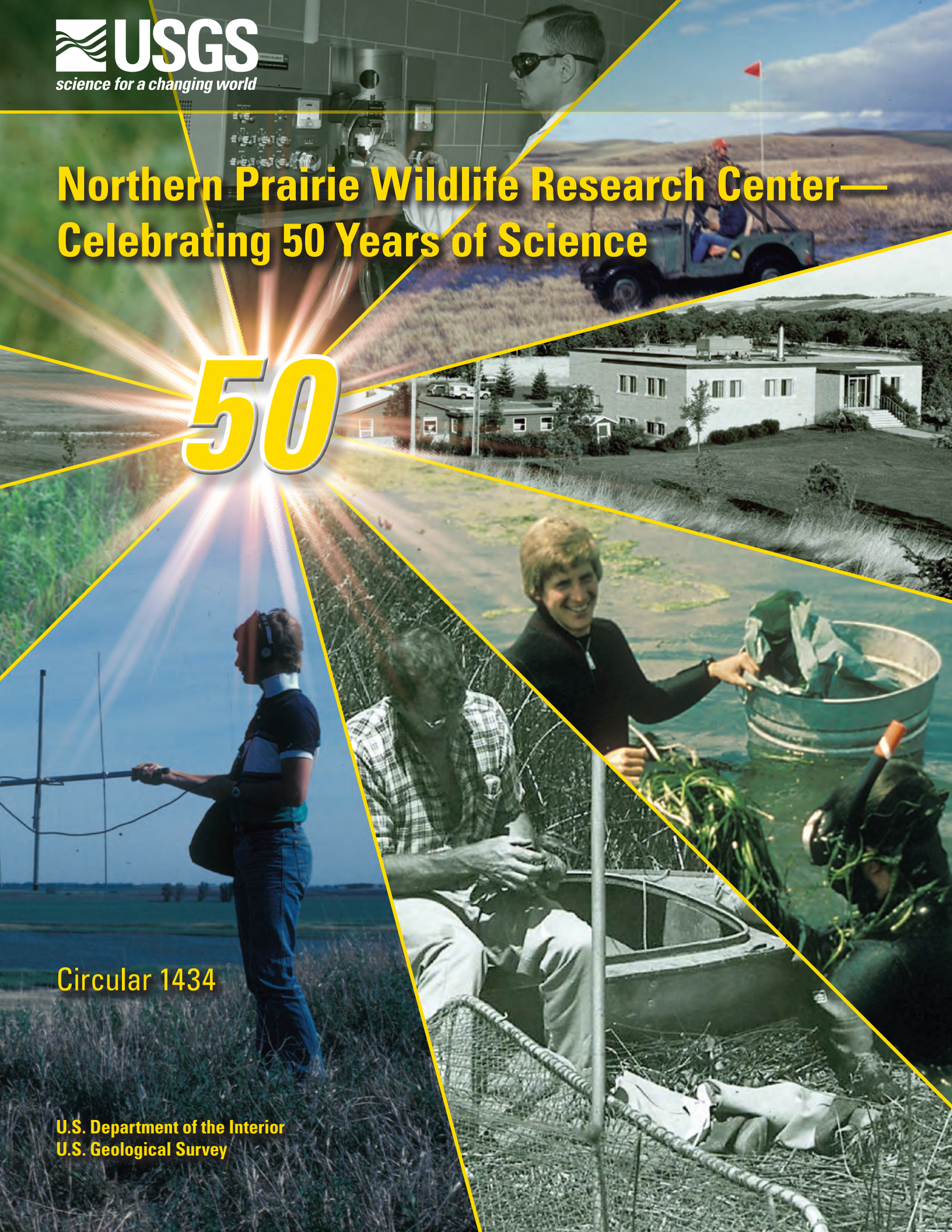
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Northern Prairie Wildlife Research Center—
Celebrating 50 Years of Science
50
Circular 1434
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Cover. *A,* Female blue-winged teal ready for release after attaching a back-pack radio-transmitter. *B*, John Shoesmith holds an Erlenmeyer flask up to a laboratory instrument. *C*, An old military jeep is used to drag a cable-chain and locate duck nests in a grassland in early spring. *D*, Early photograph of Northern Prairie Wildlife Research Center's main administration building, 1970. *E*, Waist deep in waters of the Upper Mississippi River, a technician pulls up a mass of aquatic vegetation while a second technician stands nearby holding a galvanized tub. *F*, A technician bands a hen mallard. *G*, From a grassy hill overlooking a wetland, a technician locates radio-marked ducks using a yagi antenna and receiver. *H*, Tom Eagle removes an American mink from its den and hands it to Todd Arnold. *I*, Early photograph of the Woodworth Field Station. All photographs, maps, and illustrations used in this publication were produced or taken by former or current personnel of the U.S. Fish and Wildlife Service or U.S. Geological Survey and are in the public domain.

Northern Prairie Wildlife Research Center—Celebrating 50 Years of Science

By Jane E. Austin, Terry L. Shaffer, Lawrence D. Igl, Douglas H. Johnson, Gary L. Krapu, Diane L. Larson, L. David Mech, David M. Mushet, and Marsha A. Sovada

An aerial view of the Northern Prairie Wildlife Research Center near Jamestown, North Dakota.

Circular 1434

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

U.S. Department of the Interior
RYAN K. ZINKE, Secretary

U.S. Geological Survey
William H. Werkheiser, Acting Director

U.S. Geological Survey, Reston, Virginia: 2017

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A technician holds a hen mallard while a second technician applies an aluminum leg band to her right leg.

Contents

Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
mile (mi)	1.609	kilometer (km)
acre	0.4047	hectare (ha)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)

Facing page: Trumpeter swans and other waterfowl on a wetland at Lacreek National Wildlife Refuge, South Dakota.

Abbreviations

CAP	Cropland Adjustment Program
CRP	Conservation Reserve Program
DNC	dense nesting cover
DOI	Department of the Interior
EMAP	Environmental Monitoring and Assessment Program
FWS	U.S. Fish and Wildlife Service
GAP	Gap Analysis Program
GIS	geographic information system
HAPET	Habitat and Population Evaluation Team
ILM	Integrated Landscape Management
MCP	Midcontintent Population
NGO	nongovernment organization
NPAM	Native Prairie Adaptive Management
NPWRC	Northern Prairie Wildlife Research Center
NWR	national wildlife refuge
PPJV	Prairie Pothole Joint Venture
PPR	Prairie Pothole Region
SUMP	Small-Unit Management Project
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

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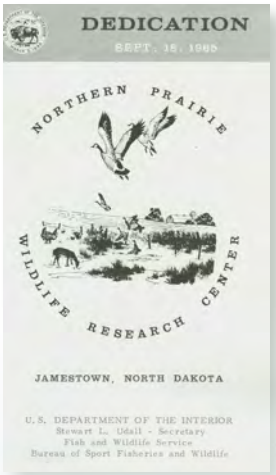
By Jane E. Austin, Terry L. Shaffer, Lawrence D. Igl, Douglas H. Johnson, Gary L. Krapu, Diane L. Larson, L. David Mech, David M. Mushet, and Marsha A. Sovada

Abstract

The Northern Prairie Wildlife Research Center (NPWRC) celebrated its 50-year anniversary in 2015. This report is written in support of that observance. We document why and how the NPWRC came to be and describe some of its many accomplishments and the influence the Center's research program has had on natural resource management. The history is organized by major research themes, proceeds somewhat chronologically within each theme, and covers the Center's first 50 years of research. During that period, Center scientists authored more than 1,700 publications and reports. More than 1,000 seasonal or temporary field personnel, and more than 100 graduate students, contributed to the Center's success; many went on to have exemplary careers in natural resource management, conservation, and education. The mission of the Northern Prairie Wildlife Research Center today remains true to the original vision: to provide the knowledge needed to understand, conserve, and manage the Nation's natural resources for current and future generations, with an emphasis on species and ecosystems of the northern Great Plains. The Center's first 50 years of applied biological research provides a deep scientific foundation on which to address emerging issues for the natural resources in the northern Great Plains and beyond.



Dedication brochure (right) and ceremony (below) for the Center, September 18, 1965.

Introduction

The Northern Prairie Wildlife Research Center (hereafter the Center) celebrated its 50-year anniversary in 2015. This report is written in support of that observance, documents why and how the NPWRC came to be, and describes some of its many accomplishments and the effect the Center's research program has had on natural resource management. The history is organized by major research themes, proceeds somewhat chronologically within each theme, and covers some ongoing projects as well as past work. Because NPWRC scientists have authored more than 1,700 publications and reports covering a broad range of important topics during the 50 years, deciding what to highlight was no easy task (all references for the studies mentioned in this report are listed in U.S. Geological Survey 2017). As with most histories, this one invariably reflects the perspectives and experiences of the writers: six long-term employees and three retirees, collectively representing 276 years with the Center.

Although scientific achievements and the scientists behind them are the focus of this document, it is important to recognize the invaluable roles of the many staff and technicians who supported the work and made the science possible. Every member of the Northern Prairie team, from administrative staff to maintenance personnel to information technology specialists and statisticians, has contributed to the effort in some essential way. A cadre of highly talented and dedicated biological support staff, including long-term and short-term employees, has been critical to the Center's success. The number of seasonal and temporary field personnel who collected the data is unknown but surely would number in the thousands. More than 100 graduate students have contributed to the scientific accomplishments of the Center. Numerous partnerships with other agencies and organizations have been integral to the success of the Center's research program. Scientific leadership has been provided by Center Directors Harvey K. Nelson (1964–74), W. Reid Goforth (1974–80), Rey C. Stendell (1979–89), Susan D. Haseltine (1989–92), Ronald E. Kirby (1993–2001), Jay B. Hestbeck (2001–06), Janine E. Powell (2007–08), and Robert A. Gleason (2010–present).

The many collaborations and partnerships with other institutions and organizations, from local to international, have been fundamental to the Center's success. These cooperative efforts emerged from strong relationships at both organizational and personal levels. Many examples are presented in this publication but they cannot fully capture the breadth and depth of such affiliations across 50 years. Among the strongest partnerships throughout the years have been with the U.S. Fish and Wildlife Service (FWS; National Wildlife Refuges [NWRs], Migratory Bird Program, Habitat and Population Evaluation Team [HAPET]), flyways, joint ventures, and State wildlife agencies, especially the North Dakota Game and Fish Department. These partnerships reflect the Center's original mission focusing on waterfowl and other migratory birds and its more recent charge of supporting U.S. Department of Interior (DOI) agencies. Collaboration with the USGS Water Sciences staff in Lakewood, Colorado, began in the 1960s and

The Center, 1970.

Harvey K. Nelson
(1964–74)

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(1974–80)

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(2007–08)

Robert A. Gleason
(2010–present)

Scientific leadership has been provided by eight Center Directors over its 50-year history.

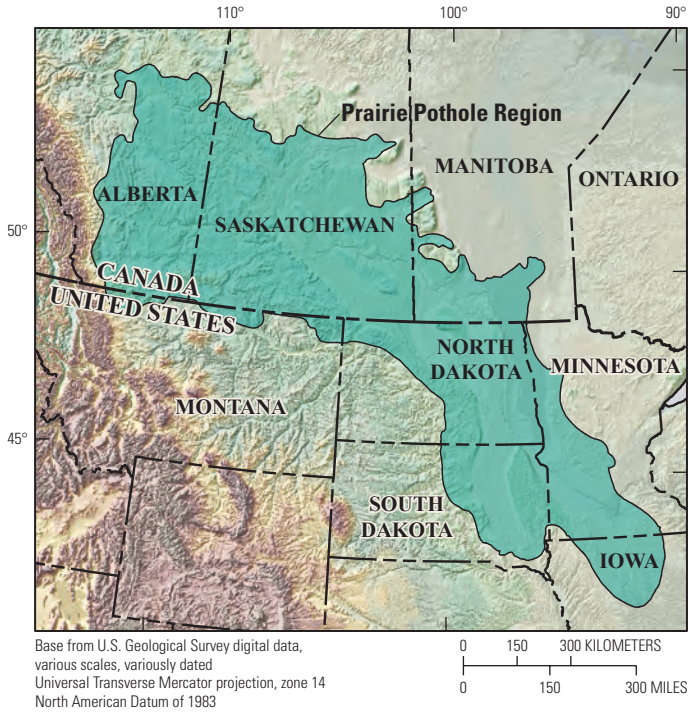
remains a key element of ongoing research. With the Center's broadened mission under USGS, Center scientists have increased and expanded collaborations with the National Park Service, U.S. Department of Agriculture (USDA), U.S. Army Corps of Engineers, State and Provincial agencies, various universities and nongovernment organizations (NGOs), and others. Partners and collaborators contribute valuable skills, expertise, and resources that complement those at the Center and lead to stronger science capability. Close affiliations with management agencies have been central to the Center's focus on applied research that contributes to scientifically based decision-making and conservation actions.

