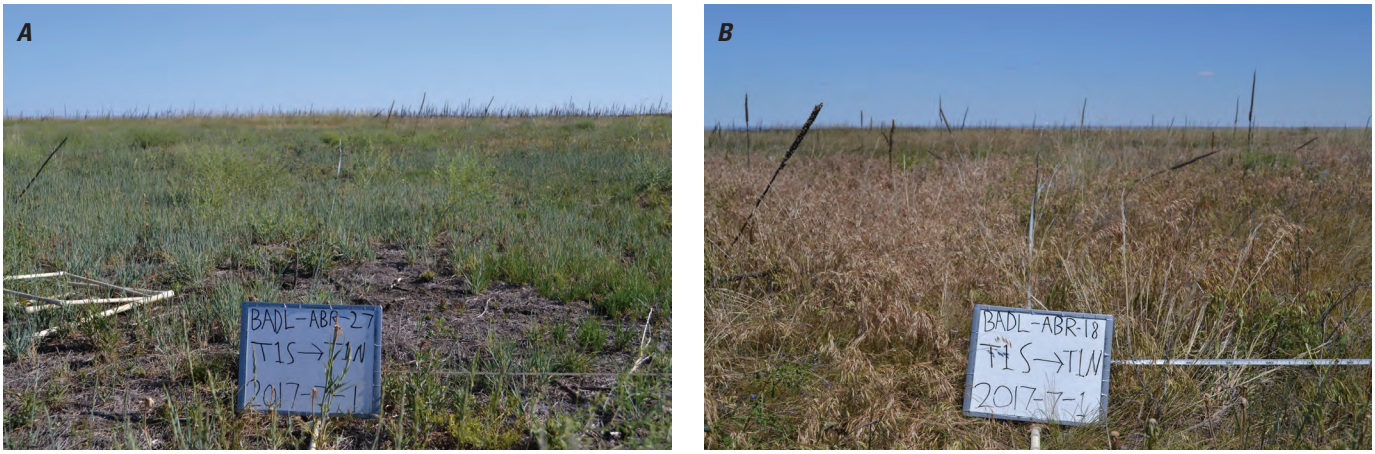
69. What Role Does Prescribed Fire Play in Managing Annual Bromes in Northern Great Plains Grasslands?

Prescribed fire is used in grasslands throughout the Northern Great Plains National Park Service units (parks) to manage fuel loads, control nonnative species, and maintain a vital ecosystem process. Questions about the effects of prescribed fire in areas with invasive annual brome grasses require answers to ensure that the application of prescribed fire produces desired results. Using an experimental approach at two parks in South Dakota and Nebraska, the objectives of this project are to determine the efficacy of prescribed fire as an annual brome management tool across a range of infestation levels and to understand if follow-up herbicide application or seed addition improves adverse effects or enhances positive effects of fire. Fall prescribed fire significantly suppressed annual brome grasses and increased native plant species cover for at least two growing seasons, but only at lower invasion levels. At higher invasion levels, postfire application of imazapic was necessary to achieve this result.

Contact: Amy J. Symstad, asymstad@usgs.gov

Collaborators: National Park Service, Badlands National Park, Scotts Bluff National Monument, Northern Great Plains Fire Management Office, and Northern Great Plains Invasive Plant Management Team

Timeline: Fiscal years 2015–19



Examples of grassland response to experimental fire treatments. *A*, Experimental plots burned in fall alone or followed up with a preemergent herbicide had lower invasive annual brome grass cover than *B*, unburned, untreated plots 1 year after treatment, but effectiveness of these treatments varies depending on the degree to which the system was invaded (U.S. Geological Survey photographs).

