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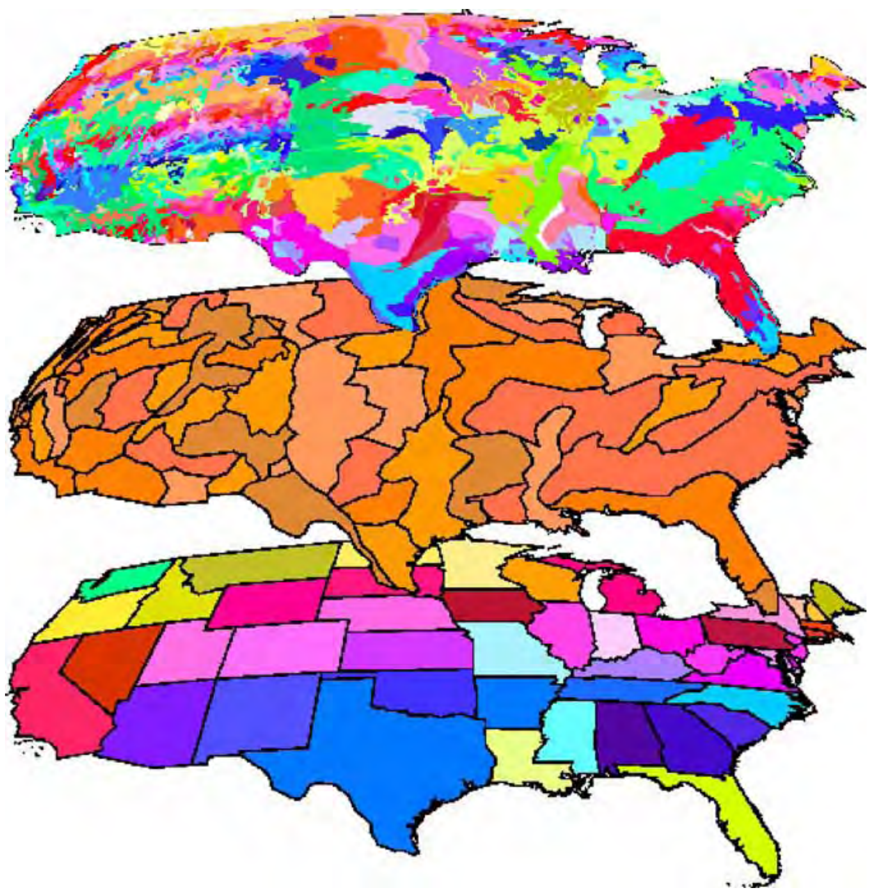
A Gap Analysis of North Dakota

April 2005 Final Report



A GEOGRAPHIC APPROACH TO PLANNING FOR BIOLOGICAL DIVERSITY

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

THE NORTH DAKOTA
GAP ANALYSIS PROJECT

FINAL REPORT

April 2005

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DEDICATION

We dedicate this first North Dakota gap analysis to past, present, and future individuals who value and work to conserve the biological resources of North Dakota.

EXECUTIVE SUMMARY □

Gap analysis is a habitat-based planning method for biodiversity conservation that produces geospatial information about the kinds and amounts of natural land cover categories and potential habitat for native vertebrate species. Land cover categories and vertebrate species poorly represented on the existing network of conservation lands constitute conservation "gaps." One purpose of gap analysis is to provide geospatial information that land managers, planners, scientists, and policy makers can use to identify proactive habitat conservation actions that might preclude the need to list species as endangered or threatened (Scott et al 1993).

The North Dakota Gap Analysis Project (ND-GAP) was initiated in 1998 by Northern Prairie Wildlife Research Center with funding from the National Gap Analysis Program (GAP) of the U.S. Geological Survey. The project was a cooperative effort among more than 30 federal, state, Native American, and private conservation organizations in North Dakota (ND) (Table 1). The major objectives of the project were to (1) produce digital maps and associated databases for actual land cover, land stewardship, and potential distribution of terrestrial vertebrate species in ND; (2) describe the distribution of natural land cover categories and terrestrial vertebrate species among land stewards, and identify elements that currently are not represented or are underrepresented in areas managed for long-term maintenance of biodiversity; and (3) to facilitate cooperative development and use of information so that institutions, agencies, and private landowners may be more effective stewards of ND's natural resources. The ND-GAP is a preliminary step toward more detailed efforts and studies needed for long-term planning for biodiversity conservation in ND.

A map of the land cover of ND circa 1997 was prepared from the analysis of 42 Landsat-5 Thematic Mapper (TM) images acquired between August 1992 and May 1999 and digital National Wetlands Inventory data (Wilen and Bates 1995). The spatial resolution of the land cover map is the same as the TM imagery, 0.09 ha. The legend for the land cover map is hierarchical with eight general land cover categories at the upper level and 39 detailed land cover categories at the lower level. Approximately 118,760 km^2 (65%) of the surface area of ND has been tilled at some time with 30,543 km^2 of this land planted to perennial herbaceous vegetation at the time the map was made. Map estimates of the area of natural and semi-natural prairie, wetlands, and shrublands are 35,681 km^2 (19%), 16,297 km^2 (9%), and 5,281 km^2 (3%), respectively. The area of woodland (natural and anthropogenic) is estimated at 4,284 km^2 (2.3%). The area of sparsely vegetated land cover including natural badlands was estimated at 1,897 km^2 (1%) and the area of developed land covers at 953 km^2 (0.5%). An accuracy assessment of the land cover map has been conducted. The overall accuracy of the eight general land cover categories delineated was 62%.

Potential distribution maps were developed for 281 terrestrial vertebrate species comprising 184 species of breeding birds, 71 species of mammals, 11 species of amphibians, and 15 species of reptiles. Range limits of each species were delineated on a grid of 635 km^2 hexagons using >200,000 locality records. Within the hexagons, species potential distributions were modeled based on species-land cover category affinities. The accuracy of the vertebrate potential distribution models was assessed by comparison with published species lists from six natural areas in ND. Percent agreement averaged 94% (range 84–98%, n= 5), 89.6 % (range 86–94%, n=3), and 92% (range 85–100%, n=3) for birds, mammals, and herptiles, respectively. Limitations and uncertainties in species distribution maps are discussed.

Approximately 6.4% of the land in ND is managed by public agencies with 4.3% under federal management and 2% under state jurisdiction. Approximately 4.2% of the land in ND occurs within the boundaries of lands governed by five Native American tribal governments. Lands managed by non-profit conservation organizations account for less than half of one percent of the land in ND. Private land owners are responsible for management of more than 90% of the land in ND. Lands were assigned to one of four management status classes to reflect the relative degree of stewardship for conservation of biodiversity. Status 1 signifies the highest degree of biodiversity conservation, e.g., national parks and Nature Conservancy preserves; status 4 denotes lands with no mandate to preserve biodiversity values. Status 1 and status 2 lands occupy 383 km^2 and 1566 km^2, respectively, in ND, which combined is slightly more than 1% of the state and 17% of the area in public and private conservation lands. Federal stewards are responsible for 97% of status 1 and 2 lands. Seventy-five percent of federal public lands were multiple-use and assigned a status of 3. Seventy-nine percent of lands managed by state government stewards were assigned a status of 4, and the remaining 21% of state public lands was assigned a status of 3.

All five of the general natural vegetation land cover categories (prairie, wetland, shrubland, woodland, and sparse vegetation) have their greatest abundance on private lands. Approximately 79% of the prairie land cover category occurs on private lands; the U.S. Forest Service (USFS), ND State Land Department (NDSL), and the U.S. Fish and Wildlife Service (USFWS) manage 5.9%, 5.1%, and 1.7% of prairie, respectively. Lands governed by the Native American Standing Rock Sioux and Three Affiliated Tribes (NATAT) account for 4.5% and 2.0% of the prairie land cover category. Nine individual stewards have less than 1% of the prairie land cover category on the lands they manage.

Private land owners are responsible for stewardship of approximately 77% of the wetland land cover category. The USFWS has responsibility for 5.9% of the wetland land cover category, with the Native American Spirit Lake Tribe and the NDSL responsible for 2% and 1%, respectively. Thirteen stewards individually have responsibility for less than 1% and together 3.5% of the wetland land cover category.

Approximately 69% of shrublands occurred on private lands. The USFS, NATAT and the NDSL manage approximately 13.4%, 6.5%, and 3.5%, of shrublands, respectively. Stewardship responsibilities for shrublands may be distorted due to the difficulty mapping shrublands.

Seventy percent of the woodland land cover category occurs on private lands. This is probably an overestimate of the proportion of natural woodlands on private lands as many woodlands in ND are planted. Stewards, in decreasing order of responsibility for natural woodlands, include the USFS, NATAT, Native American Turtle Mountain Chippewa, ND Game and Fish Department, USFWS, and U.S. Army Corps of Engineers.

Of all the prairie types in ND, the Bluestem-Needlegrass-Wheatgrass prairie may have the highest conservation concern because of its uniqueness at the national scale. This type has been identified as a transition between tallgrass prairie to the east and mixed prairie to the west (Kuchler 1964; Dix and Smeins 1967; Ricketts et al. 1999). Once the dominant prairie community in ND (Stewart 1975), much of this prairie has been lost through conversion to cropland. The order of the genera in the name of this prairie category was changed from that used by Kuchler (1964) to conform to observations by early plant ecologists (Clements 1920; Shantz 1923, 1924; Weaver and Fitzpatrick 1934) in the Dakotas and our field observations. Kuchler (1964) noted that his map units were large (encompassing portions of several states) and there was considerable geographic variability in species dominance within the map units. This species-rich prairie category occurs primarily on glacial till parent materials. Plant species have complex spatial distributions over short distances related to soil and topographic heterogeneity and its influence on availability of moisture and nutrients. Kentucky bluegrass (*Poa pratentis*) and smooth brome (*Bromus inermis*), two introduced grass species, and western snowberry (*Symporicarpos occidentalis*), a native shrub species, are highly successful competitors and serious threats to native grass and forb species in this prairie type (Whitman and Barker 1994). Wetlands are an important component of the Bluestem-Needlegrass-Wheatgrass landscape and the combination of prairie and wetland habitats results in a landscape with a high vertebrate species richness.

Mesic tallgrass prairie has experienced the largest percentage loss of all prairie categories in ND. The high percentage of mesic tallgrass prairie on lands classified as status 1 and 2 (24%) is largely the result of a decision by the USFS to designate portions of the Sheyene National Grassland as tallgrass prairie restoration areas in its 2002 management plan for Dakota Prairie Grasslands.

The other prairie types in ND have a small proportion of their area on lands classified as status 1 and 2 (1- 5%) and are components of mixed prairie or prairie with special soil characteristics (sand prairie and saline prairie). Most of these prairie categories have greater spatial extents in states and Canadian provinces adjacent to ND. For example, fescue prairie and needlegrass prairie have significant areas in the Canadian provinces and wheatgrass prairie is common in South Dakota and Montana.

Floodplain woodlands are another land cover category with a high conservation concern. Many floodplain woodlands on the Missouri and other rivers in ND are threatened by the elimination of natural hydrogeomorphic processes following the construction of dams. Dams have dramatically reduced the rate of river meandering by altering the magnitude of peak flows. Flow alteration and a decline in meandering rate has two major consequences for floodplain woodland: (1) a reduction in the amount of new alluvium produced for tree and shrub regeneration, and (2) an increase in the successional ages of established woodlands due to an extension in their life spans (Johnson 2002).

Ponderosa pine woodlands in ND are at the northeastern-most extent of the species geographical range and have a small total area (~10 km^2). Twenty-three percent of the area mapped as ponderosa pine woodlands occurs on Research Natural Areas or Special Interest Areas by the USFS.

Palustrine temporary and palustrine seasonal wetlands have higher conservation priorities than other wetland types. Lacustrine and palustrine semi-permanent wetlands have much larger representation (12% and 5%, respectively) on lands classified as status 1 and 2 than palustrine temporary (2%) and palustrine seasonal wetlands (1%). Palustrine temporary and palustrine seasonal wetlands also have low representation, about 2 % of each category, on public lands classified as status 3.

Twenty-five percent of the terrestrial vertebrate species have 1% or less of their potential habitat distribution represented on status 1 or 2 lands. Ninety-five percent of the species have 5% or less of their potential habitat distribution represented in status 1 or 2 lands. Forty-three of the species with 5% or less of their potential habitat distribution in status 1 or 2 lands have been identified by the ND Game and Fish Department as having high (n=19) or moderate (n=24) levels of conservation concern.

Private land owners, by virtue of the large amount of the land in ND under their stewardship, bear an important responsibility for biodiversity conservation in ND. Wetland and prairie conservation easements on private lands could not be included in the gap analysis due to a lack of spatially explicit information on their locations. However, their contribution can be assessed in part with summary statistics available from the USFWS. In 2004, there were 3,349 km^2 of wetlands (about 27% of all wetlands on private lands) and 620 km^2 of prairie (about 2% of all prairie on private lands) protected by USFWS perpetual easements.

Although the ND-GAP does not provide all the information needed for biodiversity conservation, the spatially and thematically detailed statewide datasets for actual land cover, potential vertebrate species distributions, and land stewardship created by the ND-GAP should provide an excellent starting point for many important conservation decisions.

Table 1.1 Cooperators in the North Dakota Gap Analysis Project.

Federal Government
USDI Bureau of Indian Affairs
USDI Bureau of Land Management
USDI Bureau of Reclamation
USDI Fish and Wildlife Service
USDI Theodore Roosevelt National Park
USDI Geological Survey
USDA Farm Services Administration
USDA Natural Resources Conservation Service
USDA Forest Service Dakota Prairie Grasslands
USDD Army Corps of Engineers

Native American Governments
Three Affiliated Tribes
Standing Rock Sioux Tribe
Sprit Lake Sioux

State Government
ND Geological Survey
ND Forest Service
ND State Land Department
ND Natural Heritage Program
ND Information Technology Department
North Dakota State Water Commission
North Dakota Agricultural Statistics Service
North Dakota Department of Transportation
North Dakota Fish and Game
University of North Dakota
North Dakota State University
Minot State University
University of Montana, Wildlife Spatial Analysis Lab

Private Conservation Organizations
The Nature Conservancy
Nature Serve
Ducks Unlimited
The Audubon Society

Upper Mid-West State Gap Projects
South Dakota Gap Analysis Project
Iowa Gap Analysis Project
Nebraska Gap Analysis Project
Kansas Gap Analysis Project

ACKNOWLEDGEMENTS

An effort of this magnitude requires the input, assistance, and support from many people. We have attempted to identify and thank all of those people and we apologize for unintentional omissions.