The Center takes tremendous pride in the impact its many alumni have had on natural resource management, conservation, and education. During these 50 years, thousands of dedicated individuals began their professional careers at the Center as temporary, seasonal, or term hires, students, contractors, or volunteers. These talented individuals were instrumental in collecting data in the field, often under challenging conditions, or working in the bird pens, laboratories, or office. They were trained and mentored by Center staff and by one another, and carried their training and experiences on to productive careers as biologists, managers, researchers, educators, or policy makers. More than 100 graduate students have contributed directly to the Center's science through their studies; some became permanent staff at NPWRC or at other USGS research centers. Many of these students have gone on to exemplary careers in natural resource management. During the 1980–90s, three of four FWS flyway representatives had begun their careers at NPWRC. The network of Center alumni, and in turn the Center's impact, spans Federal, State, local, and NGOs across the Nation.

Foundation and Background of the Center

The 1950s and 1960s were a period of major change in the Prairie Pothole Region (PPR). The Federal Government subsidized the drainage of potholes, which led to widespread wetland loss and, together with continuing conversion of native prairie to cropland, threatened the future of the continent's primary duck production area. Federal and State waterfowl managers, alarmed by loss of waterfowl habitat and supported by waterfowl hunters, succeeded in moving Congress to amend the Duck Stamp Act in 1958 to fund the Small Wetlands Acquisition Program in an attempt to slow the loss of breeding habitat for waterfowl. Resource managers also recognized that remaining waterfowl habitat would need to be more productive if duck populations were to be maintained at levels adequate to satisfy the growing interest in waterfowl hunting. Making waterfowl breeding habitat more productive and sustainable over the long term would require increased knowledge of the breeding ecology of prairie-nesting ducks, waterfowl predators, wetland ecology, and an understanding of waterfowl-land-use relationships.

In the early 1960s, long-time waterfowl managers began to develop a research facility to address key information needs for increasing duck production. Named the Northern Prairie Wildlife Research Center, it was administered by the Bureau of Sport Fisheries and Wildlife (later the FWS). The Center's mission was to produce information that



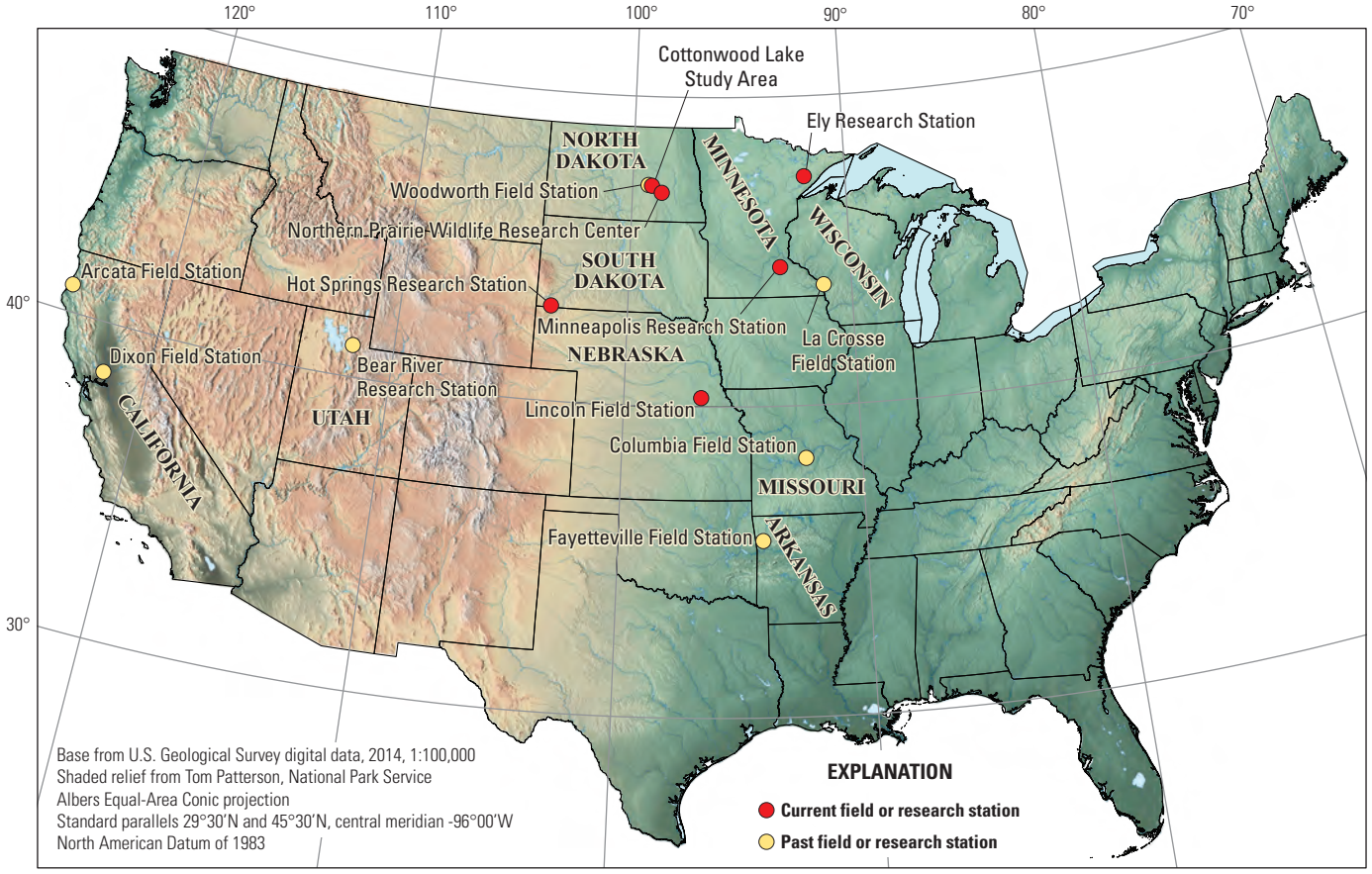
Location of the Prairie Pothole Region in the United States and Canada (Mann, 1974).

Aerial view of the Prairie Pothole Region.

would improve management of waterfowl breeding habitats. Dr. I. G. Bue, former Commissioner of the North Dakota Game and Fish Department, was charged with locating a suitable site for the Center and an associated field research station, designing and developing plans for the buildings, and managing construction contracts. Bue chose to locate this new research facility at Jamestown, North Dakota, in the heart of the PPR. Bue died of a heart attack while hunting in October 1963 before construction of the Center began. Harvey K. Nelson, who also played a major role in planning for the Center, moved from Region 3 (FWS) headquarters in Minneapolis to Jamestown in the summer of 1964 to become the Center's first Director. The Center at Jamestown officially opened on September 18, 1965. The 1,230-hectare Woodworth Study Area was purchased as a waterfowl production area in 1963 with funds from the Federal Migratory Bird Hunting and Conservation Stamp (duck stamp dollars); the study area, located 72 kilometers (45 miles) from the Jamestown headquarters, served as an important research area for the Center into the late 1980s.

Developing a broad-based research program required teams of scientists from several disciplines to work together. The transfer and hiring of staff began several years before the Center was officially dedicated. Harvey Nelson brought together a cadre of highly skilled and experienced biologists and managers who understood prairie habitats and waterfowl to lead the new research program. In 1993, biological research staff and functions from several agencies in the DOI, including NPWRC, were consolidated into the short-lived National Biological Survey (later National Biological Service) and in 1997 transferred into the U.S. Geological Survey (USGS), where they remain today.

Facilities at the Woodworth Study Area in the early 1970s.



Locations of the Center, field and research stations, Woodworth Study Area, and Cottonwood Lake Study Area.

Waterfowl

Research planners recognized the need for a balanced, long-term scientific research program to provide information about factors regulating waterfowl populations, which required improved insights into the ecology of breeding waterfowl to better understand the complex relations controlling reproduction and determining populations. Among potential benefits of the research program was an increased capacity to manage lands more effectively for duck production. Initial investigations focused primarily on gathering baseline data on waterfowl breeding biology, wetland habitats, and estimating duck nest success rates. Some of the Center's earliest work on these topics was by Jerome (Jerry) H. Stoudt, who, prior to joining the NPWRC in 1963, had initiated a 12-year study of breeding canvasbacks (*Aythya valisineria*) near Minnedosa, Manitoba, Canada. Also in 1961, Horatio (Ray) W. Murdy initiated work on waterfowl and wetlands on the Yellowknife Study Area, located along the north shore of Great Slave Lake, Northwest Territories. Other work started in the early 1960s and continued as Center projects, including baseline waterfowl and wetland studies near Woodworth, N. Dak., by Robert (Bob) E. Stewart, Sr.; Harold (Hal) A. Kantrud; Keith D. Bayha; and David L. Trauger.

A founding mission of the Center was to learn how to make the FWS's national wildlife refuges and waterfowl production areas more productive for waterfowl. This mission led to the early formation of a research team charged with investigating wildlife-land-use relationships. Studies were carried out at the Woodworth Study Area and other grassland landscapes in the PPR. Leo M. Kirsch, an experienced FWS Refuge manager and biologist, managed the Woodworth Study Area and its research program during 1964–79, later followed by Kenneth (Ken) F. Higgins (1979–86) and Michael (Mike) Callow (1986–89). Early studies by this team focused on differences in duck use and nesting success among various wetland types and cover types, and the roles of prescribed fire, grazing, and various cover plantings in influencing duck nest success. Work by Harvey W. Miller, Kirsch, Higgins, Harold F. Duebbert, Albert (Tom) T. Klett, John T. Lokemoen, and Arnold (Arnie) D. Kruse, with assistance from James (Jim) L. Piehl, Robert (Bob or Woody) O. Woodward, and hundreds of summer students, provided valuable information about nesting ducks and grassland management. By 1974, the Center had become a renowned source of information on prairie-nesting ducks and the importance of grassland management for waterfowl production. Researchers and managers came from all over North America and the world to learn about prairie ducks, grassland management, and how to improve duck production.

At the Woodworth Study Area, biological surveys of various kinds, including nest searches and repeated counts of ponds, duck breeding pairs, and duck broods, were carried out annually and led to an extensive, long-term database that was the foundation for a monograph by Ken Higgins and others about waterfowl production. Kirsch's use of prescribed burning and grazing to manage the area's upland habitats spurred interest in these methods for managing grasslands for wildlife. By the 1970s, workshops, presentations, and publications by Kruse, Higgins, and Kirsch established the Center as a primary resource for information about prescribed fire for prairie management.

Through the early 1960s, searching for waterfowl nests in herbaceous vegetation was a time-consuming effort that had largely been accomplished by pulling a rope between two people, beating the vegetation with sticks, or using dogs. Nest searching was greatly facilitated by pulling a combination cable and chain between two motor vehicles, a development made by Higgins, Kirsch, and I. Joseph (Joe) Ball. The cable-chain drag made it possible to efficiently locate large numbers of duck nests and paved the way for numerous duck-nesting

A Center biologist carries a wooden box containing ducks captured in drive-trap nets in a wetland near Minnedosa, Manitoba, Canada, 1978.

Researchers monitor a burning fire break at Arrowwood National Wildlife Refuge, North Dakota, 1984.

Leo Kirsch (left) and Ken Higgins (right) setting up a cable-chain drag for nests.

studies through the 1980s by NPWRC scientists and cooperators and for monitoring programs throughout the United States and Canada. In 1986, Klett, Duebbert, Craig A. Faanes, and Higgins authored a techniques publication, including data forms, for conducting duck-nesting studies. This publication led to greater implementation of this detailed protocol by refuge staff and others for finding and monitoring waterfowl nests. The nest-drag method was later modified to locate nests of passerines and other ground-nesting grassland birds. The nest-drag technique remains a critical tool for monitoring a large variety of grassland-nesting birds.