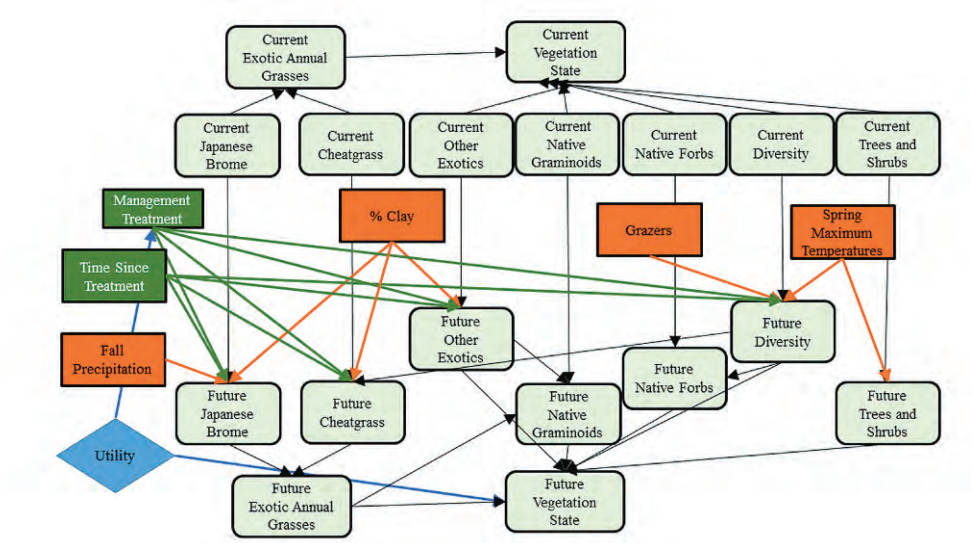
70. An Adaptive Management Framework to Control Invasive Annual Brome Grasses in Northern Great Plains Parks (Annual Brome Adaptive Management Project)

Invasion by annual brome grasses (cheatgrass and Japanese or field brome) into National Park Service units (parks) in the Northern Great Plains impacts park historical and ecological integrity by reducing native plant diversity and altering ecosystem functioning. Historically, parks have implemented few management actions targeting annual bromes; consequently, these species persist and have increased in some parks. Uncertainty about the effectiveness of specific management treatments in controlling annual bromes and limited capacity to apply management treatments make the problem of managing bromes complex. The Annual Brome Adaptive Management project tackles this problem through a cooperative effort between the NPWRC and seven parks and their supporting management and monitoring networks. The project has developed a structured adaptive management framework in which a Bayesian model built from previous monitoring data and experimental results predicts the effects

of management actions on park management units. These predictions inform management decisions and management actions are applied. Vegetation monitoring data are collected and used to update model parameters, and the learning gained from actions is applied to the next year's decision making.

Contact: Amy J. Symstad, asymstad@usgs.gov

Collaborators: National Park Service, Agate Fossil Beds National Monument, Badlands National Park, Devils Tower National Monument, Fort Laramie National Historic Site, Little Bighorn Battlefield National Monument, Scotts Bluff National Monument, Wind Cave National Park, Northern Great Plains Invasive Plant Management Team, Northern Great Plains Fire Management Office, Northern Great Plains Inventory and Monitoring Network, Northern Rocky Mountains Invasive Plant Management Team, and Rocky Mountain Inventory and Monitoring Network



Schematic of the Annual Brome Adaptive Management (ABAM) decision-support tool. Pale green boxes (nodes) are vegetation metrics or states, orange nodes are environmental variables with significant effects on vegetation nodes, dark green nodes indicate management actions and time since those actions, and the blue "utility" node contains park-specific preferences for specific vegetation states and weighting of vegetation outcome versus cost of action. Arrows indicate how each node influences other nodes. Graphic from Ashton and others (2020).

Timeline: Fiscal years 2017–23

Products:

Ashton, I., Symstad, A., Baldwin, H., Post van der Burg, M., Bekedam, S., Borgman, E., Haar, M., Hogan, T., Rockwood, S., Swanson, D.J., Thomson, C., and Wienk, C., 2020, A new decision support tool for collaborative adaptive vegetation management in northern Great Plains national parks: Parks Stewardship Forum, v. 36, no. 3, p. 510–518. [Also available at https://doi.org/10.5070/P536349865.]