Thanks to Amos Eno and the staff of the National Fish and Wildlife Foundation, who funded the early development of the gap analysis concept and to the originators including J. Michael Scott, Blair Csuti, and Jack Estes and the pioneering scientists who forged the way. Thanks to John Mosesso and Doyle Frederick of the US Geological Survey Biological Resource Division (BRD) Office of Inventory and Monitoring, for their support of GAP, especially during its transition from the U.S. Fish and Wildlife Service to the National Biological Service and then to the U.S. Geological Survey BRD. Thanks to Reid Goforth and the staff at the USGS BRD Cooperative Research Units for administering GAP's research and development phase from headquarters. Without those mentioned above, there could not have been a GAP. Thanks also to the staffs of the GAP, Center for Biological Informatics, and Biological Resources Division headquarters. We are grateful to Michael Jennings, Patrick Crist, Kevin Gergely, Ree Brannon, Becky Sorbel, and Elizabeth Brackney with the GAP office in Moscow, Idaho for administrative support and encouragement.

Portions of this report are standardized in all GAP project reports to provide continuity among the state reports. We acknowledge contributions to this report by Chris Cogan, Patrick Crist, Blair Csuti, Tom Edwards, Michael Jennings, and J. Michael Scott; as well as the previous GAP projects.

The ND-GAP Analysis Project benefited greatly from many discussions and collaboration with staff of the South Dakota (Jonathan Jenks, Vickie Smith, Chad Kopplin, Dorothy Fecske) , Iowa (Erwin Klaus, Kevin Kane, Katherine Anderson, Patrick Brown, Robin McNealy), Nebraska (Jim Merchant, Marlin Eve, Geoff Henebry) and Kansas gap projects (Jack Cully, Glennis Kaufman, Stephan Egbert, Todd Hoernemann, Christine Wooley, and Chris Lauver). All of these people were a constant source of support and encouragement for the ND-GAP analysis. Erwin Klaus deserves special acknowledgement for his efforts to lead discussions of the importance and conduct of accuracy assessments for the land cover maps.

Special acknowledgement is also due to Bill Waltman and Ron Luethe with the Natural Resources Conservation Service. Bill traveled from Nebraska to attend the first organizational meeting for the ND-GAP and presented an overview of geospatial data he and Ron had prepared for ND and other states in the Great Plains. Bill was a great motivator and source of encouragement for the ND-GAP analysis. Ron Luethe was unwavering in his support and contributed numerous data sets and assistance throughout the life of the ND-GAP analysis project.

Assembling and creating the data for a state gap analysis is a long and arduous task. Jason Heier, Michele Brewer, Dan Zerr, Mike Gerbig, Anne Coyle, and Rich Olsen were part of the ND-GAP analysis team at NPWRC for various amounts of time and helped to achieve the objectives. Special acknowledgement must be given to Jason Heier and Michele Brewer. Their long term contributions, inquisitive and positive attitude, and careful attention to details and accuracy in the performance of repetitive and tedious tasks are greatly appreciated. In addition we acknowledge the help of other staff at Northern Prairie Wildlife Research Center including Betty Euliss, Larry Igl, Marsha Sovada, Jeff Jundt, Wes Newton, Deb Buhl, Stephen Magill, Mike Schwartz, Keith Van Cleave, Pam Pietz, Gary Krapu, and Diane Larson. We thank Terry Shaffer and Doug Johnson for their administration of university research work orders. We are grateful to the directors Ron Kirby and Jay Hestbeck for their support, and to all other members of the administrative and maintenance staff for help with finances, personnel, and equipment. We appreciate the assistance of Mary Owens and Karen Dywer, Human Resource Specialists with the USGS Central Region, for their assistance with job announcements and the sometimes complicated hiring procedures.

Developing a ND vegetation classification scheme for use with Thematic Mapper imagery that incorporated the National Vegetation Classification System (NVCS) was a difficult task. Darla Lenz was valuable source of information about the various vegetation classification systems used in ND and her experiences with them. William Barker, Lee Manskse, and Harold Kantrud also shared their experiences with classifying the vegetation of ND. Shannon Mennard, Don Faber-Landendoen, and Jim Drake provided documents and discussions of the ND Portion of the NVCS.

The land cover mapping objective benefited greatly from recent land cover mapping activities in ND. Duane Pool and Chuck Loesch shared imagery and land cover maps for the Prairie Pothole Portion of ND developed in a joint project between Ducks Unlimited and the U.S. Fish and Wildlife Service. Rolly Redmond and Jeff DiBenedetto shared land cover maps for western ND developed by the University of Montana for the U.S. Forest Service. Rick Mueller and Dath Mita shared imagery and land cover maps developed by the National and ND Agricultural Statistical Services. We are also grateful to Jim Von Loh, Kathy Duttenhefner, Darla Lenz, Ron Luethe, and Patsy Chamrad for sharing land cover maps developed for smaller areas within the state.

The accuracy assessment of the land cover map was a huge undertaking. Al Cilurso, Jim Bredy and Brian Lubenski with the U.S. Fish and Wildlife Service acquired the aerial photography. Al Cilurso deserves special acknowledgement for his help in planning the photo mission. We are grateful to Brian Natwick with the USDA Farm Service Administration for facilitating and coordinating our request for 2001 FSA crop compliance slides and land cover maps for the sample units from the 53 county FSA offices in ND. Harold Kantrud performed ground surveys of land cover for a portion of the sample units. We are also indebted to the more than 600 private land owners who granted us trespass permission to collect the data used in the accuracy assessment of the land cover map.

The vertebrate modeling component could not have been accomplished without the expertise of Jacquie Ermer, Ted Hoberg, Lawrence Igl, Bill Jensen, Jeff Jundt, Glennis Kaufman, Ron Martin, Robert Seabloom, Marsha Sovada, and Dan Svingen. We are also indebted to the experts involved in the review of vertebrate models developed by the South Dakota and Iowa Gap Analysis Projects.

Several individuals provided stewardship data including Chuck Loesch, Dave Azure, Mick Erickson, Neil Shook, Gregg Knutson, Craig Hultberg, Will Meeks, and Kristine Askerooth with U.S. Fish and Wildlife Service; Phil Sjurgens and Charlene Gentry with U.S. Forest Service; Kathy Jewel, Shelley Johnson, and Corrine Walter with the Bureau of Land Management; Brad Quayle, Eric Morrison, Mike Morris, Greg Pavelka, Laura Banker, Bob Martin, Keith LeClaire with Army Corps of Engineers; Amy Lieb and Patsy Chamrad with Bureau of Reclamation; Kevin Kadding, Brian Hosek, and Brandon Mason with the ND Game and Fish; Chris Dirk and Jesse Hanson with ND State Parks and Recreation; Brad Wentz with the ND Dept. of Transportation; Jan Slaats, Eric Rosenquist, and Robert Self with the Nature Conservancy; and Donna Schneider and Genevieve Thompson with Audubon Society.

The quality of the ND-GAP data bases is due in a large part to the willingness of cooperators to share data and information. More than thirty organizations contributed data to the ND-GAP. This data sharing occurred prior to the recent explosion in the availability of information on ftp and web sites. Acquiring the data almost always required contacting an individual in an organization who was willing to find time in their busy schedules to help us. We were fortunate to have developed such relationships with a long list of professionals including Susan Rinehart, Phil Sjursen, Jerry Bird, Bernadette Braun, Dan Svingen, David Haugen, and Pat Miles with the U.S. Forest Service; Larry Edlin, Stephen Brady, Arnold Mendenhall, Ray Sinclair, Sharon Waltman, Dave Dewald, Dean Chamrad, Jeff Printz with the Natural Recources Conservation Service; Ralph Gabrysh, Coral Huber, and Gary Ledbetter with the Army Corps of Engineers; Gerry Anderson and Chad Prosser with the Agricultural Research Service; Steve Hager and Jim Von Loh with the National Park Service; Ron Wencl with the U.S. Geological Survey; Patsy Chamrad, and Amy Lieb with the Bureau of Reclamation; Ron Reynolds, Mike Estey, Stu Wacker, Roger Collins, Karen Smith, Bob Murphy, Todd Grant, Will Meeks, Dave Azure, Paulette Scherr, Mick Erickson, Gregg Knutson, Kim Santos, and Bill Wilen with the U.S. Fish and Wildlife Service; Pat Keatts and Tom Young with the Bureau of Indian Affairs; Marle Baker, Paul Danks, Jim Heckman, Carey Dreyer, and Delvin Driver, Jr. with the Three Affiliated Tribes; Annette Yellow Fat and Randy Whitebull with the Standing Rock Sioux; Si Ironheart, Jr. with the Spirt Lake Sioux; Kathy Duttenhefner, Darla Lenz, and Chris Dirk with the ND Natural Heritage Program; Mike Brand with the ND State Land Department; Mike Johnson, Jerry Gulke, Bill Jensen, Randy Kreil, and Brian Kietzman with the ND Department of Game and Fish; Bob Nutsch with the ND Information Technology Department; Dath Mita and Eric Waldhaus with the ND Agricultural Statistical Service; Bob Harsel, Tom Karch, Jason Weinerman, and Tom Nowatzki with the ND Forest Service; Ryan Waldkirch with the ND Geological Survey; Duane Pool and Jim Ringleman with Ducks Unlimited; Ed Madei and Eric Rosenquist of The Nature Conservancy; Paul Nyren, Jack Norland, William J.

Bleier, James W. Grier and Kevin Sedivec with ND State University; Richard D. Crawford and Robert Seabloom with the University of ND; and Chuck Lura and Ron Royer with Minot State University.

INTRODUCTION

How This Report is Organized

This report is a summation of a scientific project. While we endeavor to make it understandable for as general an audience as practicable, it reflects the complexity of the project it describes. A glossary of terms is provided to aid the reader in its understanding, and for those seeking a detailed understanding of the subjects, the cited literature should be helpful. The organization of this report follows the general chronology of project development, beginning with the production of the individual data layers and concluding with analysis of the data. It diverges from standard scientific reporting by embedding results and discussion sections within individual chapters. This was done to allow the individual data products to stand on their own as testable hypotheses and provide data users with a concise and complete report for each data and analysis product.

We begin with an overview of the GAP mission, concept, and limitations. We then present a synopsis of how the current biodiversity condition of the project area came to be, followed by land cover mapping, animal species distribution prediction, species richness, and land stewardship mapping and categorization. Data development leads to the Analysis section, which reports on the status of the elements of biodiversity (natural community alliances and animal species) for North Dakota (ND). Finally, we describe the management implications of the analysis results and provide information on how to acquire and use the data.

Gap Analysis Program Mission

The mission of the GAP is to prevent conservation crises by providing conservation assessments of biotic elements (plant communities and native animal species) and to facilitate the application of this information to land management activities. This is accomplished through the following five objectives (1) map actual land cover as closely as possible to the alliance level of the National Vegetation Classification System (FGDC 1997), (2) map the predicted distribution of those terrestrial vertebrates and selected other taxa that spend any important part of their life history in the project area and for which adequate distributional habitats, associations, and mapped habitat variables are available, (3) document the representation of natural vegetation communities and animal species in areas managed for the long-term maintenance of biodiversity, (4) make all GAP project information available to the public and those charged with land use research, policy, planning, and management, and (5) build institutional cooperation in the application of this information to state and regional management activities.

To meet these objectives, it is necessary that GAP be operated at the state or regional level but maintain consistency with national standards. Within the state, participation by a wide variety of cooperators is necessary and desirable to ensure understanding and acceptance of the data and forge relationships that will lead to cooperative conservation planning.

None of the databases needed for the ND-GAP analysis were available on a state-wide extent at the initiation of the ND-GAP analysis in 1998. The expertise of the federal, state, and private organizations using digital geospatial data for natural resources planning in ND varied greatly from well staffed and equipped organizations expanding the state-of-the-art to others with little or no staff and equipment. Coordination among the various organizations was primarily informal although a GIS technical committee to facilitate coordination of GIS activities among state agencies was established by an executive order in 1995. We worked closely but informally with a large number of cooperators to develop the products of the ND-GAP analysis (Table 1.1). The cooperation was primarily the sharing of data and information. The ND-GAP Analysis is the largest effort to date for a multi-institutional cooperative approach to the development, distribution, and use of digital geospatial data for habitat-based biodiversity conservation in ND.

Gap Analysis Concept

The GAP brings together the problem-solving capabilities of federal, state, and private scientists to tackle the difficult issues of land cover mapping, animal habitat characterization, and biodiversity conservation assessment at the state, regional, and national levels. The program seeks to facilitate cooperative development and use of information. Throughout this report we use the terms "GAP" to describe the national program, "GAP Project" to refer to an individual state or regional project, and "gap analysis" to refer to the gap analysis process or methodology.

Much of the following discussion was taken verbatim from Edwards et al. 1995, Scott et al. 1993, and Davis et al. 1995. The gap analysis process provides an overview of the distribution and conservation status of several components of biodiversity. It uses the distribution of actual land cover and predicted distribution of terrestrial vertebrates and, when available, invertebrate taxa. Digital map overlays in a GIS are used to identify individual species, species-rich areas, and vegetation types that are unrepresented or underrepresented in existing management areas. It functions as a preliminary step to the more detailed studies needed to establish actual boundaries for planning and management of biological resources on the ground. These data and results are then made available to the public so that institutions as well as individual landowners and managers may become more effective stewards through more complete knowledge of the management status of these elements of biodiversity. GAP, by focusing on higher levels of biological organization, is likely to be both cheaper and more likely to succeed than conservation programs focused on single species or populations (Scott et al.1993).

Biodiversity inventories can be visualized as "filters" designed to capture elements of biodiversity at various levels of organization. The filter concept has been applied by The Nature Conservancy, which established Natural Heritage Programs in all 50 states. The Nature Conservancy employs a fine filter of rare species inventory and protection and a coarse filter of community inventory and protection (Jenkins 1985, Noss 1987). It is postulated that 85-90% of species can be protected by the coarse filter without having to inventory or plan reserves for those species individually. A fine filter is then applied to the remaining 15-10% of species to ensure their protection. Gap analysis is a coarse-filter method because it can be used to quickly and cheaply assess the other 85-90% of species. GAP is not designed to identify and aid protection of elements that are rare or of very restricted distribution; rather it is designed to help "keep common species common" by identifying risk far in advance of actual population decline. These concepts are further developed below.

The intuitively appealing idea of conserving most biodiversity by maintaining examples of all natural community types has never been applied, although numerous approaches to the spatial identification of biodiversity have been described (Kirkpatrick 1983, Margules and Nicholls 1988, Pressey and Nicholls 1989, Nicholls and Margules 1993). Furthermore, the spatial scale at which organisms use the environment differs tremendously among species and depends on body size, food habits, mobility, and other factors. Hence, no coarse filter will be a complete assessment of biodiversity protection status and needs. However, species that fall through the pores of the coarse filter, such as narrow endemics and wide-ranging mammals, can be captured by the safety net of the fine filter. Community-level (coarse-filter) protection is a complement to, not a substitute for, protection of individual rare species.