In the early 1970s, Harvey Miller and Douglas (Doug) H. Johnson coordinated an analysis of nesting data collected in North Dakota and South Dakota. From this mass of data came the then-surprising result: nests found later in development were more likely to be successful than those found earlier. Researchers soon discovered that Harold F. Mayfield had made a similar observation and had developed a method to address the bias. Doug Johnson went on to develop a variance estimator for Mayfield's method and a series of methods to estimate nest success under a variety of circumstances. These methods were widely adopted for nesting studies and were extended by Terry L. Shaffer in 2004 for more detailed analysis of factors affecting nest success.

The extensive studies of duck nesting by NPWRC staff and collaborators led to an enormous collection of nesting data and the development of a data repository, curated since 1992 by Thomas K. [Tom] Buhl. By 2015, the Center nest file included more than 143,000 records from 11 States and 3 Provinces and encompassed 54 species. In 1988, Klett, Terry Shaffer, and Doug Johnson published results of a detailed analysis of data from the Center nest file that provided compelling evidence that duck nest success in the U.S. PPR was below levels needed to maintain populations of most

Howard Thornsberry (left) with Forrest Lee (right) checking an artificial nesting structure for waterfowl.

species. These are but a few of many efforts that helped establish the NPWRC as a leader in generating information on duck recruitment.

The many studies of upland-nesting waterfowl also led to the growing recognition of the importance of tall, dense cover to nesting ducks. Kirsch observed higher nest success and density in idled (no management treatment) compared to grazed grasslands and recommended that lands managed for waterfowl production be periodically idled to maximize their return for waterfowl. Harold Duebbert and John Lokemoen noted the high duck nest densities and apparent nest success in grasslands established on retired cropland. Harold Duebbert promoted dense nesting cover (DNC)—a mixture of tall, robust grasses and legumes planted to benefit duck production. DNC produced dense residual cover for nesting waterfowl and had higher nest densities than other vegetative cover, such as native prairie or smooth brome (*Bromus inermis*). DNC became the preferred nesting cover planted on most public lands managed for waterfowl production.

Cartoon illustrating the need for dense nesting cover for ducks. Illustration by Mavis Meyer.

Meanwhile, other Center researchers focused their efforts on filling crucial information gaps about duck breeding biology. By the late 1960s, NPWRC biologists had established study sites across the PPR in the United States and Canada, into forested regions of Minnesota, and northward to the subarctic of Canada. NPWRC had one of the first wildlife disease specialists, Gary L. Pearson (Doctor of Veterinary Medicine), contributing to waterfowl research related to disease and mortality and also had a disease staff based at the Bear River Research Station located at Brigham City, Utah, (1969–72) to study avian botulism. Food habit studies were breaking new ground in understanding how wetland dynamics influenced waterfowl productivity. Existing knowledge in the 1950s and 1960s led to the widely held conclusion that ducks feed mostly on plants, which was based on examination of gizzard contents. George Swanson suspected gizzards did not accurately reflect foods consumed by ducks in prairie wetlands. By comparing food habits of blue-winged teal (*Spatula discors*) based on food items present in esophagi and gizzards, Swanson, working with James (Jim) C. Bartonek, determined that gizzard samples strongly underrepresented invertebrate consumption. His finding provided an impetus for further investigations that would lead to the discovery that macroinvertebrates served a vital role in fueling reproduction in prairie ducks.

Gary L. Krapu hypothesized that female dabbling ducks select animal foods because of their high protein requirements during egg production. Focusing on food habits of female northern pintails (*Anas acuta*), he showed that macroinvertebrates dominated the diet during the rapid follicular development and laying stages. Selection of animal foods during egg production was further substantiated in studies of gadwalls (*Mareca strepera*) by Jerome (Jerry) R. Serie and mallards (*Anas platyrhynchos*) by George Swanson and others. Jan L. Eldridge and Krapu followed up with an experimental study that showed that a diet consisting solely of plants resulted in reductions in clutch size, egg size, laying rate, number of nesting attempts, and total eggs laid. Based on studies in NPWRC's experimental ponds and sampling invertebrates in the field, Swanson determined that shallow wetlands, after being drawn down and then re-flooded, produced exceptional blooms of macroinvertebrates of the types sought by prairie waterfowl during reproduction. Together, the body of knowledge identifying dietary needs of prairie-nesting waterfowl and the role of shallow wetlands in supplying these needs became the impetus for expanded research on wetland-waterfowl relations and led to support for wetland conservation policies in the PPR, across North America, and elsewhere in the world.

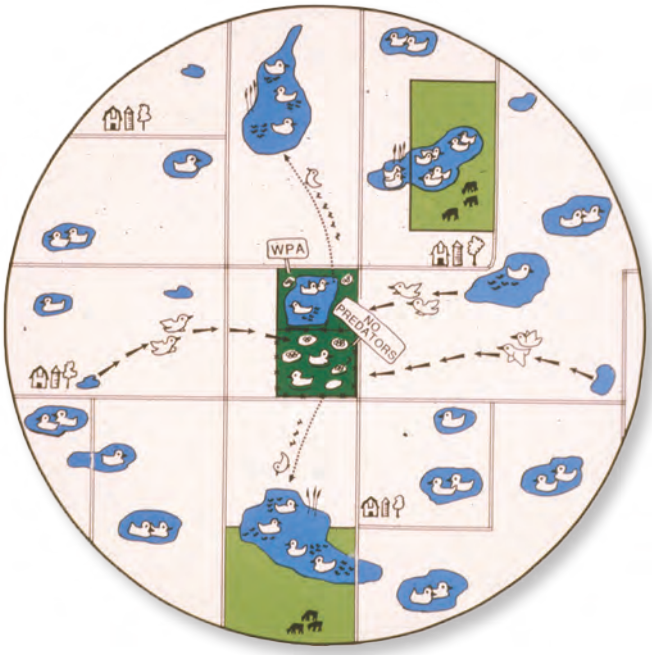
The finding that prairie ducks require a nutrient-rich diet during breeding also shed light on factors affecting distribution patterns of ducks at the landscape level in the PPR. Gary Krapu, Tom Klett, and Dennis G. Jorde used the North American May waterfowl population and pond surveys to show that mallard pair density was correlated with pond density, which varied with numbers of seasonal and temporary ponds present. John Lokemoen, Harold Duebbert, and David (Dave) E. Sharp

Bruce Hanson sieves aquatic invertebrates from a plexiglass invertebrate sampler at the edge of a wetland.

Harold Duebbert and Leo Kirsch prepare to mark a duck nest with a willow stick.

Dave Sharp and Harold Duebbert examine a banded blue-winged teal hen.

concluded that settling patterns also were influenced by nesting history; female mallards and gadwalls that had nested successfully at a site during the previous year were more likely to return to nest at the same site the following year. This finding had important implications to mallard and gadwall management because the potential existed for building high pair and nest densities. Such a situation was reported by Duebbert, Lokemoen, and Dave Sharp for a 4.5-hectare island in Miller Lake, N. Dak., in 1977, where nest success was high and the wetland base was sufficient to meet needs of nesting waterfowl. In 1987, a multifaceted follow-up study, the Small Unit Management Project, was initiated to test this hypothesis. The study involved many Center researchers and



Drawing illustrating the Small Unit Management Project.

Technicians take morphological measurements of a hen mallard in preparation for radio-marking.

its experimental design centered on the use of predator-proof exclosures and predator control to provide secure blocks of cover for nesting ducks. Although the study was cut short by extreme drought in the early 1990s, it provided a pathway for many important findings highlighted elsewhere in this document.

In related work, Doug Johnson compared settling patterns of waterfowl breeding in the midcontinent region by analyzing May pair and pond count data collected during 1955–81 and identified important differences in species' settling patterns linked to favored types of wetland habitats. Homing generally was more pronounced among species living in landscapes with wetland types that hold water in most years, such as redhead (*Aythya americana*), canvasback, lesser scaup (*Aythya affinis*), mallard, gadwall, and northern shoveler (*Spatula clypeata*). In contrast, there was opportunistic settling in species such as blue-winged teal and northern pintail, which are prone to shift their distribution between years to take advantage of newly flooded, shallow wetlands in landscapes with limited stable water. Together, NPWRC studies indicated wetland conditions and available wetland types strongly influence distributions of all prairie-nesting ducks, but settling strategies differ

John Lokemoen candles a duck egg to determine incubation stage.

widely among species. This knowledge is now widely considered by waterfowl managers when interpreting the results of May pair and pond counts, targeting management practices toward certain species or groups of species, and guiding conservation planning.

In several species of ducks, reproductive rate was noted to vary by hen age. David Trauger studied lesser scaup in the subarctic Yellowknife study area and determined that brood:hen ratios varied with age of the hen. Jerry Serie, David Trauger, and Jane E. Austin concluded that re-nesting effort, success, and return rate of canvasback hens breeding on the Minnedosa Study Area in southwestern Manitoba increased with hen age. Several NPWRC studies reported that younger and less experienced female mallards were less likely to breed initially or to re-nest. For example, John Lokemoen, Harold Duebbert, and Dave Sharp reported mallards and gadwalls were less likely to breed under very crowded conditions. These findings underscore the major influence of hen age on reproductive success in several species of prairie waterfowl and have implications for waterfowl management.

Above, Dave Trauger with nasal-marked lesser scaup.

At left, Jerry Serie weighs a male canvasback that was captured on the upper Mississippi River.

Early-nesting waterfowl such as mallards and northern pintails arrive and begin nesting before foods become plentiful in prairie wetlands. Studies of mallards by Gary Krapu in North Dakota and of canvasbacks by Jerry Serie and Dave Sharp in southwestern Manitoba determined that females acquire large fat reserves prior to nesting and channel a major part of their fat reserves into producing eggs, which makes it possible for early-nesting females to lay large clutches. Lewis M. (Lew) Cowardin led a study using radio-telemetry to examine factors influencing mallard recruitment in agricultural landscapes in North Dakota. He determined that the probability that female mallards produced eggs and the number of eggs laid were greater among females in better condition. Center research on fat reserve dynamics relative to egg production also served as a major impetus for research addressing cross-seasonal effects on waterfowl body condition and production. Studies in Nebraska's Rainwater Basin by Krapu, Robert (Bobby) R. Cox, Jr., and Aaron T. Pearse demonstrated the importance of this spring staging area for fat acquisition by greater white-fronted geese (*Anser albifrons*), snow geese (*Anser caerulescens*), and northern pintails. Aaron Pearse, collaborating with Ray Alisauskas (Canadian Wildlife Service), concluded that amount of fat stored by white-fronted geese at spring stopovers in Saskatchewan increased from the 1970s to the 1990s but was insufficient to fully compensate for the lost opportunity to store fat in the Rainwater Basin; as a result, pairs fledged fewer young. Pearse and Cox identified increased human activity in the Rainwater Basin during the annual spring conservation hunt of snow geese and declining availability of waste corn as important factors in changing fat acquisition in the Rainwater Basin. These findings have important implications to waterfowl populations that rely primarily on corn to acquire fat in preparation for reproduction. In the Rainwater Basin, Federal, State, and private waterfowl managers have undertaken a major wetland restoration effort, in part to broaden the distribution of spring staging waterfowl to help limit food shortages. These studies relating acquisition and use of nutrient reserves for reproduction have led to a more holistic approach to waterfowl management that takes into account habitat needs across seasons and have been used to support habitat conservation efforts on important wintering grounds and spring staging areas of waterfowl.

Gary Krapu holds a nasal-marked lesser scaup hen.