71. Sourcing Plants for Conservation and Restoration—Developing a Risk Assessment Framework

Tallgrass prairie species are planted in a variety of settings (for example, retired farmland and roadsides) for a variety of reasons (for example, plant conservation, pollinator diversity, and game-animal habitat). Much of the seed used for these plantings is produced commercially in agricultural-like conditions and can be contaminated by "weed seeds" (for example, exotic and invasive). In this study, funded by the USGS Northeast Climate Adaptation Science Center, we are creating an analytical tool to assess the risk of inadvertently introducing weed seeds into a prairie planting. We propose that increasing the distance between the production location and the planting site increases the risk of introducing

A tallgrass prairie planting being seeded. Photograph by Diane Larson, U.S. Geological Survey.

a new weed species to a landscape. However, increasing that distance also makes obtaining enough seed to create high-quality plantings more feasible. Our tool will balance these two factors, weed risk and seed availability, and provide evidence-based guidance to land managers making seed sourcing choices. We anticipate that our analytical framework will be broadly applicable to conservation concerns in tallgrass prairies. For example, we anticipate using the framework to determine if the balance between weed risk and seed availability will change if managers adopt sourcing strategies that attempt to anticipate climate change (for example, sourcing seed from farther south).

Contact: Diane L. Larson, dlarson@usgs.gov

Collaborators: USDA, Forest Service, Northern Research Station.

Timeline: Fiscal years 2019–21

72. Grazing Resources for Integrated Conservation of Bison and Native Prairie at Badlands National Park, South Dakota

Spatially heterogeneous bison grazing—from the square meter shown here to the park scale shown in the graphic in section "39. Integrated Conservation of Bison and Native Prairie at Badlands National Park, South Dakota"—reflects a diversity of grassland plant communities across Badlands National Park.

Badlands National Park contains one of the largest protected expanses of mixed-grass prairie in the United States, much of which supports a herd of nearly wild bison. The park, nevertheless, is too small to accommodate bison's natural nomadic behavior, which in the past resulted in their ephemeral but intense effect on Great Plains grasslands. Consequently, active management of the number of bison in the park is necessary to conserve the plant species and communities on which the bison and other wildlife depend. This research assesses the spatial distribution of productivity, composition, and consumption of park vegetation; the location and condition of water resources in the park; and the temporal variation of bison diet. Results will be used to determine the park's capacity to simultaneously support desired vegetation conditions and more bison. A companion project (number 37 in this report) is assessing the temporal and spatial distribution of bison in the park using GPS collars. Combined results from these studies will be used to explore the feasibility of various bison population and vegetation objectives under different management and weather scenarios. These evaluations are key for National Park Service managers to determine a successful management strategy for the mutual benefit of native prairie and bison at Badlands National Park.

Contact: Amy J. Symstad, asymstad@usgs.gov; Glen A. Sargeant, gsargeant@usgs.gov

Collaborators: National Park Service, Badlands National Park

Timeline: Fiscal years 2016–21

Fish and Wildlife Disease

73. Effects of Population Density on Prevalence of Chronic Wasting Disease, Physical Condition, and Vital Rates of Elk at Wind Cave National Park, South Dakota

A bull elk with chronic wasting disease at Wind Cave National Park. The emaciated appearance and drooping ears are characteristic of latter stages of infection. Photograph provided by National Park Service.

Chronic wasting disease (CWD) is a degenerative neurological disease caused by infectious proteins called prions. Although documented cases are invariably fatal, infected elk commonly survive for months or years. The infected elk pass prions directly to other individuals and into the environment, where the prions bind to surfaces or soils and can persist indefinitely. CWD reached Wind Cave National Park in about 1997 and rapidly became the leading cause of mortality for adult elk. By 2016, prevalence reached about 30 percent in the eastern park, an unsustainable level that threatens persistence of the population. Although CWD constitutes a crisis for park management, CWD also presents an unprecedented opportunity for studying effects of population density on CWD prevalence, physical condition, and vital rates of elk. During 2016 and 2017, the National Park Service removed 262 elk from Wind Cave National Park, reducing the population by about one-half. We are working with National Park Service partners to evaluate effects of the reduction and to develop guidance for management of CWD and high-density elk populations not only at Wind Cave National Park, but in other parks and preserves.

Contact: Glen A. Sargeant, gsargeant@usgs.gov

Collaborators: National Park Service, Wind Cave National Park, Biological Resources Division, and Midwest Regional Office; Washington State University

Timeline: Fiscal years 2016–Ongoing

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For more information about this publication, contact:
Director, USGS Northern Prairie Wildlife Research Center
8711 37th Street Southeast
Jamestown, ND 58401
701–253–5500
For additional information, visit: https://www.usgs.gov/centers/npwrc
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