Gap analysis is essentially an expanded coarse-filter approach (Noss 1987) to biodiversity protection. The land cover types mapped in GAP serve directly as a coarse filter, the goal being to assure adequate representation of all natural vegetation community types in biodiversity management areas. Landscapes with great vegetation diversity often are those with high edaphic variety or topographic relief. When elevational diversity is very great, a nearly complete spectrum of vegetation types known from a biological region may occur within a relatively small area. Such areas provide habitat for many species, including those that depend on multiple habitat types to meet life history needs (Diamond 1986, Noss 1987). By using landscape-sized samples (Forman and Godron 1986) as an expanded coarse filter, gap analysis searches for and identifies biological regions where unprotected or underrepresented vegetation types and animal species occur.

More detailed analyses were not part of this project, but are areas of research that GAP as a national program is pursuing. For example, a second filter could combine species distribution information to identify a set of areas in which all, or nearly all, mapped species are represented. There is a major difference between identifying the richest areas in a region (many of which are likely to be neighbors and share essentially the same list of species) and identifying areas in which all species are represented. The latter task is most efficiently accomplished by selecting areas whose species lists are most different or complementary. Areas with different environments tend to also have the most different species lists for a variety of taxa. As a result, a set of areas with complementary sets of species for one higher taxon (e.g., mammals) often will also do a good job representing most species of other higher taxa (e.g., trees, butterflies). Species with large home ranges, such as large carnivores, or species with very local distributions may require individual attention. Additional data layers can be used for a more holistic conservation evaluation. These include indicators of stress or risk (e.g., human population growth, road density, rate of habitat fragmentation, distribution of pollutants) and the locations of habitat corridors between wildlands that allow for natural movement of wide-ranging animals and the migration of species in response to climate change.

General Limitations

Limitations must be recognized so that additional studies can be implemented to supplement GAP. The following are general project limitations; specific limitations for the data are described in the respective sections:

1. GAP data are derived from remote sensing and modeling to make general assessments about conservation status. Any decisions based on the data must be supported by ground-truthing and more detailed analyses.

2. GAP is not a substitute for threatened and endangered species listing and recovery efforts. A primary argument in favor of gap analysis is that it is proactive: it seeks to recognize and manage sites of high biodiversity value for the long-term maintenance of populations of native species and communities before they become critically rare. Thus, it should help to reduce the rate at which species require listing as threatened or endangered. Those species that are already greatly imperiled, however, still require individual efforts to assure their recovery.

3. GAP data products and assessments represent a snapshot in time generally representing the date of the satellite imagery. Updates are planned on a 5-10 year cycle, but users of the data must be aware of the static nature of the products.

4. GAP is not a substitute for a thorough national biological inventory. As a response to rapid habitat loss, gap analysis provides a quick assessment of the distribution of vegetation and associated species before they are lost, and provides focus and direction for local, regional, and national efforts to maintain biodiversity. The process of improving knowledge in systematics, taxonomy, and species distributions is lengthy and expensive. That process must be continued and expedited, however, in order to provide the detailed information needed for a comprehensive assessment of our nation's biodiversity. Vegetation and species distribution maps developed for GAP can be used to make such surveys more cost-effective by stratifying sampling areas according to expected variation in biological attributes.

Study Area

North Dakota ranks 17th among the 50 states in area, 3rd in total cropland harvested, and 47th in human population with 642,200 residents in 2000 (NDASS 2001). Of the 70,702 miles^2 of surface area in ND, 2.5% is water and 4.3% is owned by the federal government. The 65,917 miles^2 of non-federal land in ND consists of 58.6% cropland, 24.5% rangeland, 2.8% pasture land, 1% forest land, and 3.2 % developed land (NRCS 2000).

ND is located in the center of the North American continent and includes roughly equal proportions of the Central Lowlands and Great Plains physiographic provinces (Fenneman 1931). The geological history and processes shaping the modern landscape of ND has been described in detail by Bluemle (2000). All but the southwestern corner of state has been glaciated at some time with the latest glacial epoch ending about 10,000 years ago. The flora and fauna of ND is dominated by species that have colonized the state from surrounding regions following glacial events (Dix 1962, Axelrod 1985, Hoffman and Knox 1970).

ND's climate is characterized by large temperature variation across all time scales, irregular light-to-moderate precipitation, plentiful sunshine, low humidity, and nearly continuous wind (Enz 2003). Cold, dry air masses originating in the far north; warm, humid air masses originating in tropical regions; and mild, dry air masses resulting from modification of northern Pacific air masses by the Rocky Mountains regularly overflow the state. The average length of the freeze-free period is about 110 days in the northeast and north-central regions, increasing to 120 days over most of the rest of the state, and reaching 130 days in the southeast and south-central. Average annual precipitation ranges from about 36-56 cm (14–22 inches) from northwestern to southeastern ND. This increase reflects the decreasing distance to the Gulf of Mexico which is the water source for most of the state's precipitation. On average, about 75% of the annual precipitation falls during April to September and 50–60% falls during April through July. Precipitation occurs on an average of 65 to 100 days during the year, but over 50% of these events produce less than 0.25 cm. Evaporation exceeds precipitation throughout ND with an annual precipitation/potential evapotranspiration ratio ranging from 0.90 in the east to 0.57 in the west. Thornthwaite (1931) categorized the climate as subhumid in eastern ND and semiarid in the west.

From a biological perspective, the climate of ND is better characterized by variation, extremes, and drought and wet periods than by temperature and precipitation averages. The ranges and abundance of flora and fauna contract and expand with changes in resource availability in response to variation in the climate.

Prairie and wetlands dominated the land cover of ND prior to the late 1800s; woody vegetation was restricted to forests along major river channels and to local sites with a favorable microclimate (Stewart 1975). Kuchler (1964) in his map of the potential natural vegetation of the conterminous United States identified four prairie types and three woodland types in ND. Three prairie types arranged along a decreasing precipitation gradient from east to west are (1) Bluestem Prairie (Andropon-Panicum-Sorghastrum), (2) Wheatgrass-Bluestem-Needlegrass (Agropyron-Andropogon-Stipa), and (3) Wheatgrass-Needlegrass (Agropygon-Stipa). Kuchler also included a small fragment of prairie that he identified as Nebraska Sandhills Prairie (Andropogon-Calamovilfa) along the border with South Dakota in southeastern ND. The woodland types included a Northern Floodplain Forest (Populus-Salix-Ulmus) along major rivers and streams, Oak Savanna (Quercus-Andropogon) in the Turtle Mountains, Sheyene Delta, and smaller patchs near Devils Lake, along the Souris River, and east of Pembina Gorge, and a small area of Eastern Ponderosa Forest (Pinus) in southwestern ND.

Hundreds of thousands of shallow ponds and lakes in the glaciated region of the state were also an important component of the natural land cover of ND (Stewart and Kantrud 1971, Kantrud et al. 1989).

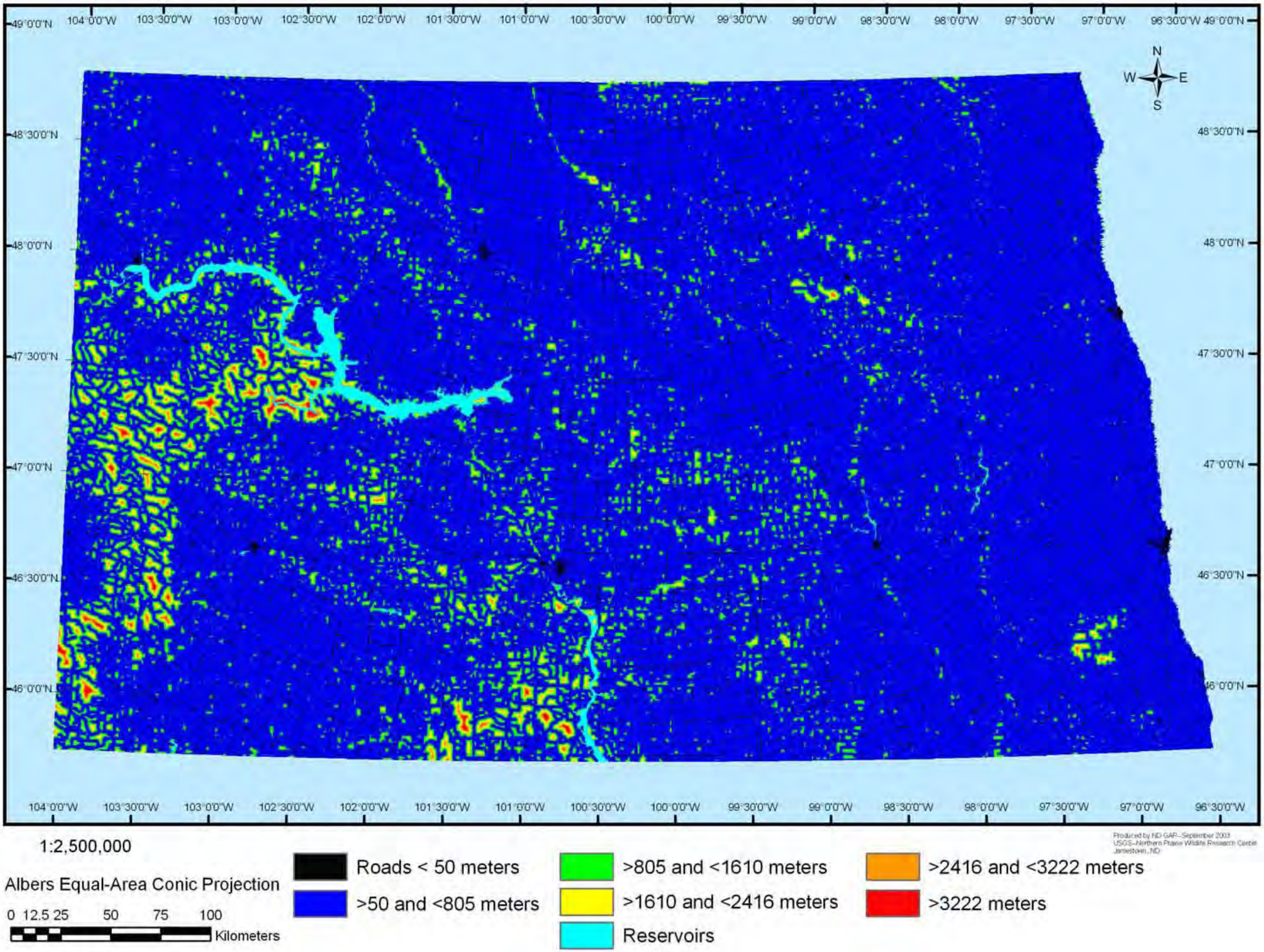
The plight of the Great Plains has been the subject of several recent books (Bouzaher and Johnson 1995; Samson and Knopf 1996, Johnsgard 2003). Since the mid-1800's, wildlife populations in ND have undergone overwhelming changes at the hands of man of white European stock first as a result of excessive and unregulated hunting, and latter through changes in land cover and land use. In about six decades, the most spectacular large mammal concentrations on the continent were eliminated. The last great bison hunt in ND took place in 1882 on the headwaters of the Cannonball River, where 600 well-armed hunters on horseback killed 5,000 animals in two days (Bailey 1926). By 1886, American bison numbers in the Great Plains were reduced to a few hundred from an estimated 30–40 million. Large predators such as the grizzly bear and the Great Plains wolf suffered a similar fate. Although never very abundant, the last recorded observation of bighorn sheep in ND prior to their reintroduction was a ram shot in 1905. Elk and pronghorn antelope originally ranged over all of ND and their abundance and range has been greatly reduced.

The history of the settlement of ND has been described in detail by Robinson (1966). The Dakota Territory was created in 1861 and opened to homesteading in 1863. Settlement of ND was slow until completion of the Northern Pacific Railroad provided dependable transportation. ND's population was recorded as 2,400 in 1870, increasing to 191,000 in 1890, 577,056 in 1910, and reached a peak population of 681,000 in 1930. This increase in population was a result of the rapid transfer of lands to private ownership through the cumulative effects of the Homestead Act, the Timber Culture Act, and the Preemption Act (Knue 1988). The homesteaders caused dramatic changes in land use. Large expanses of prairie were replaced by an almost equally endless sea of intensively cultivated fields. In 1919, ND was ranked 6th in the nation with respect to land in harvested crops with an estimated area of 19,760,741 acres or 44% of total land area (Shantz 1924). The drought of the 1930s and the failure of farming led to the creation of the Sheyene and Little Missiouri National Grasslands which are the largest contiguous blocks of public land in ND today. Concern with dwindling North American waterfowl populations in the early 20th century led to the Migratory Bird Treaty Act of 1918, the Migratory Bird Conservation Act of 1929 and the Migratory Bird Hunting Stamp Act of 1934. Most of the National Wildlife Refuges in ND were established in the 1930s and 1940s and an amendment of the Migratory Bird Hunting Stamp Act in 1958 resulted in the creation of the Small Wetlands Acquisition Program and the purchase of fee-title Waterfowl Production Areas (Krapu and Duebbert 1989).

In 2000, the area of harvested cropland in ND was estimated at 20,901,000 acres (47% of total land area) while the area of total cropland, lands that have been tilled at some time and could be put into crop production with minimal effort, was estimated at 27,025,000 acres (61% of total land area) (NDASS 2001). Although the state is sparsely populated, the area of public lands is small and wilderness and natural areas are almost non-existent. ND land surface is highly fragmented by roads. Ninety percent of the state's land area is within 0.805 km (0.5 miles) of a road, 99% is within 3.28 km (2 miles) of a road, and the maximum distance from a road is 4.82 km (3 miles) (Map 1).

Tallgrass prairie has been reduced to remnant fragments in the Red River Valley. Most of the remaining prairie is mixed prairie located the Missouri Coteau and Missouri Plateau in areas where relatively rugged topography and reduced amounts and reliability of precipitation made the conversion to cropland more difficult than in the Drift Plain. Tens of thousands of wetlands in the glaciated portion of the state have been drained and farmed. Magnificent stands of floodplain forest along the Missouri and other rivers have been greatly reduced by water development projects and agriculture. Shelterbelts, tree claims, and field windbreaks have resulted in a large increase in woody vegetation in ND (Haugen et al. 1994).