Renesting after a failed nest has a major influence on whether ducks are successful breeders in the PPR because of high losses among early nests. Several NPWRC studies have shown renesting effort in most species is highest during wet years, but limited insight existed about interspecific differences and the underlying factors involved. Existing theory held that all species of temperate-nesting ducks are absolutely photorefractory (that is, terminate breeding efforts under long day lengths), causing ducks to stop initiating nests by early summer. In 1993, a dry spring followed by heavy, late-summer rains provided a unique opportunity to test whether prairie ducks were absolutely photorefractory. Krapu capitalized on this unusual event by organizing a study using repeated brood surveys during 1993–95. That study revealed that mallard, gadwall, and blue-winged teal continued to nest into late summer (that is, were not absolutely photorefractory), whereas northern pintail and northern shoveler did not, demonstrating that mechanisms controlling the termination of breeding are more complex and varied than previously thought. Reduced renesting capacity observed for northern pintails, combined with a low nest success rate, provided insight into why the pintail has been the least capable of prairie ducks to maintain their continental population under growing agricultural intensification.

Early in the Center's history, NPWRC researchers recognized brood research to be a high priority. Movements, habitat use, and survival of ducklings were studied in the prairie potholes, forested wetlands of north-central Minnesota, and California marshes. Doug Johnson, James D. Nichols (Patuxent Wildlife Research Center), and Michael (Mike) D. Schwartz used a mathematical model to identify brood survival as the second most important factor (following nest success) limiting recruitment of mallards and other duck species. Gary Krapu, Pamela (Pam) J. Pietz, David (Dave) A. Brandt, Deborah (Deb) A. Buhl, and Bobby Cox, with help from many others, conducted a series of groundbreaking studies using radio-marked brood hens and miniature transmitters to monitor duckling mortality events and to identify causes of death, with study sites distributed across a broad prairie pothole landscape during dry and wet periods. These studies established that brood loss was much higher than previously thought and furnished new insights into factors limiting brood survival. Findings reinforced conclusions from other NPWRC studies that seasonal wetlands are vital in maintaining high duck productivity in prairie pothole landscapes and also underscored the value of maintaining high nest success rates of early clutches. Predation by American mink (*Mustela vison*), the primary duckling predator, was reduced

Canvasback hen with ducklings.

Marsha Sovada holds an American mink after attaching a radio collar, 1979.

Lew Cowardin examines wetland maps.

during post-drought periods in landscapes with few permanent wetlands. Exposure to cool, wet conditions was an important determinant of brood loss rate. A study of canvasback ducklings at Agassiz NWR by Carl E. Korschgen, Kevin P. Kenow, and William (Bill) L. Green highlighted the significance of exposure to adverse weather conditions in duckling survival; this finding later led Korschgen and Kenow to examine heat loss in ducklings and effects of transmitter attachment methods. These results and others provided waterfowl managers with a greatly improved understanding of factors limiting brood survival along with improved estimates of mallard brood survival rate for the Mallard Model, an important tool for predicting annual mallard recruitment rates within portions of the PPR.

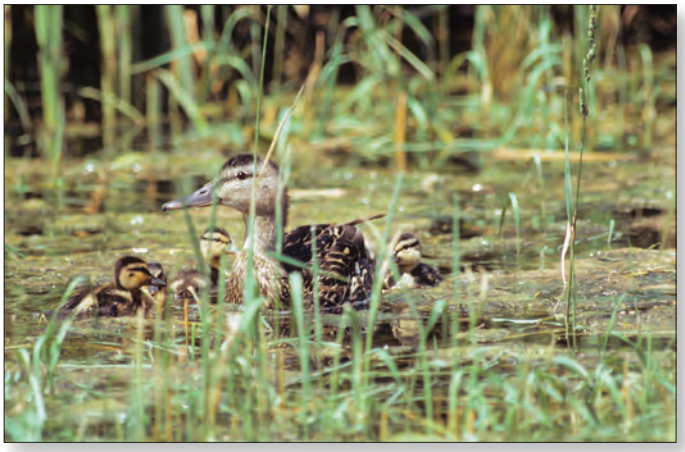
The Mallard Model started when Doug Johnson and Alan (Al) B. Sargeant (Sarge) approached several NPWRC researchers who were studying various aspects of duck breeding biology. Johnson and Sargeant were enthused about the use of models after using them to examine the role of red fox (*Vulpes vulpes*) predation on nesting mallards in creating disparate sex ratios. The idea they broached was for all to focus on a single species (the mallard), study it in a comprehensive manner, and use a model to combine information and identify the most fruitful avenues for further research. Lew Cowardin quickly recognized the value of the modeling effort. He initiated a major radio-telemetry study of breeding mallards to evaluate assumptions made in the Mallard Model and to provide better estimates of parameters in the model that were poorly known. His research team, known as the "Mallard Mafia," included a number of seasonal employees who would go on to have exemplary careers in the wildlife profession.

Cowardin realized that the Mallard Model, although initially intended to guide research, could be valuable for addressing questions from waterfowl managers. This recognition led to the application of the Mallard Model to a number of management issues, including planning a new waterfowl refuge, examining management options within wetland

Deb Buhl monitors signals from radio-marked ducks from a pickup truck.

management districts, projecting the outcome of installing a large number of nest structures throughout the PPR, and many more. In a related development, Cowardin, working with Phillip (Phill) M. Arnold (FWS and later with NPWRC), recognized that certain components of the Mallard Model could address a critical need of waterfowl managers to provide annual estimates of breeding duck numbers and productivity from public and private lands in the U.S. portion of the PPR. The team developed a method using remote sensing to identify annual wetland conditions on 4-square-mile plots and duck pair-pond regression models first developed by Doug Johnson and later expanded by Terry Shaffer. The Mallard Model and what became known as the Four-square-mile Survey were so influential they spurred the formation of two FWS HAPET offices, one in Bismarck, N. Dak., and one in Fergus Falls, Minnesota, in 1990. The Four-square-mile Survey continues today as an operational FWS survey and provides a cornerstone for many conservation delivery decisions by Prairie Pothole Joint Venture (PPJV) partners. Perhaps the most powerful and widely used tool in the PPJV's arsenal, and a product of the Four-square-mile Survey, is the so-called thunderstorm map, brainchild of long-time HAPET leader and NPWRC alumnus, Ronald (Ron) E. Reynolds. The thunderstorm map identifies areas with greatest potential for duck production throughout the PPJV area based on land cover, wetland data, and species ecology. The Mallard Model and Four-square-mile Survey have been subsequently refined and improved by NPWRC and HAPET staffs.

Waterfowl managers have long recognized the importance of waterfowl production on private lands. A long-standing focus of Center research has been the role of various cropland retirement programs, such as the USDA's Water Bank, the Cropland Adjustment Program (CAP), and most recently the Conservation Reserve Program (CRP), in providing critical habitat for nesting ducks. Harold Duebbert, studying CAP fields in the early 1970s, and Hal Kantrud, working in CRP fields in the early 1990s, were first to demonstrate the potential of large-scale cropland retirements to enhance duck nest success. In one of the largest duck-nesting studies ever, Terry Shaffer and Wesley (Wes) E. Newton, in collaboration



Mallard hen with ducklings.

Clay-colored sparrow nest with clay-colored sparrow eggs and brown-headed cowbird eggs in South Dakota.

with Ron Reynolds and other PPJV partners, demonstrated a game-changing positive relation between the amount of perennial cover at the 4-square-mile landscape scale and duck nest success. They went on to show that, during peak enrollment years, the CRP was responsible for an additional 2 million ducks in the fall flight each year. This finding played a critical role in various congressional re-authorizations of the CRP and designation of the PPR as a priority area for the CRP.

The Center's mandate to provide scientific information needed by decision makers at flyway and national levels laid the foundation for international cooperation and partnerships early on. Early study locations ranged from the Beaufort Sea, arctic and subarctic Alaska and Canada, and the Great Slave Lake in the Northwest Territories, throughout the prairie Provinces of Canada, to the wintering grounds in California and Mexico. This long-time relation between Canadian and Center biologists (and other State and Federal biologists in the United States) fostered the single most extensive international waterfowl recruitment study in North America: the Stabilized Duck Hunting Regulation Study (1979–85). The breeding-ground portion of the study, led by Raymond (Ray) J. Greenwood and Al Sargeant, was designed to provide an understanding of breeding populations, availability of breeding habitats, and rates of nest success and recruitment. The ultimate goal was to evaluate factors regulating duck populations and to determine management actions needed to ensure adequate populations. The Center's contribution was paramount, providing an assessment of nest success and recruitment rates at multiple locations throughout the PPR of Canada. Results provided estimates of temporal and spatial variation in nest success; identification of principal causes of nest failures; identification of predator species composition, densities, and spatial distribution; and estimates of mallard recruitment rates. A bonus of the research was exposing nearly 100 seasonal technicians to the biology of breeding waterfowl across the prairie Provinces and providing a solid foundation for the many who went on

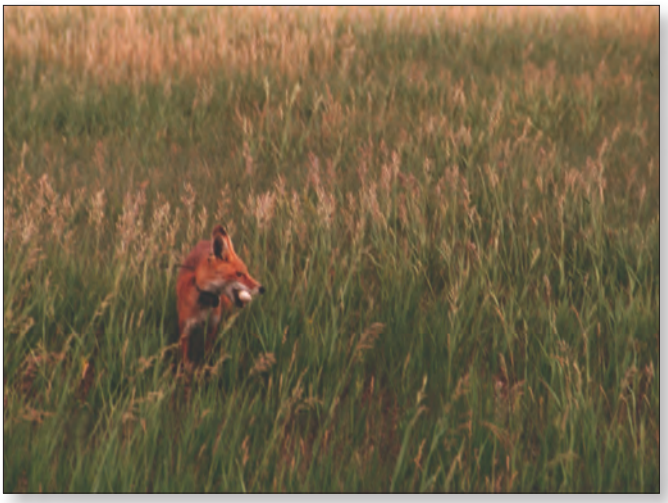
to leadership positions influencing waterfowl management and research.

In the 1970s and 1980s, Al Sargeant and Ray Greenwood conducted research to understand the role of predators in waterfowl population dynamics. Their research was the first to document that predation was the major factor influencing waterfowl recruitment and that the high levels of predation in modern landscapes reflect changes in land use and predator community composition, changes brought on by European settlement in the region. Sargeant and Greenwood, later joined by Jim Piehl and Marsha A. Sovada, conducted studies on many predator species, gaining insights into their biology as well as the dynamics of the predator community, interactions among the predator species, and the role of alternative prey species for mitigating predation pressure on nesting birds. Some of the greatest gains in development of management tools were a result of studies that examined the basic biology of the predator species. For example, the devastating impact of red fox predation on duck hens and duck nest success, coupled with information on interspecific relations between red fox and coyote (*Canis latrans*), helped explain why some areas were more productive than others and why duck nest success increased as coyote populations expanded across the region. Studies by Sargeant and colleagues evaluating the efficacy of predator removal as a means of increasing duck production were complemented with investigations by John Lokemoen, who examined the economics of using naturally occurring or constructed peninsulas and islands to exclude predators from duck-nesting areas.

In the 1990s and 2000s, the predator research program evolved to address more complex questions. These later studies focused on understanding the linkages among grassland landscapes, waterfowl productivity, predators, and their alternative prey within the context of practical management concerns. Sovada, Greenwood, and Rolf R. Koford collaborated with Minnesota Department of Natural Resources biologists to examine the influence of grassland fragmentation and patch size on nest predation and predator activity. That study led to another conducted by Sovada, Greenwood, and collaborators from Iowa State University and Ducks Unlimited to evaluate how nest success and the use of habitats by predators vary in relation to grassland conditions, wetland density, and landscape configuration. The study provided new insights for managing habitat composition at a landscape scale to enhance recruitment.

Jim Piehl and Carol Nustad collect grassland vegetation data, 1982.

By the early 1970s, there was growing recognition of the importance of the wintering period and cross-seasonal influences to waterfowl populations. The NPWRC established two field stations in California: the Arcata Field Station in 1973, led by Paul F. Springer, and the Dixon Field Station in 1979, under the leadership of David S. Gilmer; a substation was also maintained at the Kern NWR for several years, led by Douglas A. Barnum. The field stations were well placed to address ongoing concerns about habitat loss, contaminants, and ecology of wintering waterfowl in California and Oregon.



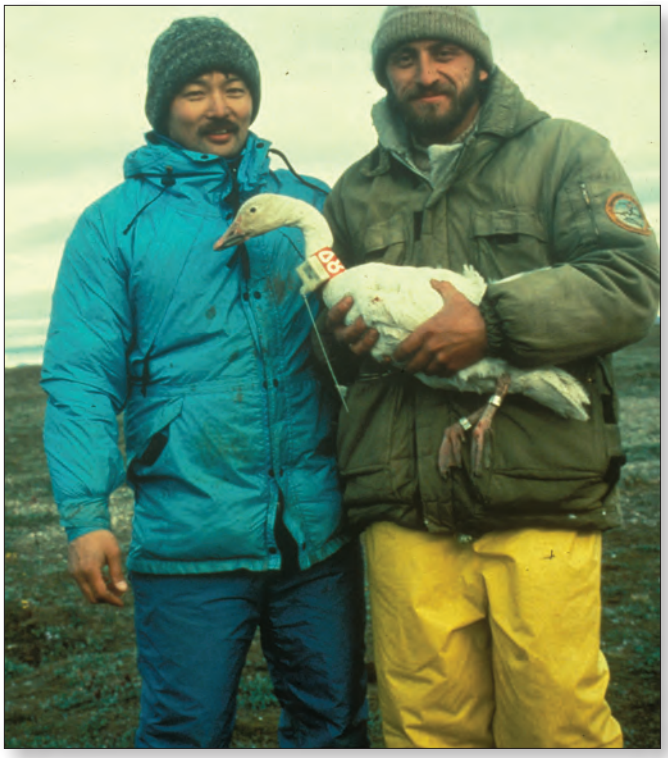
A radio-collared red fox in a grassland carries a duck egg in its mouth.

Wayne Norling tracks radio-marked ducks with a hand-held yagi antenna.

Springer led pioneering work on the tule greater white-fronted goose (*Anser albifrons elgasi*) and the endangered Aleutian Canada (now cackling) goose (*Branta hutchinsii leucopareia*). Research by Dixon staff encompassed a broad range of ecological issues and built a more complete understanding of the impacts of irrigation drain-water contamination and wintering waterfowl ecology to guide water, habitat, and population management. Michael (Mike) R. Miller, along with Joseph (Joe) P. Fleskes and Dennis L. Orthmeyer, developed a comprehensive research program on the wintering ecology of northern pintails, including survival, feeding ecology, nutritional dynamics, population energetics, habitat use, harvest, and the role of rice and wet/dry periods to wintering birds. Dave Gilmer contributed to early applications of telemetry and remote sensing for migratory waterfowl habitat in the Pacific Flyway. John Y. Takekawa led investigations on survival and population dynamics of lesser snow geese and white-fronted geese in the flyway. Results from these studies have been instrumental in guiding wetland management and harvest policies in the region and provided a valuable foundation for continued research and management of wintering and migratory waterfowl in the Pacific Flyway. In 1993, the Dixon Field Station and staff were assigned to what is now the Western Ecological Research Center.

During the 1950s and 1960s, severe degradation and loss of riverine habitat in the northern portions of the Mississippi Flyway shifted migrating diving ducks away from traditional concentration areas, which led to increasing concerns among waterfowl biologists. In 1977, a Center field station was established in La Crosse, Wisconsin, under the leadership of Carl Korschgen, to serve as a focal point for research on migrating diving ducks and other waterbirds, particularly in the Upper Mississippi River system. Early research was linked to the Center's studies of breeding canvasbacks at Minnedosa, Manitoba, Canada, and documented the importance of navigation pools on the Upper Mississippi River Navigation (Pools 7, 8, and 14) as fall staging areas for canvasback, then a species of special concern. NPWRC studies by Jerry Serie, David Trauger, and Dave Sharp demonstrated that the intensive use of the Mississippi River by canvasback and other diving ducks was directly related to the diverse and abundant food resources available. A suite of studies on the navigation pools led by Carl Korschgen, with Kevin Kenow, Bill Green, and others, revealed the importance of American eelgrass (*Vallisneria americana*; also known as wild celery) to canvasback during fall stopovers, provided information on factors influencing aquatic food productivity, and documented the impact of hunting and boating disturbances to staging diving ducks. Research on migratory and wintering diving ducks in the

Waist deep in waters of the upper Mississippi River, a technician pulls up a mass of Potamogeton vegetation while a second technician stands nearby holding a galvanized tub.



John Takewaka and Russian colleague hold a satellite-marked snow goose, Wrangel Island, Russia, 1991.

Technicians transfer canvasbacks from a swim-in trap to a holding box on an upper Mississippi River pool.

region also extended to the Great Lakes. Christine M. Custer's research on the Great Lakes was among the first to highlight the importance of invasive zebra mussels (*Dreissena polymorpha*) as food for staging diving ducks. These projects laid the foundation for the long-term management of these pools by the Upper Mississippi NWR and the U.S. Army Corps of Engineers and for the continuing research on this system by the USGS. In 1993, the La Crosse Field Station and staff were assigned to what is now the Upper Midwest Environmental Sciences Center.

A technician sets up a miniature camera to monitor predator and parental activity at a grassland songbird nest.

Unprecedented declines in the continental populations of greater and lesser scaup (*Aythya marila* and *Aythya affinis*) starting in 1985 generated substantial concern among biologists and waterfowl hunters. Jane Austin led a series of workshops to explore the challenges to the scaup population with biologists and managers from the United States and Canada and initiated development of a strategic, biologically based decision framework for a scaup conservation action plan. The prototype framework that emerged from this collaborative effort was among the first to encompass the revised goals of the North American Waterfowl Management Plan, integrating objectives for waterfowl populations, habitat conservation, and societal needs and desires.

A semi-permanent wetland in Stutsman County, North Dakota.

Other Birds

Sandhill Cranes

The NPWRC has played a pivotal role in providing information sought by managers of the Midcontinent Population (MCP) of sandhill cranes (*Grus canadensis*). The MCP is widely hunted and has the lowest annual recruitment rate of North American game birds; hence, Central Flyway biologists sought detailed insight into population dynamics. An early effort involved collecting sandhill cranes migrating through North Dakota to determine what fraction of them were greater sandhill cranes (*Grus canadensis tabida*), considered a rare subspecies by FWS. From that effort, Doug Johnson and Bob Stewart developed a statistical tool for managers and biologists to assign individual cranes to migratory subspecies based on morphological measurements.

Part of the focus of the MCP studies has been on habitat requirements of cranes in the Central Platte River Valley in south-central Nebraska, where about 80 percent of the population stages in spring. By the 1970s, intense competition among States and irrigators for greatly reduced flows of the Platte River threatened the use of the Central Platte River Valley by the MCP and the Aransas/Wood Buffalo population of whooping cranes (*Grus americana*). Gary Krapu, with major contributions by Kenneth J. Reinecke (Patuxent Wildlife Research Center), led the Platte River Ecology Study; they assessed sandhill crane requirements during their annual stopover and evaluated how loss of this migration stopover might impact the population. The final report became a major source of information used by crane managers for the next two decades on issues pertaining to sandhill crane use of the Central Platte River Valley ecosystem. The Central Platte River was designated as critical habitat for whooping cranes in 1978, and Krapu served as the Government's biological expert on sandhill and whooping crane use of the Central Platte River Valley during several legal challenges to the critical habitat designation.

Aerial view of braided river and sandbar habitat along the central Platte River, Nebraska.

In 1997, the USGS initiated a Platte River Ecosystem Initiative. NPWRC scientists contributed the biological studies, investigating sandhill cranes (Gary Krapu and Dave Brandt), invertebrate food resources for cranes in riparian meadows (Jane Austin and Janet R. Keough, in collaboration with scientists from the Whooping Crane Maintenance Trust), avian response to meadow restoration (Doug Johnson), and habitat use by staging waterfowl (Bobby Cox). Gary Krapu initiated a comprehensive, 10-year study to re-examine the role of the Central Platte River Valley for MCP cranes, along with an examination of the contribution of other stopover sites in meeting crane needs. The resulting monograph authored by Krapu, Brandt, Paul J. Kinzel (USGS Geomorphology and Sediment Transport Laboratory), and Aaron Pearse summarized key findings and identified factors influencing length and pattern of stay, habitat use, and the growing scarcity of waste corn vital to cranes' acquisition of lipids for migration. Results provided crane managers throughout the Central Flyway with updated insight into crane habitat needs and how the MCP had adjusted to major changes in the Platte River ecosystem. In addition to the re-assessment of the Central Platte River Valley for cranes, Krapu and Brandt expanded the crane research using satellite telemetry to study the MCP across its entire range in North America and northeastern Asia. Results of that effort identified four subpopulations for management purposes and a means to identify size and distribution of harvest by subpopulation, documented spatial and temporal distributions, and allowed estimates of annual recruitment by subpopulation.

Two technicians collect waste corn samples in a harvested field in early spring in Nebraska.

Dave Brandt (front left) works with colleagues to attach colored leg bands and a satellite transmitter to an adult whooping crane.

Together, these findings provided Central Flyway resource managers with key baseline information on the MCP that will help guide future population management. An unexpected finding was that 23 percent of the MCP, or 140,000 sandhill cranes, breed in northeastern Russia in an area that extends from the eastern edge of the Chukchi Peninsula bordering the Bering Strait to near the Lena River Delta, 2,400 kilometers west into Russia.

Center scientists also have made significant contributions to improved survey methods for sandhill cranes. Doug Johnson has collaborated with crane managers from across North America since the 1970s to develop more reliable survey techniques, analyze crane survey data, and interpret results. Johnson worked with Flyway pilot Douglas S. Benning to use high-altitude photography on the Central Platte River Valley in spring to provide reliable annual estimates of the size of the MCP. Recognition of the survey's limitations led Center scientists to investigate other approaches, such as use of infra-red videography and comparison of survey data to locations of the large number of radio-marked cranes from the Platte River study.

For many decades, biologists assumed there were three subspecies of sandhill cranes, but one subspecies (*Grus canadensis rowani*) had been classified based on a very limited sample of morphological data. Gary Krapu, Jane Austin, Doug Johnson, and Dave Brandt contributed to three genetics studies that indicated *Grus canadensis rowani* should be considered a transitional form and included within *Grus canadensis tabida*.

Controversy over habitat management and crop depredation problems in southeast Idaho led to a 4-year study of breeding and population ecology of greater sandhill cranes at Grays Lake NWR. Jane Austin, collaborating with Joe Ball and Adonia R. Henry at the Montana Cooperative Wildlife Research Unit, determined that the number of breeding crane pairs was similar to that reported in the early 1970s but nest success rates had declined; water levels affected nest survival more than grazing or burning. Study results have contributed to the refuge's comprehensive conservation and habitat management plans, monitoring protocol for spring and fall populations, and negotiations over water management.

Adult American white pelicans at their nests at Chase Lake National Wildlife Refuge, North Dakota, 2009.

Adult male bobolink in grassland field in Montana, 2010.

Nongame Birds

Although the original mission of the NPWRC focused on research related to waterfowl production and wetland ecology, the Center has had a long history of research on nongame migratory birds that has encompassed multiple ecological levels (species, population, community, ecosystem) and spatial and temporal scales. Research and scientific inquiry on nongame birds began at the NPWRC in the early 1960s by Bob Stewart and Hal Kantrud. By the time the Center officially opened its doors in 1965, Stewart and Kantrud already had spent considerable time in the field developing sampling protocols and gathering information on avian and plant species and their distribution and habitats in the northern Great Plains. These early studies set the foundation for future research on nongame birds in grasslands, wetlands, agro-ecosystems, and other habitats in this region. Stewart's extensive field work and knowledge of avian species were encapsulated in his 1975 book, "Breeding Birds of North Dakota," which remains a primary resource about breeding birds in the State.