These land use changes have had equally dramatic consequences for wildlife. Although croplands have resulted in abundant food supplies for many species of wildlife, they are comparatively sterile and bleak with respect to use by breeding vertebrates and general richness of biota (Stewart 1975). The abundance of food resources available to wildlife from croplands is decreasing with increases in the harvesting efficiency of farm equipment (Krapu et al. 2004). Grassland birds have shown more consistent and steeper widespread declines than any other group of North American bird species (Peterjohn and Sauer 1999). The decline in grassland nesting bird populations may be due in part to large changes in the distribution and abundance of predator species resulting from habitat alterations, human-inflicted mortality, and interspecific relations among predator species (Sargeant et al. 1993). Farm conservation programs that retire croplands from production and place the lands in an idle grassland cover for multiple years can have a huge positive effect on many grassland-nesting birds by virtue of the large areas involved in the programs (Johnson 2000, Reynolds et al. 2001). The Conservation Reserve Program is the most recent of these programs with over 3 million acres of perennial grass and legume cover established on previously tilled cropland in ND. Such large acreages make significant changes to landscape composition and configuration, and to vertebrate species distribution, reproduction, and survival.



Map1.1. Distance from roads and trails in North Dakota. Data from North Dakota Department of Transportation GIS Base Map Data, version 1.

LAND COVER CLASSIFICATION AND MAPPING

Introduction

Vegetation patterns are an integrated reflection of the physical and chemical factors that shape the environment of a given land area (Whittaker 1965). They also are determinants for overall biological diversity patterns (Franklin 1993, Levin 1981, Noss 1990), and they can be used as a currency for habitat types in conservation evaluations (Specht 1975, Austin 1991). A central concept of the gap analysis "coarse filter" approach to conservation biology is that the physiognomic and floristic characteristics of vegetation (and, in the absence of vegetation, other physical structures) across the land surface can be used to define biologically meaningful biogeographic patterns (Scott et al. 1993). The mapped extent and distribution of existing land cover is used in gap analysis to determine the representation of natural land cover categories within areas managed for biodiversity conservation, to model wildlife habitat and the potential distribution of terrestrial vertebrates, and to provide a land cover map which can be used to determine land cover trends by comparison with land cover maps developed at other times (Jennings 2000).

Vegetation classification and vegetation mapping are complex, distinct but intimately related, continually evolving activities which have received much attention and debate (Mueller-Dombois and Ellenberg 1974, Kuchler and Zonneveld 1988). Plant communities at various levels of geographic scale can be identified and described by the combined use of physiognomy, structure and floristics based on the principle of relative similarities and differences that underlies all systems of biological and ecological classification (Mueller-Dombois and Ellenberg 1974, Kuchler and Zonneveld 1988). Vegetation classification is the process of generalization and abstraction from individual stands of vegetation to a description of the kinds of plant communities. A common limitation of all vegetation classification systems is a certain amount of inflexibility with regard to the natural variability of vegetation. Vegetation mapping is the process of portraying the location and spatial pattern of plant communities in the landscape. A map can serve as a test of a vegetation classification because the mapper is forced to accommodate all of nature’s kaleidoscopic arrangement of plants.

Land Cover Classification

The National Vegetation Classification System (NVCS) is a relatively recent attempt towards a unified vegetation classification system for the United States (FGDC 1997). The origin of this system is referred to as the UNESCO/TNC system (Lins and Kleckner 1996) because it is based on the structural characteristics of vegetation derived by Mueller-Dombois and Ellenberg (1974), adopted by the United Nations Educational, Scientific, and Cultural Organization (UNESCO 1973) and later modified for application to the United States by Driscoll et al. (1983, 1984). The Nature Conservancy, the Natural Heritage Network, and the Ecological Society of America Vegetation Classification Panel have worked to improve upon this system in recent years with partial funding supplied by GAP (Grossman et al. 1998, Jennings et al. 2003).

The NVCS is a hierarchal vegetation classification system based upon physiognomy and structure of vegetation at the higher levels and floristic composition at the lower levels (Grossman et al. 1998). Vegetation units at the lowest and most detailed level in the classification system are identified as associations. An association is a generalization or abstraction based upon the study of individual stands of vegetation and has a defined range of species composition, diagnostic species, habitat conditions, and physiognomy (Jennings et al. 2003). An alliance, the vegetation unit at the level above the association, involves an additional amount of abstraction. It is defined as a group of associations with a defined range of species composition, habitat conditions, and physiognomy, and which contains one or more of a set of diagnostic species, typically at least one of which is found in the upper most or dominant stratum of the vegetation (Jennings et al. 2003). At this early stage in its development, the NVCS does not contain quantitative information summarizing the variability in the species composition, structure and habitat characteristics within and among associations and alliances.

GAP guidelines call for mapping existing vegetation to the alliance level of the NVCS from analysis of Thematic Mapper imagery and ancillary data with individual alliance accuracy objective of 80% or greater. A review of the literature on vegetation and land cover mapping for rangeland ecosystems (Brown et al. 1983, Carneggie et al. 1983) and two recently completed land cover mapping projects in ND (EarthSat 1996, Redmond 1997) revealed this goal would be difficult to achieve.

The starting point for the development of the land cover classification system for the ND-GAP was a document prepared by the Nature Conservancy that identified and described 68 natural vegetation alliances in ND (Drake and Faber-Langendoen 1997). A provisional land cover classification system was prepared at the beginning of the ND-GAP by aggregating the 68 natural vegetation alliances into 33 natural and semi-natural land cover categories, and identifying an additional 8 land cover categories consisting of seven planted/cultivated land cover categories, and an urban land cover category (Appendix 2.1). Although, there was a concern that the number of land cover categories was still too ambitious given the limited potential to extract floristically defined land cover categories from digital analysis of remotely sensed imagery (Graetz 1990, Verstraete et al. 1996), acceptance of a provisional land cover classification system was needed so that the terrestrial vertebrate component of the project could proceed simultaneously with the land cover mapping component.

Methods

Overview

The land cover map for the ND-GAP was developed from a digital geospatial data base that included observations from spring, summer and fall Landsat Thematic Mapper imagery for all of ND. Each pixel in the data base was classified individually and independently of other pixels in the data base on the basis of its multi-temporal spectral reflectance measurements. Wetlands were mapped using National Wetlands Inventory (NWI) data (Wilen and Bates 1995). Urban and developed land cover categories were mapped using the 1992 ND National Land Cover data base (Vogelman et al. 2001). Ancillary data and manual editing were used during the analysis and classification process to reduce land cover classification errors. Data for the accuracy assessment was collected in a probability-based sampling design using ground surveys and aerial photography. Software used in the land cover mapping process included MicroImages Map and Image Processing System (www.microimages.com), CART (www.salford-systems.com), and SAS (wws.sas.com).

Mapping Standards and Data Sources:
We maintained the 30 x 30 m (0.09 ha) cell size of the Landsat Thematic Mapper imagery in the construction of the land cover map. Most of the Thematic Mapper images used in the ND-GAP were acquired from the Multi-resolution Land Cover Characteristics Project (MRLC) (Loveland and Shaw 1996). The MRLC images were georegistered to a UTM map projection using 3-arc-second digital terrain elevation data and ground control points by the U.S. Geological Survey's EROS Data Center. The root mean square registration error for the MRLC TM images is less than 1 pixel (30 meters). Thematic Mapper images acquired from other sources were georegistered and resampled to the extents of an MRLC image for the orbit path and row using control points located in the image and the MRLC image. The root mean square registration error was less than 1 pixel.

A May, July, and September Landsat-5 Thematic Mapper image was acquired for each of fourteen orbit path and row combinations required for complete coverage of ND (Table 2.1). The dates of the May, July, and September images for rows 27 and 28 in path 31, rows 26, 27, and 28 in path 32, and rows 27 and 28 in path 34 were identical within the path and the data were combined for the analysis. This reduced the number of path and row defined data sets from fourteen to ten. The TM data for a path and row was clipped to the common spatial extent among the three dates of imagery. A vegetation and land cover map was derived independently for each of the ten subsections of ND. The vegetation and land cover database for the state was produced by mosaicking the ten independently derived land cover maps (Fig. 2.1). In the areas of overlap between the subsections, priority was given the path and row combination that had the most recent May TM image. Inspection of the state land cover mosaic revealed a 7.4 sq km area at the intersection of path 31 row 26, path 30 row 27 and the state boundary with Minnesota that did not have land cover data. Land cover data from the ND 1992 National Land Cover data set corresponding to the missing data location was translated to the categories of the ND-GAP land cover database and inserted into the state land cover mosaic to complete the coverage for ND.

Wetlands are an abundant and important land cover component in ND, particularly in the Prairie Pothole Region. Many of the temporary and seasonal wetlands are small relative to the pixel size of the TM imagery. Because of the difficulty mapping small wetlands using TM imagery (Ozesmi and Bauer 2002), wetlands for the ND-GAP land cover database were extracted from digital NWI data (Wilen and Bates 1995). NWI data for ND were developed from manual stereoscopic interpretation of ~1:60,000 scale aerial photography acquired from 1979-1984. NWI data for the Prairie Pothole Region of ND was obtained from the U.S. Fish and Wildlife Service (USFWS) Region 6 Habitat and Population Evaluation Team and NWI data for areas west and south of the Missouri river was obtained from the USFWS NWI.

Urban and developed land cover categories for the ND-GAP land cover map were extracted from the 1992 ND National Land Cover data base (Vogelman et al. 2001). The four categories included in the ND-GAP land cover database were Low Intensity Residential, High Intensity Residential, Commercial/Industrial/Transportation and Urban/Recreational Grasslands.

Table 2.1. Dates of Landsat 5 Thematic Mapper imagery used to create the ND-GAP land cover map. Rows within a path are grouped together when dates of May, July, and September images within the path are the same. A land cover classification was developed for each of the ten subsections of North Dakota.

Index Number	Landsat 5 path/row	Spring Image	Summer Image	Fall Image
1	Path 30 Row 27	26 May 1999	10 July 1998	10 August 1992
2	Path 30 Row 28	4 May 1997	26 July 1998	17 September 1994
3	Path 31 Row 26	1 May 1999	1 July 1998	8 September 1994
4	Path 31 Row 27	16 May 1993	14 July 1997	27 September 1995
	Path 31 Row 28	16 May 1993	14 July 1997	27 September 1995
5	Path 32 Row 26	26 May 1994	2 July 1996	2 September 1995
	Path 32 Row 27	26 May 1994	2 July 1996	2 September 1995
	Path 32 Row 28	26 May 1994	2 July 1996	2 September 1995
6	Path 33 Row 26	14 May 1993	9 July 1996	25 September 1995
7	Path 33 Row 27	12 May1998	15 July 1998	22 September 1994
8	Path 33 Row 28	12 May1998	15 July 1998	1 September 1998
9	Path 34 Row 26	3 May1998	30 July 1995	10 September 1993
10	Path 34 Row 27	3 May1998	30 June 1996	5 September 1997
	Path 34 Row 28	3 May1998	30 June 1996	5 September 1997

There were four primary sources of training data used for land cover mapping (Fig. 2.2). We conducted land cover surveys within 28, 28.6- x 28.6- km sample units in the summer of 1999. The location of the sample units was subjectively chosen after consideration of (1) access to public lands, (2) the amount of natural and semi-natural vegetation, and (3) surface geology, topography, and soils. Most of the sample units were located within the overlap area of adjacent TM orbit paths to make maximum use of the training data and our resources for land cover surveys. Additional sample units were located outside the overlap areas of TM images to include plant communities and environmental conditions which could not be represented within the overlap areas. Land cover within a sample unit was delineated on a 1:31,680 scale (2 inches per mile) color composite of TM imagery by a single observer for all 28 sample units. Land cover polygons were delineated primarily from roadside surveys because the logistics of obtaining trespass permission on private lands for an extensive land cover survey was prohibitive at this stage in the ND-GAP. The observer used the provisional ND-Gap land cover classification when assigning labels to the polygons. Many of the polygons for natural and semi-natural vegetation were labeled with multiple land cover categories as it was not possible to delineate the complexity of vegetation community boundaries at this scale and from the road.

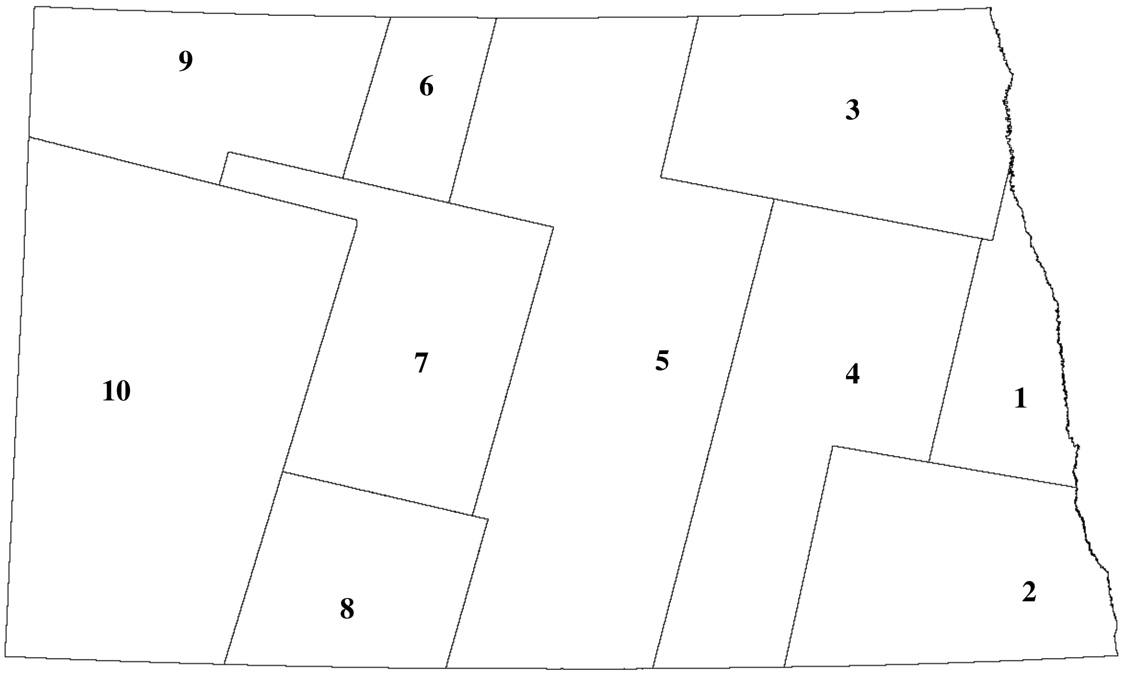


Fig. 2.1. The ND-GAP land cover map was produced from a mosaic of land cover maps developed independently for ten subsections of the state defined by the date of the TM images. The index numbers in the figure correspond to the path and rows of TM imagery in Table 1.