Stewart and Kantrud's pioneering study of breeding birds throughout North Dakota in 1967 provided important baseline data for Center scientists and other agencies (for example, USDA) to evaluate subsequent changes (for example, 1992–93) in statewide breeding bird populations. Through time, Center scientists built upon these formative studies on nongame birds to address questions related to grassland bird response to disturbance (natural and human-induced), changes in land use and cover, biological invasions (for example, leafy spurge [*Euphorbia esula*]), USDA Farm Bill programs (for example, Soil Bank, CRP), water development (stock dams and ponds), energy development (wind, oil and gas), changes

in local and regional climate, habitat restoration, and habitat fragmentation (for example, Grassland Bird Conservation Area concept). For example, Hal Kantrud and Russell (Rusty) L. Kologiski surveyed breeding birds across six States in the northern Great Plains and identified optimal habitat for different bird species in terms of grazing, soils, and dominant plant species. John Lokemoen was among the first to examine the effects of minimum-tillage, organic, and conventional farming practices on ground-nesting birds (passerines, waterfowl, and shorebirds). Pam Pietz translated the body of knowledge amassed on waterfowl nest predation into new studies to better understand the effects of predation and land management practices on grassland-nesting passerines. Studies by Doug Johnson, Lawrence (Larry) D. Igl, Jill A. Dechant (later Shaffer), Craig Faanes, Rolf Koford, and Abby N. Powell, as well as numerous graduate students, have contributed to our broader knowledge of avian ecology.

Several Center studies highlighted the value of long-term over short-term approaches to studying grassland and other nongame birds, including Doug Johnson's long-term evaluation (1971–2013) of breeding bird response to burning in the mixed-grass prairie at the Woodworth Study Area and Johnson and Igl's ongoing study (1990–present) of breeding bird use of grasslands enrolled in the Conservation Reserve Program in nine counties in four States in the northern Great Plains. The latter study was instrumental in demonstrating the benefits of Farm Bill programs for grassland birds.

The Center's expertise and leadership in avian ecology have proven beneficial for research on grassland birds and other nongame birds and have attracted new partners and cooperators. In 1993, the Center established the Grasslands Ecosystem Initiative. For more than a decade, the Initiative served as a focal point for studies on grassland birds and other topics in the Great Plains. The Initiative also served as a catalyst for information dissemination among partners and the general public, including the development of the Center's award-winning website and the extensive review and synthesis of literature on the effects of management practices on grassland birds. Together, past and recent studies have helped to develop the knowledge base essential for ecologically sound management of habitats for grassland and other nongame birds in this region. The current scientific program and expertise placed NPWRC in a strong position to address emerging issues and challenges facing management and conservation of grassland and other nongame birds in the region.

Studies of nongame waterbirds have emphasized population biology, habitat use, and resource needs of species such as marbled godwits (*Limosa fedoa*), willets (*Tringa semipalmata*), American avocets (*Recurvirostra americana*), yellow rails (*Coturnicops noveboracensis*), and black-crowned night herons (*Nycticorax nycticorax*). Research largely focused on conservation of these populations and improved management of their habitats. For example, a study by Jane Austin and Janet Keough at Grays Lake NWR, a large montane wetland system in southeastern Idaho, examined the abundance and responses of waterbirds, waterfowl, and the plant community to grazing, burning, and idle management practices. Studies by Jan Eldridge and Gary Krapu demonstrated the vital role of dipteran larvae in prairie wetlands to *Calidris* sandpipers for accumulating fat reserves that fuel spring migration and supply part of their reproductive needs. Starting in the mid-2000s, there has been a special focus on American white pelicans (*Pelecanus erythrorhynchos*) because of severe production failures at several colonies. Studies by Marsha Sovada, Pam Pietz, and others revealed pelicans' unique susceptibility to West Nile virus and a decline in productivity that is linked to climate change. Ongoing studies continue to assess pelican ecology.

Technician surveying grassland birds in a Conservation Reserve Program field in northeastern Montana, 2008.

Imperiled Species

The Center has contributed its expertise to the restoration, ecology, and management of a number of imperiled birds and mammals. The first program focused on the restoration of giant Canada geese (*Branta canadensis maxima*) and the Aleutian Island subspecies of Canada geese (now classified as cackling geese). Giant Canada geese, once believed extirpated, were rediscovered in Minnesota in 1962. Hired in 1965, Forrest B. Lee pioneered waterfowl propagation and husbandry techniques and raised thousands of birds for release in North Dakota. Lee worked closely with State and FWS biologists in North Dakota and South Dakota to successfully restore breeding populations of giant Canada geese in the region. The techniques developed by Lee were widely disseminated to Federal and State recovery programs across the United States during the 1960s and 1970s and were an important contribution to the full recovery of the subspecies. Lee's waterfowl propagation expertise also was a major contributor to an international effort with Japan and Russia to restore cackling geese to the Aleutian Islands. Paul Springer analyzed band recoveries and field data and discovered important wintering habitat used by this species; his recommendation of no hunting in critical areas used by the wintering birds resulted in an immediate recovery of the species. These combined efforts led to the removal of Aleutian cackling geese from the endangered species list in 2001.

Pair of Canada geese on water.

Forrest Lee holds a Giant Canada goose.

Carnivore species of special concern, such as the gray wolf (*Canis lupus*), swift fox (*Vulpes velox*), island fox (*Urocyon littoralis*), and Canada lynx (*Lynx canadensis*), also have been the focus of research and conservation efforts by Center scientists. Studies focused not only on the ecology of these species but also on the issues surrounding them, which often are contentious. Marsha Sovada served on recovery teams and conducted field research on swift fox and the endangered island foxes. Her research objectives for swift fox included assessment of population status, evaluation of factors affecting populations, and understanding the ecology of the fox species and predator-prey relationships. Ultimately, the information gathered provided managers with the foundation to develop effective management plans and to provide the fundamentals for managers to respond to the concerns of the public. For island foxes, Sovada collaborated with the St. Louis Zoo to assess factors that influence reproductive success with research conducted on captive populations located on two Channel Islands that are occupied by island foxes. In 2016, the FWS removed the San Miguel (*Urocyon littoralis littoralis*), Santa Rosa (*Urocyon littoralis santarosae*), and Santa Cruz (*Urocyon littoralis santacruzae*) Island fox subspecies from the List of Endangered and Threatened Wildlife because of increased populations. This remarkably rapid recovery of the island fox demonstrates the power of partnerships, focus, and science.

L. David (Dave) Mech and Michael E. Nelson were assigned to the NPWRC in 1999, bringing the Wolf Project to the NPWRC. Mech has studied wolf ecology and behavior

Marsha Sovada holds a fox pup dug out from its den, 1996.

and the species' role within the ecosystem for half a century, largely in Minnesota but also throughout the world. Along with Shannon M. Barber-Meyer, hired to replace the retiring Nelson in 2011, Mech developed a broad research program that involved many aspects of predator-prey relationships, such as the role of prey nutrition in buffering wolf depredation of game animals and livestock, dynamics of prey populations such as white-tailed deer (*Odocoileus virginianus*) and moose (*Alces alces*) in Minnesota and elk (*Cervus elaphus*) in Yellowstone National Park, and dispersal of Canada lynx from Canada to Minnesota. Mech and Barber-Meyer continue to monitor the wolf population in the Superior National Forest to evaluate factors such as diseases that affect long-term population trends. These studies provide insights that are useful to recovery and restoration of populations and for building more realistic population models. Findings allow managers and administrators to assess the progress of restoration programs and recovery of wolves and to anticipate the biological and the political problems that might arise.

Large river ecosystems are a major feature of the midcontinent landscape and provide important habitat for migratory birds during breeding and migration. Federally listed piping plovers (*Charadrius melodus*) and least terns (*Sternula antillarum*) nest on sandbars and shorelines on several major midcontinent river systems, including the Platte and Missouri

Swift fox holding a ground squirrel in its mouth near its den.

Radio-collared gray wolf.

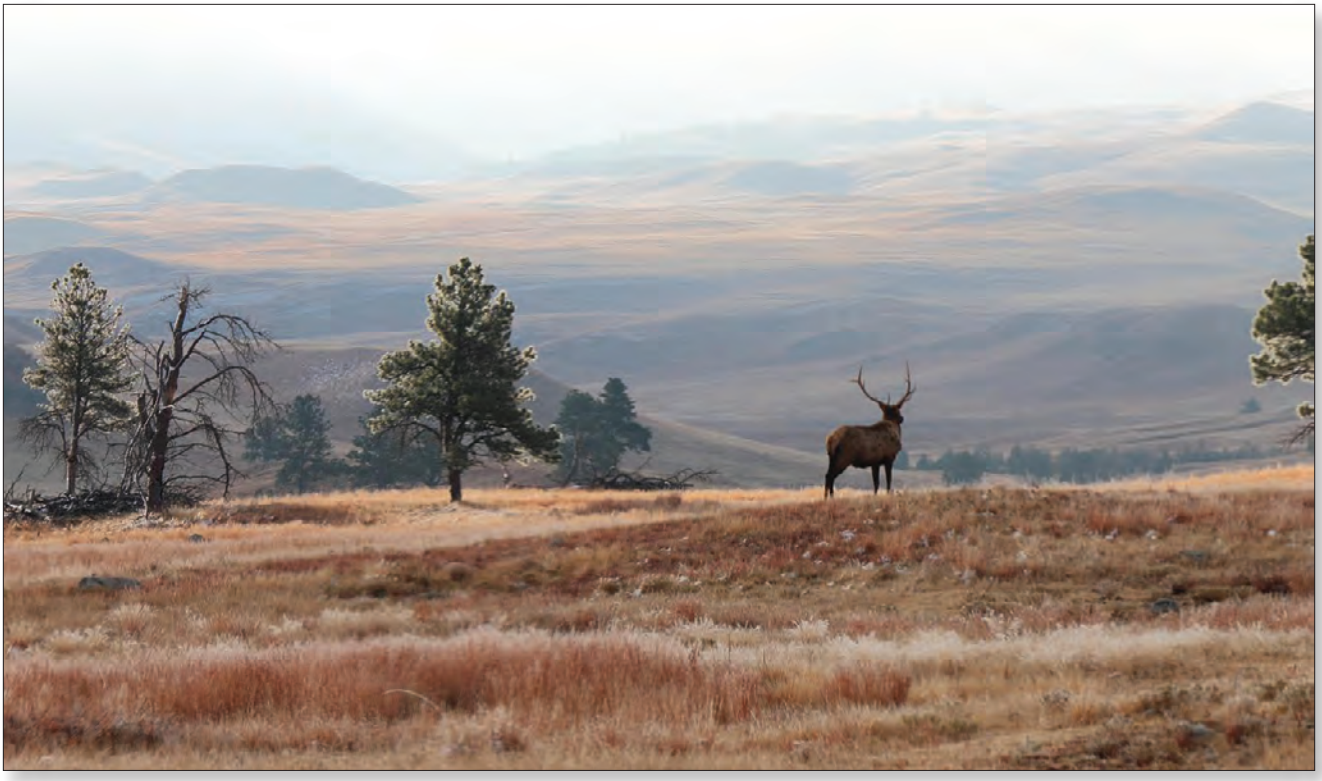
Rivers. Both river systems have been hydrologically altered by construction of dams and water withdrawals, with subsequent effects on abundance and quality of nesting habitat for these species. In 2005, the Center's long-term expertise in migratory bird research led to an invitation from the U.S. Army Corps of Engineers to develop a major research effort focused on quantifying the importance of the upper Missouri River system and understanding relations between management of the system and responses by piping plovers and least terns. The Center's research team (Michael [Mike] J. Anteau, Colin M. Dovichin, Erin A. Roche, Terry Shaffer, Mark H. Sherfy, Marsha Sovada, Laurence [Larry] L. Strong, Jennifer H. Stucker, and Mark T. Wiltermuth) has had a major presence on the upper Missouri and Platte River systems ever since. Studies revealed the importance of fluctuations in reservoir water levels to Missouri River plovers and identified conditions under which reservoirs function as a population sink. Another study uncovered major biases in the long-term population monitoring program for both species and proposed improvements to the program, many of which are being implemented. Evaluation of nest-site selection by least terns at multiple scales revealed important differences between natural and constructed sand bar habitat and the importance of scale in estimating available habitat. Other work included investigating effects of the 2011 flood on tern and plover demographics and a large-scale mark-resight study to better understand the role of the upper Missouri River system in achieving recovery goals for the northern Great Plains population of piping plovers.

Beginning in 2009, Aaron Pearse and Dave Brandt began an ambitious research effort with collaborators from the FWS, Canadian Wildlife Service, and several nongovernmental organizations to study the Aransas-Wood Buffalo population of endangered whooping cranes (*Grus americana*). The Center's experience and innovative techniques to capture and mark sandhill cranes provided the necessary foundation for this effort to be successful. This study of wild whooping cranes using Global Positioning System (GPS) technology represents a significant opportunity to enhance understanding of whooping cranes and to assess risks they face during their entire life cycle.