We also used a land cover data set prepared for 45 systematically spaced 40.5 km^2 hexagons in the Prairie Pothole Region. Land cover was created from interpretation of 1996 aerial photography by the Environmental Protection Agency and Northern Prairie Wildlife Research Center for a Prairie Pothole Region Wetland Environmental Monitoring and Assessment Project (EMAP) (Guntenspergen et al. 2002). The land cover classification included 14 land cover categories including natural grassland, planted hayland, planted grassland, cropland, woodland, shrubland, odd areas, barren, developed, and temporary, seasonal, semipermanent, permanent, and riverine wetlands.

Another source of training data for land cover mapping was obtained from Ducks Unlimited (DU) and the USFWS. The data was collected for training and accuracy assessment of their circa 1995 land cover map for the prairie pothole region of ND. The data set consisted of a combination of land cover from manual interpretation of aerial photographs and field surveys for a stratified random sample of 10.4 km^2 sample units (Cowardin et al. 1995) and additional land cover samples collected in a systematic sample design from roadside surveys. The land cover classification system was similar to the land cover classification of the EMAP data set.

The ND State Land Department was another source of training data. The Department is responsible for the management of approximately 714,000 acres of school trust lands, the majority of which is semi-natural grassland located in the western two-thirds of the state, and is leased for grazing by domestic livestock (Brand et al. 1988). Range inventory data was collected from 1980-1997 by three observers with many years of prior experience appraising range conditions in ND. The inventories were conducted on all State School Land tracts larger than 40

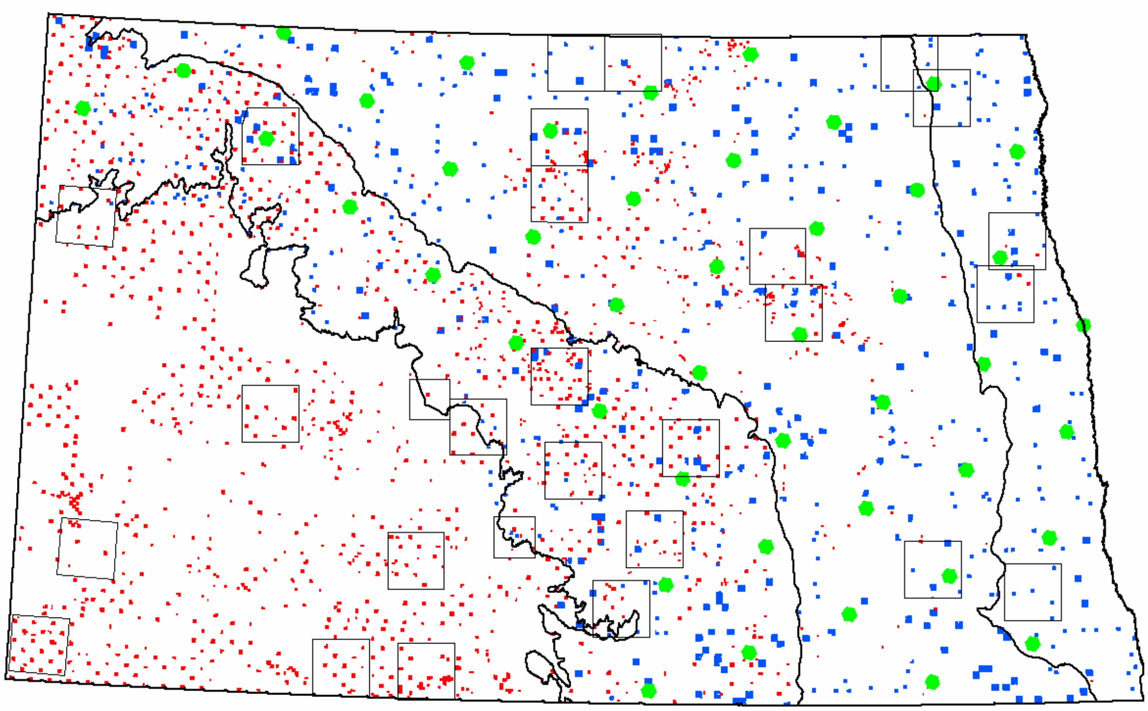


Fig. 2.2. Sources and distribution of training samples for land cover mapping. The boundaries of the 28, 818 km^2 sample units used for land cover surveys in 1999 are outlined in black. The solid green hexagons are 40.5 km^2 land cover sample units from the Prairie Pothole EMAP project. The solid blue features are land cover sample units from the USFWS and DU data set. The solid red features are state school lands.

acres with the exception of tracts managed by Grazing Associations in conjunction with National Grasslands. Using procedures similar to those in the National Range Handbook (USDA 1976), the observer made ocular estimates of the relative amount (%) of the total forage biomass by species for graminoids and by life form for forbs and shrubs for the primary range site of the tract. Surveys conducted in the latter years recorded data for more than one range site if the tract had large scale heterogenity in range sites. A total of 3,468 range worksheets were completed for the 2,864 school land tracts surveyed. The plant species composition and biomass data from the range surveys were transcribed from microfiche and word-processing files into a SAS data set. The data was exported as a dbase file and linked to a vector of the state school land tracts. The vector and the attached data base provided information about the range site(s), species composition and relative biomass of herbaceous plants, observations of woody plants, and topography of the tract.

We also obtained two additional sources of training data with smaller spatial extents. The ND Natural Heritage Program (NDNHP) recently completed tallgrass prairie inventories in Ransom, Richland, Sargent, and Barnes counties in southeastern ND (Shenk and Lenz 1998, Boe and Lenz 1999). Field surveys were conducted for areas of potential tallgrass prairie identified from interpretation of 1:7,920 scale enlargements of black and white National Aerial Photography Program photographs. Natural and semi-natural plant communities were classified to the association level of the NVCS and mapped on 1:24,000 scale topographic maps. We obtained vectors created by digitizing the maps. A land cover map for a 1493 km^2 area including

Theodore Roosevelt National Park and surrounding lands in western ND produced by the U.S. Geological Survey -U.S. National Park Service Vegetation Mapping Program was obtained (Von Loh et al. 2000). The map legend includes 29 natural and semi-natural land cover categories described using the NVCS and ten additional land cover categories.

Several other geospatial data bases were used in the analysis of the Thematic Mapper imagery (Table 2.2). Information about the data bases and how they were used is presented in the next section.

Table 2.2. Six geospatial data bases used in the analysis of Thematic Mapper imagery and the creation of the ND-GAP land cover map.

Omernik's Level IV Ecoregions of North Dakota (Bryce et al. 1998)
Geologic Map of North Dakota (Clayton et al. 1980)
1992 ND National Land Cover data base (Vogelmann 2001)
A circa 1992 land cover data base for the prairie pothole portion of ND (east and north of the Missouri River) available from Ducks Unlimited and the U.S. Fish and Wildlife Service (Earthsat 1996).
A circa 1992 land cover data base for western ND available from the U.S. Forest Service (Redmond et al. 1997).
ND State Soil Geographic (STATSGO) data base (NRCS 1994)

Land Cover Analysis and Mapping

The first step in the analysis of the TM imagery was the construction of cloud and water masks for the images. Cloud masks were created to determine if there were areas within the state which had cloud cover on all TM images for the area and thus would require additional imagery to map the land cover or the inclusion of a cloud category in the land cover classification. Cloud masks were created using a threshold on a TM channel 3 –TM channel 1 difference image, a threshold on the TM channel 1 image, and manual editing. Inspection of cloud masks in conjunction with extents of the TM images, including areas of overlap between paths and rows, revealed that it would be possible to map land cover for all areas of the state without acquiring additional images or the need for a cloud category. Cloud masks were used to exclude cloud pixels from train and test samples used in the classification tree analyses.

A water mask was constructed for each image using a threshold on TM channel 5. A water mask for the path and row was created by combining the individual image water masks using Boolean logic and identifying pixels that were identified as water on two or more dates. Requiring a pixel to be identified as water on a minimum of two image dates before it was included in the water mask for the path and row reduced water commission errors. Cloud shadows and other commission errors in the water mask were manually excluded. Water remaining after incorporating NWI data into the land cover classification was assigned to a generic wetland category.

The analysis of the TM imagery for each of the ten path and row subsections in ND began with binary classification tree analyses for the cropland, woodland, and planted herbaceous perennials land cover categories and for path 34 rows 27 and 28, which includes the Little Missouri Badlands, a sparsely vegetated land cover category. Each of the binary classification tree analyses separated the target land cover category from a composite category that included all other land cover categories. This binary sequential and hierarchical approach to land cover classification is an effective method for dealing with the high spectral dimensionality of multitemporal imagery (Lee and Richards 1985, Lozano-Garcia and Hoffer 1985). The spectral classification rules were developed using the classification tree algorithm in CART version 4.0 (Salford Systems 2000). Classification tree rules were output from CART, edited and imported as spatial manipulation language scripts (SML) into MicroImages Map and Image Processing System to create the land cover maps.

Multiple binary cropland/not-cropland classification tree analyses were performed using different combinations of image dates and spectral channel subsets. Different combinations of image dates were used because of the wide range in the dates of the TM images for some paths and rows. For example, the TM images available for path 30 row 28 included 4 May 1997, 26 July 1998, and 17 September 1994. The multiple binary classifications for cropland were combined to create a single image depicting all possible combinations of the binary cropland classifications. The pixel values in this image indexed classes of pixels whose member pixels had the same pattern of cropland classification among the multiple binary cropland classifications. For example, one pixel value identified a class whose pixels were classified as cropland on all of the classifications, another pixel value identified a class whose pixels were classified as cropland on all classifications except one, and so on. This cropland image was inspected by comparison with color composites of the TM imagery, digital orthophotographs, and the training data. Pixel values for classes in the image that contained a mixture of crop and not-cropland pixels were identified, and a mask was constructed for pixels belonging to these classes. A Kmeans clustering and maximum likelihood classification was performed using the mask with a subset of the TM images and spectral bands to subset the pixels into spectral classes which would reduce the classification errors for cropland. A provisional cropland mask was created by combining the cropland classes from the binary classification tree analyses and the cropland classes from the maximum likelihood analysis.

Next, the provisional binary cropland mask created in the previous step was combined with a binary cropland mask extracted from the 1992 ND National Land Cover dataset, and a binary cropland mask from either a DU/USFWS land cover classification (east and north of the Missouri River) or a U.S. Forest Service Land cover classification (west and south of the Missouri River) to depict all possible combinations of cropland as defined by the three sources. This image was inspected for cropland omission and commission errors in the provisional cropland mask and a final cropland mask was created that minimized cropland classification errors. Cropland commission errors for sparsely-vegetated badlands topography and sand dunes for path 30 row 28, path 32 rows 26,27,28, and path 34 rows 27 and 28 were reduced using thematic categories from the Ecoregions of ND and Geologic Map of ND data sets and manual editing.

Next binary woodland/not-woodland classification tree analyses were performed in a manner similar to that described for croplands. Extensive use of digital orthophotographs was used to inspect the woodland classifications. If sufficient training data was available, a woodland community type analysis was performed using classification tree analysis. Otherwise, an unsupervised Kmeans cluster analysis and maximum likelihood classification was performed for the woodland mask and correspondence of spectral classes to woodland types was determined from statistical summaries of the association of spectral classes with training samples (Homer et al. 1997). Ponderosa pine was mapped using conifer forest spectral classes with township, range, and section information for the four largest stands described in Potter and Green (1964a). The single stand of limber pine was mapped using conifer forest spectral classes with township, range, and section information for the stand described in Potter and Green (1964b).

Next binary planted herbaceous perennials/not-planted herbaceous perennials classification tree analyses were performed in a manner similar to that described for croplands and woodlands. In an effort to further reduce classification errors between planted herbaceous perennials and natural and semi-natural prairie due to their similarity in physiognomic structure and uses, a Kmeans cluster analysis and maximum likelihood classification were performed for pixels assigned to the planted herbaceous perennials mask. Statistical summaries of the association of spectral classes with planted herbaceous perennials and natural grassland training samples and manual inspection of the spatial patterns of the spectral classes were used to identify spectral classes as planted herbaceous perennials, mixtures of planted herbaceous perennials and natural grassland, and natural grassland. Spectral classes identified as planted herbaceous perennials were used to create a planted herbaceous perennials mask and spectral classes identified as mixtures of planted herbaceous perennials and natural grassland were combined to create a mask for analysis of natural and semi-natural prairie land cover categories.

National Wetlands Inventory data were quality checked for valid wetland attribute codes as defined in the Classification of Wetlands and Deepwater habitats of the United States (Cowardin et al. 1979) and an exhaustive list of the attribute codes was created. For our purpose, we aggregated wetlands to seven wetland categories on the basis of the attributes at the system and class levels, and the water regime modifier. The seven categories are Lacustrine (System Code L), Riverine (System Code R), Palustrine Forested (System and subsystem code PFO), Palustrine Scrub-shrub(System and subsystem code PSS), Palustrine Semi-permanent (System code P, subsystem code not FO or SS, water regime code F), Palustrine Seasonal (System code P, subsystem code not FO or SS, water regime code C,D, or E), and Palustrine Temporary (System code P, subsystem code not FO or SS, water regime code A, B). There were a small number of Palustine wetlands where the subsystem code is not FO or SS, and the water regime code is not A,B,C, D,E or F. Palustrine wetlands where subsystem code is not FO or SS with water regime G (intermittently exposed), H (permanently flooded), or K (artificially flooded) were classified as lacustrine wetlands. Wetlands which were complexes of 2 or more types are grouped for our purposes on the basis of the first wetland code. For example, a PSS/EMA wetland is identified as Palustrine Scrub-shrub. In the final land cover map, Palustrine Forested wetlands and Palustrine Scrub-shrub wetlands were included in the Floodplain Woodland and Lowland Deciduous Shrubland land cover categories, respectively.

The NWI vectors were converted to rasters with 5 m pixels and these rasters were resampled to rasters with 30 m pixels and spatial extents corresponding to the appropriate TM image. The conversion from vector to raster overestimated the area of wetlands particularly for small wetlands. The two-step vector to land cover data base raster conversion process reduced the overestimation of the area of wetlands.

In the land cover mapping process, a loss of wetlands was observed along the Missouri River and the current land cover for these areas was identified from analysis of TM imagery. Wetland losses may have occurred in other areas but were not detected. The water mask created from the TM imagery suggested there were also gains in the number and area of wetlands in response to an unusually wet period in ND which began in the summer of 1993 (Williams-Sether 1999). A NWI wetlands status and trend report for the period 1986-1997 also observed wetland gains in the prairie pothole region (Dahl 1997).

Urban and developed land cover categories for the ND-GAP land cover data base were extracted from the 1992 ND National Land Cover data base. The four categories included in the ND-GAP land cover database were Low Intensity Residential, High Intensity Residential, Commercial/Industrial/Transportation and Urban/Recreational Grasslands. Recent urban development in Fargo, Bismarck, Grand Forks and Minot and an omission of urban land cover in and surrounding Williston, ND was mapped using a combination of 1990 U.S. Census Block Group housing density data, a urban category from a 1998 land cover classification for ND produced by the ND Agricultural Statistical Service and TM imagery.

Pixels remaining after constructing and combining the cropland, woodland, planted herbaceous perennials, wetlands, water, and developed land masks were assigned to the prairie land cover category. An analysis of prairie community types was performed using classification tree analyses with training data developed from range inventories for ND school lands. Insufficient School Land training samples were available for path 30 row 27, path 30 row 28, and path 31 row 26. A Kmeans cluster analysis and maximum likelihood classification was performed for path 30 row 28 and prairie community type labels were assigned to the spectral classes by reference to prairie community maps for Richland, Sargent, Barnes and Ransom Counties in ND by the ND Natural Heritage Program. A prairie type analysis was not attempted for path 30 row 27 and path 31 row 26 because of insufficient data training data and the small amount of prairies in this portion of the state.

The assignment of classification tree nodes to prairie types was evaluated using statistical summaries of the association of node members with prairie community type and planted herbaceous perennials training samples and by reference to landscape position and association as determined from manual inspection of TM color composites, and digital orthophotographs. Changes in assignment of prairie community type labels to classification tree nodes were made when evaluation of the classification suggested a different prairie community type or planted herbaceous perennials would be more appropriate label for the node.

Development of a shrubland land cover category was challenging because of the difficulty defining training areas for small, sparsely distributed, and irregular shaped shrub patches, the spectral similarity of shrublands with other land cover categories, and temporal change in snowberry (*Symphoricarpos occidentalis*) shrubland communities between the date of the TM imagery and ground surveys due to haying and fire. Because of these difficulties, we were not able to create a shrubland category for all areas of the state. The shrubland category was developed, when possible, during the analysis of the woodland and prairie land cover categories. Spectral classes for the shrubland category were identified when they were detected during the process of inspecting the woodland classifications using the digital orthophotos and using a threshold on a near infrared/red ratio for the July TM image for areas identified as prairie. The logic behind the use of the July near infrared/red ratio procedure was that the grass and forb component of the vegetation would be experiencing a water deficit at this date, while the shrub component with its deeper roots would have access to water and would have a canopy with more actively growing green leaves than grasses and forbs. These phenologic conditions did not appear to be met for many of the July images as attempts to define a shrubland category resulted in excessive shrubland commission error and hence a shrubland land cover category was not created. A shrubland land cover category was developed for paths 34 rows 27 and 28, path 33 row 27, path 33 row 28, path 31 rows 27 and 28, and path 31 row 26 (See Fig. 2.1 and Table 2.1). The shrubland category for path 31 rows 27 and 28 was extended into the overlap areas for path 30 row 28 and path 32 rows 27 and 28. The shrubland category was subset into an upland deciduous shrubland category, a sagebrush shrubland category (only for areas in path 34 rows 27 and 28), and a lowland shrubland category by cross-tabulation with training area polygons.

Five post-classification stratifications using ancillary data were performed to increase the information content of the land cover map and to reduce land cover classification errors.

First, a floodplain woodland land cover category was created by intersecting a binary mask created from the Geologic Map of ND with the woodland land cover category. The initial binary geologic mask was created from two geologic categories, Holocene River Sediment, Qor, and Holocene to Pre-Wisconsin Uncollapsed River Sediment, Qcrf. The initial intersection of this mask with a binary image of the woodland land cover category revealed numerous commission errors for floodplain woodland. The binary geologic map was manually edited to exclude these commission errors. A final floodplain woodland land cover category was constructed after several iterations of manually editing the binary geologic map and inspection of its intersection with the woodland land cover category.

Second, an area of saline prairie in the northern portion of the Glacial Lake Agassiz physiographic region near Grand Forks, ND, was created by intersecting a binary mask of soil map unit ND073 from the ND State Soil Geographic (STATSGO) data base with planted herbaceous perennials and prairie land cover categories.

Third, the area of the sand prairie land cover category was increased by intersecting a binary mask of the prairie land cover category for path 31 rows 27 and 28 and path 31 row 26 with a binary mask of the Holocene Windblown Sand, Qod, category from the Geologic Map of ND.

Fourth, a fescue prairie land cover category was created in north-western ND by intersecting a binary mask of the Bluestem – Needlegrass-Wheatgrass prairie category from path 34 row 26 with a binary mask of a Fescue Prairie land cover category developed from regression tree analyses predicting the relative abundance of *Heterostipa curtiseta* and *Agropyron dasystachyum* from environmental variables (unpublished data presented at a poster session at the 55th Annual Meeting of the Society for Range Management, L. L. Strong, Integration of GIS and remote sensing for mapping rangeland plant communities of the Northern Great Plains).

Finally, the prairie land cover category was reduced by changing pixels classified as prairie to planted herbaceous perennials if the pixels were classified as cropland on five or more years in a six year land cover data base constructed from annual land cover classifications produced by the ND Agricultural Statistical Service.

Results

The classification system for the ND-GAP land cover map is hierarchical with eight general land cover categories at the upper level and 39 detailed land cover categories at the lower level (Table 2.3, Map 2.1). A description of the 39 land cover categories is in Appendix 2.2. Forty-eight percent (88,165 km^2) of the total surface area of ND was mapped as cropland. An additional 30,543 km^2 was mapped as lands planted to herbaceous perennial plants bringing to a total 118,760 km^2 or 64.9 % of ND that has been tilled at some time. These estimates appear reasonable when compared with a 1997 estimate of harvested cropland (82,775 km^2) and a 1969 estimate of total cropland area (119,216 km^2) (USDA 1999).

Ten prairie land cover categories were mapped and combined account for 35,681 km^2 (19%) of ND. Wheatgrass Prairie, Needlegrass Prairie, and Bluestem-Needlegrass-Wheatgrass Prairie accounted for 23, 21 and 16 % of lands mapped as prairie, respectively. Little Bluestem and Sand Prairie each account for 12% of lands mapped as prairie. Wet-mesic Tallgrass Prairie, Mesic Tallgrass Prairie, Mesic Tall and Mixed Prairie, Fescue Prairie, and Sand Prairie each account for 6 % or less of the lands mapped as prairie.

Three shrubland land cover categories (Upland Deciduous, Lowland Decidous, and Sagebrush) accounted for 5,281 km^2 (2.9%) of the ND. As explained in the methods section, shrublands were difficult to map and shrublands were not mapped for all areas of the state and thus are underestimated. Shrubland omission errors are likely commission error for prairie, planted herbaceous perennials and woodland land cover categories. Previous small scale vegetation maps for ND have not included a shrubland land cover category and only some of the recent vegetation maps developed using remotely sensed imagery have included a shrubland land cover category. Refinement of the shrubland land cover category should be a high priority in future land cover maps.

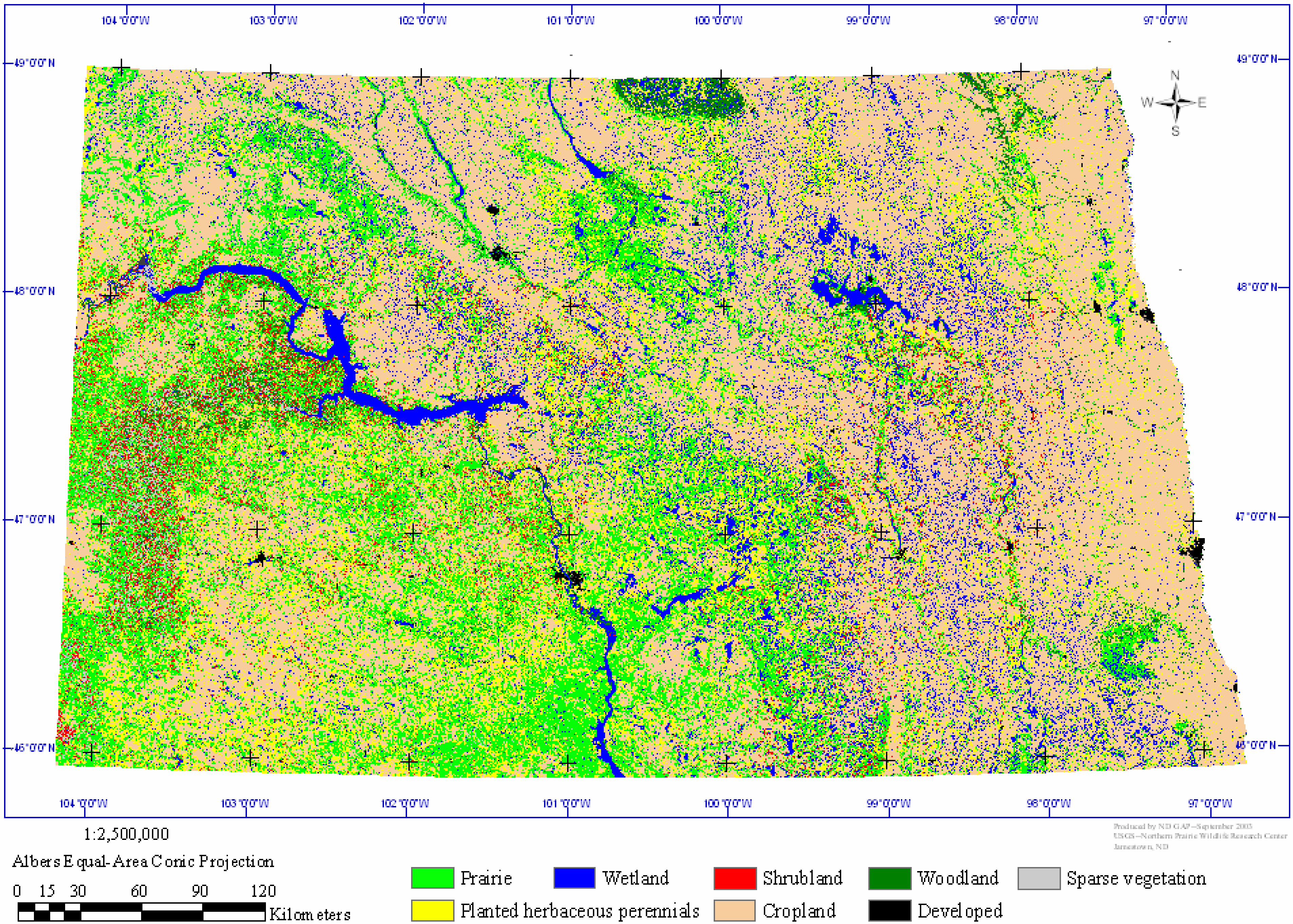
Wetlands accounted for 16,297 km^2 (9 %) of ND. The area of wetlands is likely overestimated because the process of converting NWI vectors to rasters exaggerated the area of small polygons. Seasonal wetlands accounted for the largest proportion, 32%, of wetlands. Lacustrine, Temporary, and Semipermanent wetland had roughly similar proportions accounting for 21.4, 18.9, and 17.4 % percent of wetlands, respectively. Eight percent of the wetland land cover category (1329.2 km^2) is identified as wetland based on the detection of surface water on two or more dates of TM imagery at locations not identified as wetland in the NWI data. Some of this increase in wetland area is a real increase in the area of wetland (Dahl 1997) and some

Table 2.3. Raster cell value, land cover category, area (km^2), percent of general land cover category, percent of the area of North Dakota, and area in miles^2 , hectares and acres for 39 land cover categories in the ND-GAP land cover map.

Cell value	Land cover category	Area (sq km)	% of state	% of general land cover category	Area (sq miles)	hectares	acres
1	**cropland**	**88165.9**	**48.1511**		**34040.8**	**8816588**	**21785788**
2	**planted herbaceous perennials**	**30542.7**	**16.6807**		**11792.6**	**3054274**	**7547110**
	prairie	**35681.4**	**19.4871**		**13776.6**	**3568140**	**8816874**
10	prairie - wet-mesic tallgrass	1402.3	0.7659	3.930	541.4	140232	346513
11	prairie - mesic tallgrass	156.2	0.0853	0.438	60.3	15616	38587
12	prairie - mesic tall and mixed	2054.3	1.1219	5.757	793.2	205429	507615
13	prairie - bluestem-needlegrass-wheatgrass	5851.7	3.1959	16.400	2259.4	585172	1445961
14	prairie - wheatgrass prairie	8291.1	4.5281	23.236	3201.2	829110	2048730
15	prairie - needlegrass prairie	7392.0	4.0371	20.717	2854.1	739203	1826570
16	prairie - little bluestem	4298.5	2.3476	12.047	1659.6	429849	1062157
17	prairie - fescue	444.4	0.2427	1.245	171.6	44436	109802
18	prairie - sand	4267.7	2.3308	11.961	1647.8	426772	1054555
19	prairie - saline	1523.2	0.8319	4.269	588.1	152321	376384
	shrubland	**5281.1**	**2.8842**		**2039.0**	**528112**	**1304965**
20	shrubland - upland deciduous	4299.2	2.3480	81.407	1659.9	429920	1062333
21	shrubland - lowland deciduous	79.1	0.0432	1.498	30.5	7911	19549
22	shrubland - sagebrush	902.8	0.4931	17.095	348.6	90280	223083
	woodland	**4284.2**	**2.3398**		**1654.1**	**428418**	**1058621**
30	woodland - ponderosa pine	9.6	0.0053	0.225	3.7	962	2378
31	woodland - limber pine	0.3	0.0001	0.006	0.1	25	62
32	woodland - rocky mountain juniper	193.6	0.1057	4.520	74.8	19363	47845
33	woodland - mixed conifer and deciduous woodland	450.2	0.2459	10.508	173.8	45017	111236
34	woodland - floodplain	688.2	0.3758	16.063	265.7	68816	170045
35	woodland - deciduous	1601.9	0.8749	37.391	618.5	160191	395833
36	woodland - green ash	498.7	0.2724	11.640	192.5	49870	123229
37	woodland - aspen	290.1	0.1584	6.772	112.0	29011	71687
38	woodland - bur oak	234.4	0.1280	5.471	90.5	23441	57921
39	woodland - aspen and bur oak	317.2	0.1732	7.404	122.5	31722	78385

Table 2.3. (continued) Raster cell value, land cover category, area (km^2), percent of general land cover category, percent of the area of North Dakota, and area in miles^2 , hectares and acres for 39 land cover categories in the ND-GAP land cover map.