Large Mammals

Although ungulates in general are not Federal trust species, under special circumstances the expertise of Center scientists has been called upon to address issues of concern. In partnership with the National Park Service, Glen A. Sargeant has been investigating ungulates in national parks of the northern Great Plains. His studies focused on population dynamics of elk that had been restored to Wind Cave and Theodore Roosevelt National Parks. Sargeant developed models to project growth, forecast management needs, and compare the likely consequences of different management strategies. Greater knowledge about the populations emerged as a critical information need for management agencies because chronic wasting disease was detected in the Wind Cave population. In another effort, a faltering moose population in Minnesota evoked a partnership among Dave Mech, Mike Nelson, and the State of Minnesota to study the effects of climate change on moose populations.

Elk cow and her calf at Theodore Roosevelt National Park, North Dakota. Photograph courtesy of National Park Service.



Bull elk in the rolling grasslands of Wind Cave National Park, South Dakota. Photograph courtesy of National Park Service.

Wetlands

Given the innate ties between waterfowl and the wetland habitats they require, it is no coincidence that waterfowl research and wetland research at the NPWRC have gone hand-in-hand. In the late 1950s, faced with the possibility that irrigation and wetland drainage would change the hydrological characteristics of wetlands on the prairie pothole landscape, the USGS initiated detailed studies of prairie wetland hydrology. These studies initially focused on evapotranspiration from wetlands in different parts of North Dakota but were later expanded to examine wetland relations with groundwater. Beginning in 1961, Bob Stewart and Hal Kantrud surveyed vegetation of some of the same wetlands. Stewart and Kantrud's work led to understanding the range of salinity and water permanence tolerated by different plant species and subsequently the development of their wetland classification system for prairie wetlands based on diagnostic plant communities. That classification system, published in 1971, remains recognized continentally and often serves as an important guide in wetland and waterfowl studies.

The first effort by the FWS to conduct a national inventory of wetlands was initiated in 1954 based on 20 wetland types identified in FWS Circular 39. That publication was valuable and influential at the time but had a number of recognized shortcomings. Numerous other wetland classification systems were developed in the 1970s, including that of Stewart and Kantrud, which intentionally focused on the glaciated pothole region. As the FWS planned the next national wetland inventory in the 1970s, a new classification system was needed that incorporated new knowledge of wetland ecosystems and provided greater uniformity in concepts and terminology applicable across all wetland types in the Nation. Lew Cowardin worked closely with colleagues Virginia Carter (USGS–Reston), Francis C. Golet (University of Rhode Island), and Edward T. LaRoe (National Oceanic and Atmospheric Administration) to develop what is now the official FWS wetland classification system and the Federal standard. This hierarchical classification system has been instrumental not only in inventorying and mapping wetlands at multiple scales but also as an aid to researchers investigating ecosystem function and services.

Hal Kantrud stands along a barb-wired fence in native mixed-grass prairie.

Robert Stewart consults a plant taxonomy guide to verify the identities of voucher herbarium specimens.

Cottonwood Lake Study Area

In an effort to understand factors affecting use of various wetland types by waterfowl, during 1966–76 George Swanson began a study of the chemical characteristics of wetlands and small lakes. In this first extensive study of prairie wetlands and lakes, Swanson and NPWRC chemist Vyto A. Adomaitis found a wide range in water salinity and chemical composition and noted that observed salinity differences were likely due to variations in the influence of groundwater. Armed with this knowledge, Swanson teamed up with Thomas (Tom) T. Winter, a research hydrologist with USGS in Lakewood, Colo., to develop a "grass roots" interagency research program to define hydrological characteristics and processes responsible for changes in water level and the biological communities of prairie wetlands. Winter and Swanson selected a complex of 16 wetlands on a waterfowl production area near Woodworth, N. Dak., now known as the Cottonwood Lake Study Area, for their investigations. James (Jim) W. LaBaugh, a USGS research chemist also at Lakewood, joined the team in 1979 to assist Swanson with explorations of the relations among wetland chemical characteristics, hydrological characteristics, and wetland biota at the site. In 1983, the chemical laboratory at the NPWRC closed and LaBaugh assumed responsibility for all water chemistry work associated with the

George Swanson stands next to an aluminum boat rigged with an aquatic invertebrate sampler.

Cottonwood Lake Study Area efforts until 1993, when Richard (Rick) D. Nelson, from the Bismarck Office of the Bureau of Reclamation, took over that component. Donald Rosenberry, a USGS research hydrologist at Lakewood, joined the team in 1985, assisting with instrumentation of the site and research focusing on nearshore changes in flows between groundwater and wetlands.

Through the NPWRC's dedication to the study of waterfowl and prairie wetlands, the increasingly comprehensive Cottonwood Lake Study Area datasets and ongoing process-oriented research have served as a magnet, attracting researchers from a number of universities and other Government agencies. This interest has resulted in cooperative studies on wetland soils, sedimentation, greenhouse gas exchange/flux, primary production, seedbanks, climate change, pesticide effects on waterfowl, mineral content of glacial till, and a variety of other topics. Additionally, the historic and ongoing salient research at the Cottonwood Lake Study Area through the NPWRC provides a strong biological and hydrogeochemical framework that has stimulated much graduate student research at the site.

With George Swanson's retirement, Ned (Chip) H. Euliss, Jr. transferred from the Center's Dixon Field Station in California to Jamestown in 1991 to become the leader of the Cottonwood Lake Study Area research team, where he continued the tradition of cooperative research at the site. In 1992, Euliss expanded the biological research there to include detailed monitoring of invertebrates, amphibians, and birds to complement long-term examinations of vegetation and water chemistry. These studies provided new insights about population changes related to hydrogeochemical dynamics of the wetlands. USGS scientist Martin (Marty) B. Goldhaber and his research staff in Lakewood, Colo., are the most recent additions to the Cottonwood Lake Study Area's team of wetland experts; they provide new insights into the role of geology and associated geochemical processes in shaping the water chemistry and ultimately the biotic communities of prairie wetlands.

In 2014, David M. Mushet assumed the research lead for the Cottonwood Lake Study Area as Euliss retired; Mushet continues the strong history of interdisciplinary research and cooperation at the site.

Other Wetland Research

Wetland losses resulting from drainage and conversion to crop production have been a continued area of NPWRC research. Historically, wetlands throughout the region were drained using surface drains. These drainage ditches often did not completely dry wetlands and left behind basins that still performed some of the ecological processes associated with undrained wetlands. However, in the more intensely farmed areas of the PPR such as the eastern portion of the Dakotas, southwestern Minnesota, and northern Iowa, subsurface tile drains allowed for more complete drainage and facilitated the loss of more than 90 percent of the wetlands in those areas. Prevailing high agricultural commodity demands, mandates for crop-based biofuels (ethanol and biodiesel), and genetically modified row crops that can be grown in semi-arid conditions have facilitated the expansion of row-crop agriculture and use of subsurface tile drains into areas of the PPR where crops had been historically dominated by small grains. Wetland drainage across the region continues to be of great concern to the FWS and has stimulated new research on the effects of the expansion of tile led by NPWRC scientist Raymond (Ray) G. Finocchario. Another drainage practice of concern to the FWS, State wildlife agencies, and others is consolidation drainage, the process of draining wetlands in the upper reaches of a landscape with the drainage water collecting and contributing to the water budget of downgradient wetlands. Mike Anteau leads studies of the effects of consolidation drainage on waterfowl and other biotic communities supported by prairie pothole wetlands.

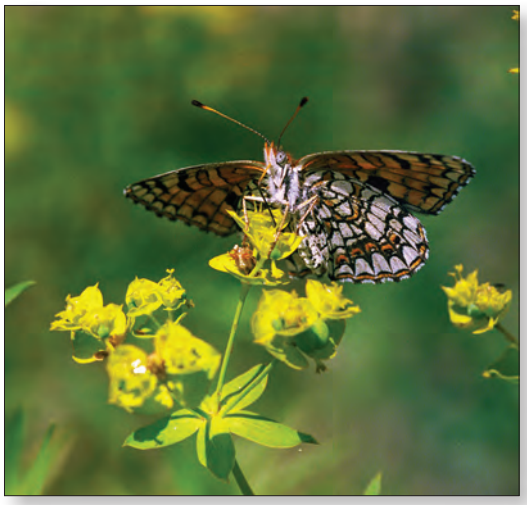
The above-mentioned research efforts provide a snapshot of the wide range of wetlands research that has been done at the Center during the past 50 years. Center scientists have also investigated wetland systems in the Central Valley of California, forested wetlands of Minnesota, riparian wetlands in the Upper Mississippi River, natural and impounded wetlands in the Little Missouri National Grasslands of western North Dakota, montane wetlands of Idaho, riparian meadows along the Central Platte River, and peatland systems in northern Michigan. Research into amphibian ecology has addressed questions about wetland quality, land use, and conservation programs. Additional significant contributions of NPWRC research to the wetland sciences include formulation of the wetland continuum concept, improvement of wetland restoration techniques and evaluation methodology, quantifications of the role wetlands play in carbon cycling and their potential to sequester atmospheric carbon, the negative impacts of agricultural-associated sedimentation on effective lifespans of wetlands, development of models facilitating quantifications of goods and services provided by prairie pothole wetland ecosystems, and more.

Invasive Species and Restoration Ecology

Plant ecology and habitat restoration have long been a part of NPWRC science, often as a facet of waterfowl habitat improvement. Early studies by Leo Kirsch, Ken Higgins, and Arnie Kruse at the Woodworth Field Station and elsewhere in the PPR helped define the role of fire in maintenance of prairie habitat. Expertise in plant identification by Bob Stewart, Hal Kantrud, Lew Cowardin, Russell (Rusty) L. Kologiski, Mavis I. Meyer, Bruce A. Hanson, and others, and the Center's extensive herbarium have been important resources valued by the larger scientific community in the northern Great Plains. As the Center's scope of work expanded in the 1990s with studies in national parks as well as NWRs and waterfowl production areas, the prevalence of invasive plant species and their effects on ecosystem function came to the fore. Included in these studies were evaluations of not only the effects of the invasive species, but also how control methods could influence native plant communities and the role of prescribed fire in invasive species management. Gary D. Willson and his team at the Center's Columbia, Missouri, Field Station (affiliated with NPWRC during 1993–97) investigated plant communities and developed monitoring protocols for prairie national parks and assessed methods to control smooth brome. Research conducted by Diane L. Larson and her students and colleagues at the University of Minnesota described effects of exotic invaders such as leafy spurge, Canada thistle (*Cirsium arvense*), and smooth brome on vegetation, seed banks, pollination of native co-flowering species, and suitability of soils for native species. David P. Fellows investigated effects of prescribed burning on biological control of leafy spurge. More recently, Amy J. Symstad and her colleagues have developed models to predict vegetation changes under various climate scenarios for national parks in the northern Great Plains, as well as monitoring protocols to track long-term trends in vegetation, and a compilation of information to aid with the interpretation of monitoring data.

As the extensive conversion of native prairies to other uses has become more widely recognized, resource managers increasingly face issues related to prairie restoration on remnant habitat and even reconstruction on former cropland. To address these issues, NPWRC science has concentrated on establishing best practices to accomplish restoration and reconstruction and on the use of formal methods such as structured decision making to focus on key aspects of the issues that will move the practice of restoration and reconstruction forward. The Center's involvement in large, multi-refuge projects—such as the Native Prairie Adaptive Management (NPAM) initiative (led by Terry Shaffer, Jill J. Gannon, and Clinton T. Moore, Georgia Cooperative Fish and Wildlife Research Unit) and the Prairie Reconstruction Initiative Advisory Team (led by USGS, The Nature Conservancy, and State agencies)—is producing tangible steps toward the transfer of science-based decision making into the hands of resource managers. Broad-scale retrospective and experimental studies of prairie reconstruction in Iowa and Minnesota, led by Diane Larson, are aimed at improving understanding of how methods and timing of planting can produce diverse and resilient prairie habitat that supports native pollinators as well as waterfowl and nongame birds. Additional pollinator research by Clint R.V. Otto and David Mushet includes modeling plant-pollinator community networks in managed prairies, determining how pollinator communities respond to the spread of invasive plant species, quantifying how land use change in the northern Great Plains influences pollinator health and habitat at large spatial scales, and developing an online database of plant-pollinator interactions.