Cell value	Land cover category	Area (sq km)	% of state	% of general land cover category	Area (sq miles)	hectares	acres
	wetland	**16297.5**	**8.9007**		**6292.4**	**1629746**	**4027101**
40	wetland - lacustrine	3482.5	1.9020	21.369	1344.6	348254	860535
41	wetland - riverine	442.0	0.2414	2.712	170.7	44199	109215
42	wetland - palustrine temporary	3086.6	1.6857	18.939	1191.7	308656	762688
43	wetland - palustrine seasonal	5162.5	2.8195	31.677	1993.2	516252	1275658
44	wetland - palustrine semipermanent	2794.7	1.5263	17.148	1079.0	279466	690561
45	wetland - water	1329.2	0.7259	8.156	513.2	132919	328443
	sparse vegetation	**1896.7**	**1.0359**		**732.3**	**189667**	**468667**
50	sparse vegetation - others	310.9	0.1698	16.391	120.0	31088	76819
51	sparse vegetation - badlands	1479.0	0.8077	77.979	571.0	147900	365460
52	sparse vegetation - riverine	106.8	0.0583	5.630	41.2	10679	26388
	urban	**953.2**	**0.5206**		**368.0**	**95318**	**235531**
60	developed - high intensity residential	89.3	0.0488	9.371	34.5	8932	22071
61	developed - low intensity residential	232.8	0.1271	24.420	89.9	23277	57518
62	developed - commerical/industrial/transporation	475.7	0.2598	49.904	183.7	47567	117538
63	developed - urban grasslands	108.6	0.0593	11.389	41.9	10856	26825
64	developed - recently developed or omissions in 1992 NLC	46.9	0.0256	4.916	18.1	4686	11579
		183102.6			70695.9	18310262	45244657



Map 2.1. North Dakota 8 Category General Land Cover, circa 1997

proportion is likely due to differences in spatial registration and representation of wetland using TM imagery and NWI data.

Ten woodland land cover categories accounted for 4,284 km^2 (2.3 %) of ND. A generic deciduous woodland category that includes farm shelterbelts, field windbreaks, other planted woodlands and natural deciduous woodlands accounts for 37% of lands mapped as woodlands. Floodplain Woodland accounted for 688 km^2 (16 %) of the lands mapped as woodlands. Green Ash Woodland and Mixed Conifer and Deciduous Woodland (woodland mixtures of Green Ash and Rocky Mountain Juniper) accounted for 939 km^2 (22%) of woodlands. Aspen and Aspen Bur Oak woodland mixtures accounted for 608 km^2 (14%) of woodlands. Bur oak had the smallest area of the deciduous woodland types with 234 km^2. Natural conifer woodlands accounted for less than 5 % of woodlands in ND with Rocky Mountain Juniper Woodland accounting for 193.6 km^2 (95%) of the area mapped as conifer woodland.

The sparsely vegetated land cover category that includes natural badland landforms and riparian sandbars account for 1% of ND.

Accuracy Assessment

<u>Introduction</u>

GAP land cover maps are primarily compiled to answer the fundamental question in gap analysis: what is the current distribution and management status of the nation's natural land cover types and wildlife habitats? Besides giving a measure of overall reliability of the land cover map for gap analysis, the assessment also identifies which land cover categories do not meet the accuracy objectives for the GAP. Thus the assessment identifies where additional effort will be required when the map is updated. We report the results of the accuracy assessment, believing that the map is the best map currently available for the project area.

The purpose of accuracy assessment is to allow a potential user to determine the map's "fitness for use" for their application. It is impossible for the original cartographer to anticipate all future applications of a land cover map, so the assessment should provide enough information for the user to evaluate fitness for their unique purpose. This can be described as the degree to which the data quality characteristics collectively suit an intended application. The information reported includes details on the database's spatial, thematic, and temporal characteristics and their accuracy.

Assessment data are valuable for purposes beyond their immediate application to estimating accuracy of a land cover map. The reference data is therefore made available to other agencies and organizations for use in their own land cover characterization and map accuracy assessments (see Data Availability for access information). The data set will also serve as an important training data source for later updates.

Even though we have reached an endpoint in the mapping process where products are made available to others, the gap analysis process should be considered dynamic. We envision that maps will be refined and updated on a regular schedule. The assessment data will be used to refine GAP maps iteratively by identifying where the land cover map is inaccurate and where more effort is required to bring the maps up to accuracy standards. In addition, the field sampling may identify new classes that were not identified during the initial mapping process.

Methods

We used a probability based sampling design and design-based inference to assess the accuracy of the ND-GAP land cover map (Stehman 2001). We had four objectives for the accuracy assessment: (1) estimates of land cover category omission and commission error for four physiographic regions (a) Glacial Lake Agazzi, (b) Drift prairie, (c) Missouri Coteau, and (d) Missouri Plateau, (2) unbiased area estimates for land cover categories in each of the four physiographic regions, (3) estimates of land cover category omission and commission error for ND, and (4) estimate of overall proportion correctly classified for ND.

The first step in conducting an accuracy assessment is specification of the sampling unit (Stehman and Czaplewski 1998). We considered four primary factors when deciding upon the characteristics of the sample unit: (1) the likelihood of obtaining a sufficient sample of observations to estimate omission errors for all of the 39 land cover categories at the finest thematic resolution of the land cover classification scheme, (2) the potential to partition classification error into attribute and location error components, (3) samping units that would be minimize the complexity of the analysis if an assessment was performed for different versions of the map or for different aggregations of the land cover categories, and (4) the logistics of travel to and obtaining trespass permission for the sample units. After careful consideration of these 4 factors, we concluded the use of large area based sample units would meet our needs with respect to the first 3 factors and decided the use of sections, 1 mile^2, in the public land survey system (PLSS) (Clawson 1968) would satisfy our needs with respect to the 4th factor. We considered each sample unit as a maplet (Stoms 1996) and created an exhaustive land cover map for each sample unit using observations of land cover from ground surveys and aerial photo interpretation.

The sample design was a stratified random single-stage cluster sample. Sixteen strata were defined by a combination of four physiographic regions and four anthropogenic land cover proportion classes. The population frame for the accuracy assessment was created by merging a PLSS vector for ND with a vector of Omernik's level III ecoregions of ND (Omernik 1987). The population frame consisted of 71,533 sections or sample units after editing for polygon slivers which occurred primarily along the Red River because of the convoluted eastern border of ND and the different representations of border in the physiographic region and the PLSS vector. Sample units which were split by a physiographic region boundary were assigned to the physiographic region which occupied the greatest area of the sample unit. We used a provisional version of the ND-GAP land cover map to calculate the proportion of anthropogenic land cover defined as cropland and developed land cover categories in each sample unit. The anthropogenic land cover proportion classes were defined as class 1 (0-25%), class 2 (26-50%), class 3

(51-75%), and class 4 (76-100%) (Fig. 2.3). We excluded 657 sample units from the population because the area of water in the sample unit (as determined by the ND-GAP

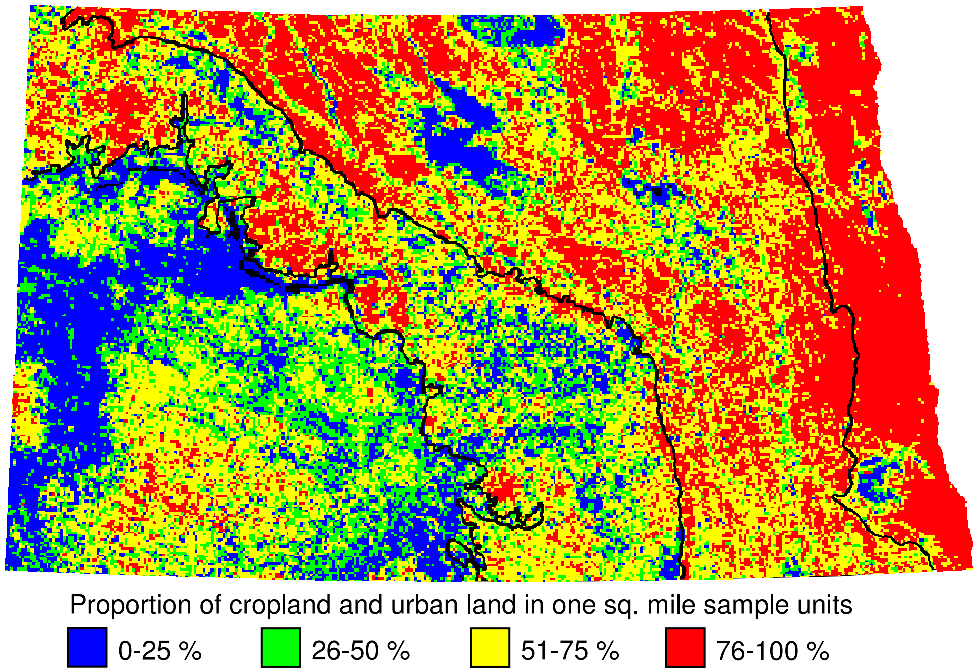


Fig. 2.3. Anthropogenic land cover proportion strata used in the accuracy assessment of the ND-GAP land cover map. The proportion of anthropogenic land cover (sum of cropland and developed land cover categories) in each sample unit was calculated from a provisional version of the ND-GAP land cover map.

land cover map) was greater than 89% of the sample unit. This resulted in a population frame of 70,876 sample units used to select the sample of sections for the accuracy assessment. The purpose of the stratification was to obtain a good geographic distribution of the sample units and an expectation that the stratification would yield observations of all of the common natural land cover categories in ND.

Samples were allocated to the 16 strata as follows. Ten sample units were allocated to anthropogenic land cover proportion class 4 (76-100% anthropogenic land cover) in each of the four physiographic regions. The decision to allocate ten sample units to these four strata was based on the maximum effort and the minimum sample size we wished to devote to these strata which are composed primarily of cropland. Two hundred sample units were allocated with unequal probability among the twelve remaining strata proportional to the square root of the number of sample units in a stratum. The number of sample units allocated to the anthropogenic land cover proportion classes 1 and 2 for the Glacial Lake Agassiz physiographic region was increased to 10 observations because the proportional allocation yielded too small of a sample. The distribution of the 253 sample units among the four physiographic units is shown in Fig. 2.4 and among strata in the population frame and in the ground sample is shown in Table 2.4.

We attempted to acquire a 1:10,000 scale color infrared (CIR) aerial photograph centered on a sample unit from 23-30 July 2002. CIR photographs were acquired for only 150 (59 %) of the sample units due to weather and the availability of aircraft and photographers. Aerial natural color 35 mm slides acquired in summer of 2001 by the Farm Service

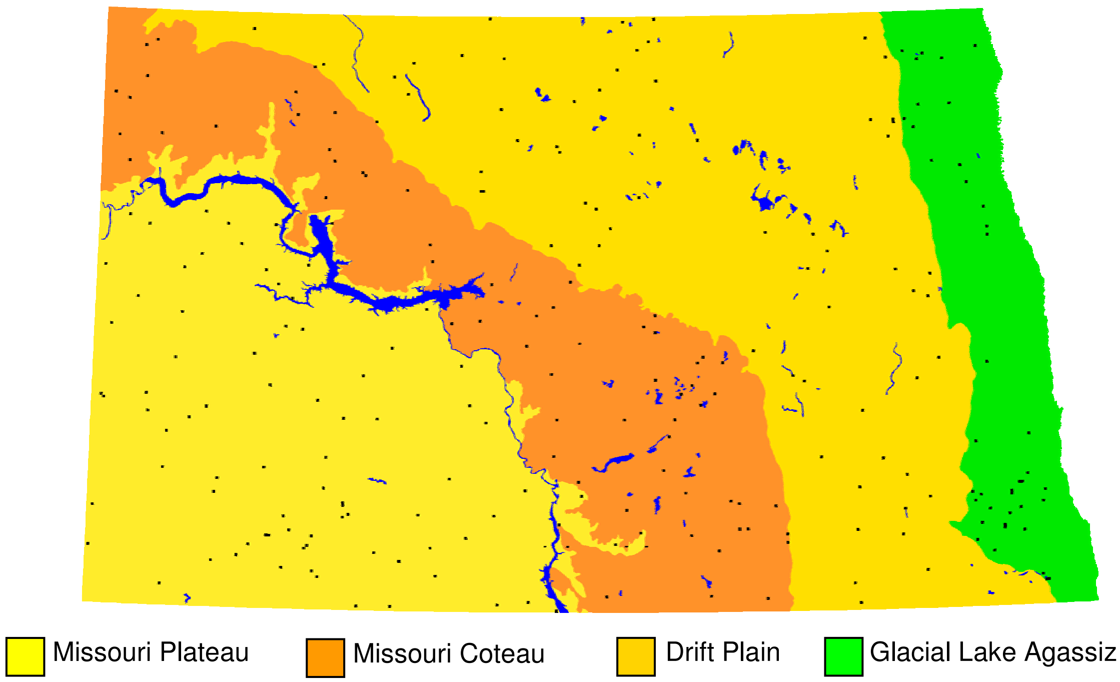


Fig. 2.4. Four physiographic regions with location of 253 one mi^2 sample units used in the accuracy assessment of the ND-GAP land cover map.

Administration and 1995-1997 ND black-and-white digital orthophotoquads were used for sample units without a 2002 color infrared photograph. A print from one of the sources of photography was used during the ground surveys of the sample units to delineate the boundaries of the land cover types observed. Ground surveys of land cover of the sample units was completed from 26 June to 16 September 2002 using an aerial photograph, 1:24,000 scale county soil map, and Farm Service Administration land use maps. Not all land cover type boundaries were delineated in the field. For example, some sample units had a large number of small wetlands and only a portion of the wetlands were delineated in the field. The remaining wetlands were delineated later in the lab from interpretation of the photograph.

The aerial photographs were scanned, georeferenced using digital orthophotographs and resampled to create rasters with 0.5 m grid cells. Observations of the land cover from the ground surveys and aerial photo interpretation were used to create an exhaustive land cover vector for each sample unit from on-screen digitizing using the georeferenced aerial photograph as a base. Land cover vectors for the sample units were merged into a single vector and converted a raster with 30 m grid cells using the ND-GAP land cover map as the reference image. Data from the accuracy assessment sample units were exported to SAS for statistical analysis.

Table 2.4. Distribution of sample units among 16 strata defined by a combination of four physiographic regions and four anthropogenic land cover proportion classes in the population frame and for the 253 sample units selected for ground surveys to assess the accuracy of the ND-GAP land cover map.

	Anthropogenic Land Cover Proportion Class				
Population Frame	**1 (0-25%)**	**2 (26-50%)**	**3 (51-75%)**	**4 (76-100%)**	**Total**
Physiographic Region					
Missouri Coteau	2397	3236	7465	2992	16090
Missouri Plateau	7255	6047	6890	818	21010
Drift Prairie	1691	1989	10595	12366	26641
Glacial Lake Aggassiz	195	222	1137	5581	7135
					70876
Ground Sample					
Missouri Coteau	14	17	25	10	66
Missouri Plateau	25	23	24	10	82
Drift Prairie	12	13	30	10	65
Glacial Lake Aggassiz	10	10	10	10	40
					253

We used design-based inference (DBI) procedures as it is appropriate to assessing the accuracy of a particular map, in this case the ND-GAP land cover map, and requires fewer assumptions than model based inference procedures (Stehman 2001). In DBI, the response observed at a pixel is viewed as a fixed value, not a random variable, and concern with the correlation among with observations within a cluster is not warranted for rigorous estimation. Accounting for chance agreement is also not necessary for describing the accuracy of a particular map because such correct classifications are a windfall gain to the map and should not be subtracted from the map's reported accuracy.