Invasion of leafy spurge and yellow sweetclover in a native grassland at Theodore Roosevelt National Park, North Dakota.



Fritillary butterfly on leafy spurge in Theodore Roosevelt National Park, North Dakota.

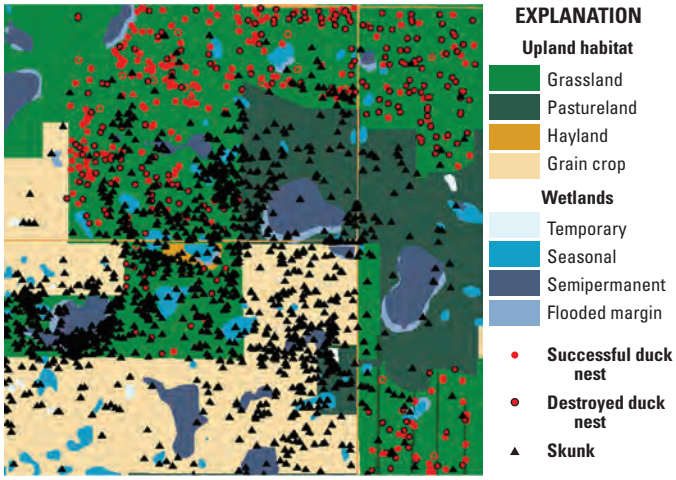
Landscape Ecology

As evidenced by many of the studies noted above, NPWRC scientists have long recognized the importance of spatial and temporal patterns at landscape scales, particularly as they influenced migratory waterfowl. During the first two decades of the Center's history, work at larger scales was pursued mainly by having multiple study sites, such as the Stabilized Regulations Study that extended across three Canadian prairie Provinces, and Kantrud and Kologiski's evaluation of the effects of soils and grazing on breeding birds across six States. Landscape-scale research advanced starting in the mid-1980s, fueled by new resources and tools such as Landsat, geographic information systems (GISs), and satellite telemetry. The continued evolution of these resources, combined with increasing power of computers and software, has allowed Center scientists to pursue ecological and management questions at much broader and more detailed scales than ever before. Below are just some of the past and current studies or programs that address issues at landscape scales that are not noted elsewhere.

In the 1980s, biologists and conservation planners identified the need to move beyond single-species approaches to deal with widespread habitat loss and threats to biodiversity. The Gap Analysis Program (GAP) was originally conceived by J. Michael Scott, then with Patuxent Wildlife Research Center, and was embraced as a national program by the FWS in 1989. GAP provides geographically explicit information on the distribution of habitat types and native vertebrate species and their management status to determine "gaps" in biodiversity protection. The program provides geospatial information to decision makers about land cover, land ownership, and potential vertebrate habitat for conservation planning. Larry Strong, H. Thomas (Tom) Sklebar, and others developed the GAP data for North Dakota, including a detailed land-cover map, wildlife-habitat relation models, and potential distribution maps for 281 mammals, amphibians, reptiles, and breeding birds. Completed in 2005, the GAP data for North Dakota are a valuable resource for the distribution and stewardship of habitats and vertebrates in the State and have been used by a diversity of agencies and organizations.

The U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) was initiated in 1989 to provide improved information on the status and long-term trends in the condition of the Nation's ecological resources. The program sought to develop measures to monitor the status and trends of wetland conditions on a regional basis with known statistical confidence and to seek associations between response indicators of wetland condition and environmental stressors. Lew Cowardin and the NPWRC were invited to take the lead role for pilot studies on PPR wetlands. A team of scientists led by Cowardin and later by Glenn R. Guntenspergen conducted a suite of studies during 1992–96 to develop and assess landscape- and basin-level measures, with study areas extending across North Dakota. EMAP studies identified indicators that were useful to assess the biological condition of wetland resources, such as invertebrate communities, amphibians, plant communities, and wetland basins. The studies also brought to light a number of challenges for implementation of the program, particularly for biotic measures, such as access to sites on private lands.

The NPWRC responded to the need to quantify ecosystem services influenced by Government-sponsored wetland restoration initiatives in the PPR. In 1997, Chip Euliss initiated an extensive survey of restored wetlands and adjacent uplands, and in 2004, Euliss and Robert Gleason expanded the effort. These surveys provided basic quantitative relation and estimates of ecosystem services derived from DOI and USDA conservation programs. Largely a result of the success of this preliminary work, the USGS initiated its Integrated Landscape Modeling (ILM) Science Thrust in 2006. Euliss and, more recently, David Mushet have continued to develop, parameterize, and validate multiple ecological models needed to facilitate the quantification of a wide array of goods and services provided by naturally functioning prairie ecosystems (for example, carbon sequestration, wildlife habitat, flood water storage, water quality improvement, crop pollination). These models facilitate explorations into how the provisioning of ecosystem goods and services valued by society might be influenced by future changes in climate and land use. Much of the ILM work conducted at the NPWRC has been accomplished through close collaborations with the USDA's Natural Resources Conservation Service and Farm Services Agency. Providing the scientific information needed to effectively implement USDA programs affecting management of private lands is an important component of maintaining wildlife populations and functioning ecosystems.



A geographic information system (GIS) was used to understand how the movement of skunks was related to the distribution of duck nests that successfully hatched versus those that were lost to a predator near Chase Lake National Wildlife Refuge, North Dakota.

Research Techniques and Information Transfer

Scientists at the NPWRC developed many research techniques and management strategies that are now routinely used by researchers and managers worldwide, many of which have been mentioned earlier in this report. Center staff pioneered methods for locating and monitoring waterfowl nests, determining incubation stage of songbird eggs, sampling invertebrate food resources used by waterfowl, and assessing wetland quality. Techniques developed at the Center for studying duck nest success and depredation and for monitoring predator populations have been widely applied across the PPR on many wildlife areas. Pam Pietz was among the first to demonstrate the value of miniature camera systems for documenting nesting behavior and depredation events at passerine nests. Center biologists made important advances in capture and marking methods for waterfowl, cranes, and shorebirds, and designed and evaluated innovative means to protect bird nests from predators. Center scientists carefully evaluated various marking methods, radio-transmitter designs, and attachment techniques to optimize data quality while ensuring minimal effects on the animal's welfare and behavior.

Research programs at the Center included cutting-edge use of wildlife telemetry systems, remote sensing imagery, and videography for gathering data. As the first remote sensing data became available in the 1970s from the Earth Resources Technology Satellite (ERTS-1) and Landsat 1, Dave Gilmer and Lew Cowardin were among the first to explore the potential of these data for monitoring waterfowl habitat. Beginning in the mid-1980s, the availability of increasingly powerful tools available to researchers—computers and associated software, GIS, better remote sensing resources, and satellite telemetry—were rapidly embraced by Center scientists and enhanced their capabilities to conduct ever larger and more complex studies. Lew Cowardin was one of the first

The Center's geographic information systems (GIS) lab in the mid-1980s: Lew Cowardin discusses GIS work with colleagues and technicians.

Carol Nustad enters data at an early computer system (circa early 1980s).

in the Nation to use aerial videography (and later the first digital cameras) for research on natural resources, combining aerial videography, high-altitude photography, newly available National Wetlands Inventory data, and ground counts to evaluate duck habitat and estimate duck population sizes. David Gilmer, Larry Strong, and others developed innovative approaches in GIS and remote sensing analysis for natural resource studies and management applications, such as the use of QuickBird imagery to assess habitat availability for piping plovers and least terns on the Missouri River.

Center statisticians gained a reputation as leaders in development of analytical methods; in particular, they advanced the methods for analysis of nest success data and modeling populations, which ultimately provide for more informed management decisions. Mathematical and computer modeling and remote sensing have become integral parts of the Center's research program. At the heart of such advances, and indeed the foundation of the Center's strong research program, was a strong statistical support team, first developed by Doug Johnson and later led by Terry Shaffer and Wes Newton. Most importantly, NPWRC has provided the technical assistance and tools for implementing research findings to improve management of the continent's migratory bird and wetland resources.

The Center has long recognized the importance of communicating research findings and ecological knowledge to managers, decision makers, and the broader biological community. Throughout the Center's 50-year history, NPWRC scientists published more than 1,700 articles in peer-reviewed journals and other professional outlets, technical reports, and

Sheel Bansal measures gas emissions from a wetland.

other products (U.S. Geological Survey, 2017). Thousands of presentations have been given at professional conferences and other venues to partners, clients, other scientists, and the public. More than 15 symposia and workshops have been organized and hosted by the Center about waterfowl (Canada geese, canvasbacks, mallards, scaup), cattail management, prescribed fire, predator ecology and management, wetland ecology, wildlife marking and telemetry, and statistics. Staff have compiled and shared extensive bibliographies and developed synthesis publications on key subjects, such as effects of management practices on grassland birds; these products are valued resources to the larger biological and management community. The Center's herbarium is the third largest in the State, holding nearly 6,000 specimens from the United States and Canada, and has been a valuable resource for many projects by Center staff and others. A professionally staffed library with an impressive collection of wildlife- and ecology-related holdings served the scholarly needs of Center researchers and partners for many years. The NPWRC was one of the first research centers within the USGS to have a web presence. The initial NPWRC website, launched in 1995, provided resources on a wide range of subjects pertinent to the northern Great Plains and the Nation, ranging from butterflies and moths and their host plants, to grassland birds and wetlands, to emerging information about malformed amphibians; it became an important resource for biologists, managers, students, and citizens and received many awards.

The Center maintains a strong tradition of providing technical assistance to managers and other decision makers. Field visits to refuges and parks to discuss research findings and translate them to on-the-ground applications are common. Center scientists are often asked to assist with developing monitoring programs or to develop research studies at individual refuges or parks. For example, Amy Symstad works with the National Park Service on inventory and monitoring needs. Max Post van der Burg provides science support to the Plains and Prairie Potholes Landscape Conservation Cooperative, including landscape modeling and research, technical review of projects, and workshops on structured decision making. Participation and representation at flyway, joint ventures, endangered species recovery teams, and other management partnership meetings is routine and often leads to the identification of critical research needs and initiation of new studies.

Prairie pothole wetlands, Stutsman County, North Dakota.

Looking to the Future

The mission of the Northern Prairie Wildlife Research Center today remains true to the original vision: to provide the knowledge needed to understand, conserve, and manage the Nation's natural resources for current and future generations, with an emphasis on species and ecosystems of the northern Great Plains. The Center's first 50 years of applied biological research provides a deep scientific foundation on which to address emerging ecological issues. The dedicated scientific and support staff of the Center continue to provide and advance high quality science needed to carry out the mission of the U.S. Geological Survey and ensure that the Center retains its long-standing stature as a premier ecological research laboratory in the northern Great Plains. While much of the Center's research remains focused on the Prairie Pothole Region, the Center's research and expertise extends to other ecoregions. Its scientific expertise is recognized globally for informing conservation of migratory birds, wolves and other species of conservation concern, and their wetland and grassland ecosystems.

The grassland and wetland ecosystems of the northern Great Plains benefit society in many ways, including furnishing wildlife habitat, surface-water storage, groundwater recharge, erosion control, carbon storage, nutrient retention, crop pollination, recreational opportunities, and intrinsically valued aesthetics. The region is particularly important for populations of migratory birds during breeding. The region also is a critically important agricultural area and hosts extensive wind, biomass, and fossil-fuel energy resources. Thus, the northern Great Plains is a landscape rich in natural resources that are important for many reasons, including farming, ranching, hunting, fishing, eco-tourism, energy production, and wildlife conservation. Embedded in this ecologically and economically important region, the Northern Prairie Wildlife Research Center is well positioned to contribute the scientific knowledge and expertise essential to decision makers facing the uncertainties and challenges of changing economic, environmental, and political environments, and effects that these changes have on the region's and the Nation's natural resources.

Tall stand of big bluestem and goldenrod growing on a hillside in late afternoon light.

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