We used the SAS SURVEYMEANS procedure with estimators appropriate to our sample design to estimate the accuracy parameters for the ND-GAP land cover map (Stehman 2001, 1997). The accuracy parameters are collective properties characterizing the proportion of correctly classified or misclassified pixels in the population. These parameters can also be interpreted as probabilities. The overall proportion correctly classified, P, is interpretable as the probability that a randomly selected pixel is correctly classified. Producer and users accuracy or their complements omission and commission errors respectively, are interpretable as conditional probabilities. Producers accuracy is interpretable as the probability that a randomly selected pixel identified as category A on the ground, is classified as category A in the map. Users accuracy is interpretable as the probability that a randomly selected pixel classified as category A by the map, is actually type A on the ground. The Taylor expansion method was used to estimate the variances. Known pixel totals for each land cover map category in the strata were incorporated into the variance estimators for overall correct classification and omission error to improve the precision of the estimates (Card 1982, Zhu et al.2000). The accuracy probabilities apply to the process of selecting a pixel at random, not to a pixel at a specific location

(Stehman 2000). These accuracy parameters are often referred to as global parameters because they do not provide information on the spatial distribution of errors. Much work remains for characterizing the spatial distribution of classification errors (McGwire and Fisher 2001, De Bruin et al. 2004). We also calculated estimates of the true proportions for land cover categories for ND and physiographic regions (Card 1982).

Results

An accuracy assessment of the eight general land cover categories has been completed for 238 sample units. The results of this analysis follow. A more detailed accuracy assessment, including the additional 15 units, is planned and will be submitted for publication in Remote Sensing of Environment.

Table 2.5. Relationship of 238 sample units which have been analyzed in relation to the 253 sample units and their distribution among 16 strata.

	Percent Anthropogenic Land Cover				
Physiographic Region	0-25	26-50	51-75	76-100	Total
Missouri Coteau	14	17	25 (24)	10	66 (65)
Missouri Plateau	25 (16)	23 (21)	24	10	82 (71)
Drift Prairie	12 (11)	13	30	10	65 (64)
Glacial Lake Agassiz	10	10 (9)	10 (9)	10	40 (38)
Total	61 (51)	63 (60)	89 (87)	40 (40)	253 (238)

The error matrix provides information about what land categories are being confused (Table 2.6). The cell entries are numbers of pixels with the total number of observations equal to the number of pixels summed over all 238 sample units. Observations along the diagonal are the number of pixels correctly classified. The off-diagonal cell entries are omission errors for the land cover category in the row and commission errors for the land cover category in the column. The confusion among the land cover categories is more easily visualized if we view the cell values as proportions of the row and columns. Table 2.7 has the error matrix cell values expressed as proportions of the row totals.

Inspection of the row and column totals reveals that the proportions of the land cover categories from the map, the column totals, are within 3 % of the land cover proportions from the ground survey, the row totals. Thus, at the state scale, the map appears to be a reasonable model for these eight simple land cover categories. Inspection of the row labeled prairie reveals that the planted herbaceous perennials land cover category accounted for the largest proportion of prairie omission errors. This is not surprising since both land cover types are dominated by perennial grasses and forbs and can have similar land uses and disturbances, grazing by large herbivores, haying, and fire. Estimates of the accuracy parameters, e.g., prairie omission error, for the map cannot be directly calculated from the error matrix as this summary of the data does not take into account

Table 2.6. Error matrix from data for 238 of 253 sample units used in the accuracy assessment of the ND-GAP land cover map.

	Map Samples								
Ground Samples	Barren	Crop-land	Grass-land	Prairie	Shrub-land	Urban	Wet-land	Wood-land	Total
Sparse vegetation	**1425**	979	700	1637	821	17	139	265	5983
Cropland	629	**207096**	25947	7933	1227	244	6601	1774	251451
Planted grassland[1]	390	40368	**71698**	35008	3796	577	7219	2664	161700
Prairie	1479	7372	22814	**87440**	7974	117	8988	3883	140067
Shrubland	607	1045	4115	13999	**3137**	16	1336	1284	25539
Urban	93	466	834	1145	199	**260**	156	161	3314
Wetland	261	6478	8225	7969	1898	145	**34033**	1753	60762
Woodland	234	4443	5892	5873	1813	434	2227	**19253**	40169
Total	5118	268247	140225	161004	20865	1790	60699	31037	**688985**

[1] Planted grassland is used as a shorthand for planted herbaeous perennials.

Table 2.7. Error matrix with data for 238 of 253 sample units expressed as proportions of row totals.

	Map Samples								
Ground Samples	Barren	Crop-land	Grass-land	Prairie	Shrub-land	Urban	Wet-land	Wood-land	Total
Sparse vegetation	**28.82**	16.36	11.70	27.36	13.72	0.28	2.32	4.43	0.87
Cropland	0.25	**82.36**	10.32	3.15	0.49	0.10	2.63	0.71	36.50
Planted grassland[1]	0.24	24.96	**44.34**	21.65	2.35	0.34	4.46	1.65	23.47
Prairie	1.06	5.26	16.29	**62.43**	5.69	0.08	6.42	2.77	20.33
Shrubland	2.38	4.09	16.11	54.81	**12.28**	0.06	5.23	5.03	3.71
Urban	2.81	14.06	25.17	34.55	6.00	**7.85**	4.71	4.86	0.48
Wetland	0.43	10.66	13.54	13.12	3.12	0.24	**56.01**	2.89	8.82
Woodland	0.58	11.06	14.67	14.62	4.51	1.08	5.54	**47.93**	5.83
Total	0.74	38.93	20.35	23.37	3.03	0.26	8.81	4.50	**100.00**

[1] Planted grassland is used as a shorthand for planted herbaeous perennials.

the sample design. Table 2.8 has the error matrix cell values expressed as proportions of the column totals and can be used to examine sources of confusion for land cover category commission errors.

Table 2.8. Error matrix with data for 238 of 253 sample units expressed as proportions of column totals.

	Map Samples								
Ground Samples	Barren	Crop-land	Grass-land	Prairie	Shrub-land	Urban	Wet-land	Wood-land	Total
Sparse vegetation	**27.84**	0.36	0.50	1.02	3.93	0.95	0.23	0.85	0.87
Cropland	12.29	**77.20**	18.50	4.93	5.88	13.63	10.87	5.72	36.50
Planted grassland[1]	7.62	15.05	**51.13**	21.74	18.19	31.12	11.89	8.58	23.47
Prairie	28.90	2.75	16.27	**54.31**	38.22	6.54	14.81	12.51	20.33
Shrubland	11.86	0.39	2.93	8.69	**15.03**	0.89	2.20	4.14	3.71
Urban	1.82	0.17	0.59	0.71	0.95	**14.53**	0.26	0.52	0.48
Wetland	5.10	2.41	5.87	4.95	9.10	8.10	**56.07**	5.65	8.82
Woodland	4.57	1.66	4.20	3.65	8.69	24.25	3.67	**62.03**	5.83
Total	0.74	38.93	20.35	23.37	3.03	0.26	8.81	4.50	**100.00**

[1] Planted grassland is used as a shorthand for planted herbaeous perennials.

Producer and user accuracies for prairie by anthropogenic land cover proportion strata within physiographic region are shown in Table 2.9. In general, there is considerable variation in the mean accuracy among the strata, and the means tend to be inversely related to the proportion of anthropogenic land cover. For example, the mean producer accuracy in the Drift Prairie physiographic region is 74% in the strata with less than 25 % anthropogenic land cover and only 5% in strata with more than 75% anthropogenic land cover. Roughly similar trends are apparent for users accuracy. Many of the prairie commission errors for the strata with more than 75% anthropogenic land cover are the herbaceous portions of farm yards. The high omission error for prairie in the strata with more than 76% anthropogenic land cover may be small patches of idle prairie that have a spectral signature similar to planted herbaceous perennials and also have a high proportion of edge pixels that are subject to positional errors. These results show that the accuracy of the land cover maps varies spatially and a single number for an entire map is of limited value. Tables for overall accuracy for ND and physiographic regions are in Appendix 2.3. Tables of producer and users accuracy for ND are in Appendix 2.4 and 2.5. Tables of producer and users accuracy for physiographic region are in Appendix 2.6 and 2.7. Tables for producer and users accuracies for the all eight general land cover categories by anthropogenic land cover proportion strata within physiographic region are presented in Appendix 2.8 and 2.9.

One exciting outcome from our sampling design is the ability to produce maps of the spatial distribution of the accuracy parameters by applying the estimates to the strata maps. For example, Fig. 2.5 shows the spatial distribution of producers accuracy for prairie. The analyses presented have been based on an assessment at the pixel scale which is a very stringent test. For example, a narrow woodland draw offset by one pixel in the ground and map representations of land cover would be identified as classification errors in the analysis at the pixel scale. Figures 2.6 and 2.7 show the relationship between map and ground estimates of area of prairie and woodland at the sample unit scale where classification error due to positional error has been eliminated. We have

Table 2.9. Sample size, mean, and standard error for producer and user accuracies for the prairie land cover category by anthropogenic land cover proportion strata within physiographic regions.

Physiographic Region	Anthropogenic Strata	P n	P mean	P SE	U n	U mean	U SE
Missouri Plateau	0-25%	16	0.588	0.0520	16	0.620	0.0479
Missouri Plateau	26-50%	20	0.622	0.0528	21	0.620	0.0549
Missouri Plateau	51-75%	24	0.520	0.0364	24	0.610	0.0528
Missouri Plateau	76-100%	7	0.062	0.0231	8	0.061	0.0348
Missouri Coteau	0-25%	11	0.813	0.0350	14	0.550	0.0847
Missouri Coteau	26-50%	15	0.710	0.0262	17	0.449	0.0510
Missouri Coteau	51-75%	24	0.611	0.0449	24	0.476	0.0350
Missouri Coteau	76-100%	6	0.732	0.1548	10	0.329	0.1793
Drift Prairie	0-25%	9	0.740	0.0844	11	0.652	0.1069
Drift Prairie	26-50%	13	0.368	0.0676	13	0.390	0.0833
Drift Prairie	51-75%	22	0.469	0.0551	30	0.290	0.0530
Drift Prairie	76-100%	5	0.054	0.0269	9	0.099	0.0420
Glacial Lake Agassiz	0-25%	10	0.706	0.0402	10	0.665	0.1281
Glacial Lake Agassiz	26-50%	9	0.735	0.0501	9	0.661	0.0829
Glacial Lake Agassiz	51-75%	7	0.366	0.0761	9	0.198	0.0668
Glacial Lake Agassiz	76-100%	5	0.095	0.0328	10	0.097	0.0449

plans to conduct the accuracy assessment at multiple spatial scales intermediate to the pixel and 1 mile^2 sample unit scales using methods recently described by Kuzera and Pontius (2004). Information about the accuracy of land cover categories as a function of scale would be useful for identifying appropriate uses of the land cover map.

The data collected in the accuracy assessment can also be used to calculate unbiased estimates with confidence intervals for the proportion and area of land cover categories by physiographic region. Table 2.10 shows the map proportion of prairie calculated from simple pixels counts and the mean and 95% confidence interval for the estimated true proportion of prairie by physiographic region. The map proportion of prairie falls within the 95% confidence interval for the estimated true proportion of prairie in all physiographic regions except the Missouri Coteau where it exceeds the confidence interval.

Limitations and Discussion

From the beginning of the ND-GAP, we recognized that it would be difficult to achieve the GAP goal of mapping natural land cover categories to the floristically defined alliance level of the NVCS with an overall probability correct of 80% or greater. Our approach to this ambitious goal was to construct a two-level hierarchical legend for the

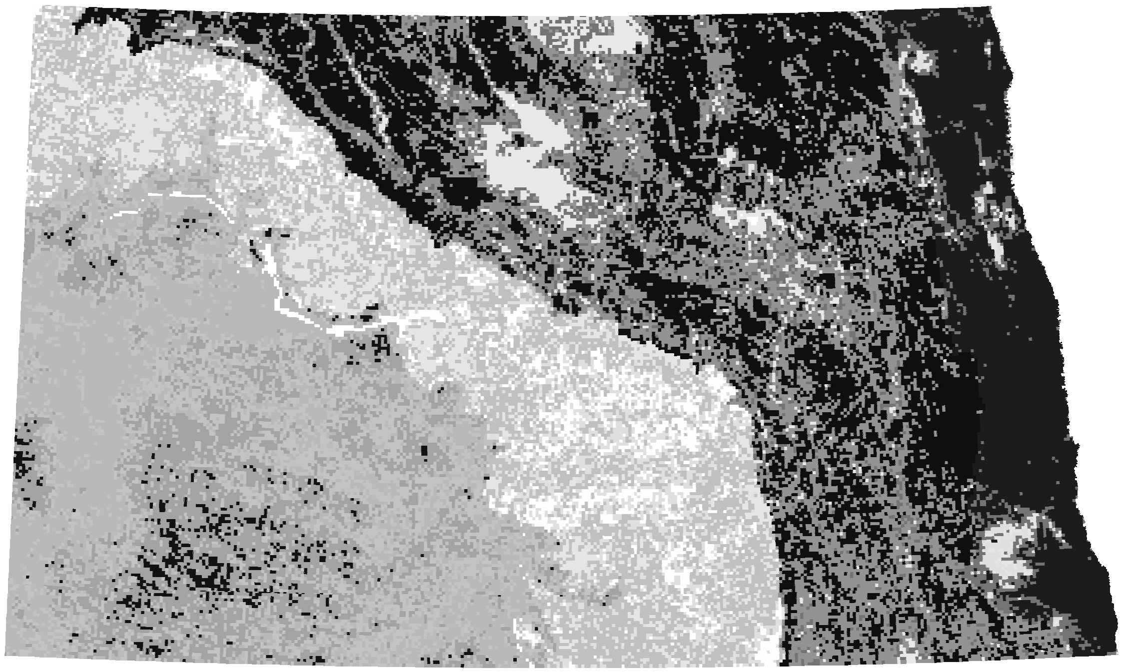


Fig. 2.5. Spatial distribution of prairie producer accuracy. Stratified mean prairie producer accuracies (Table 2.9) applied to strata maps; the brighter the intensity the higher the accuracy.

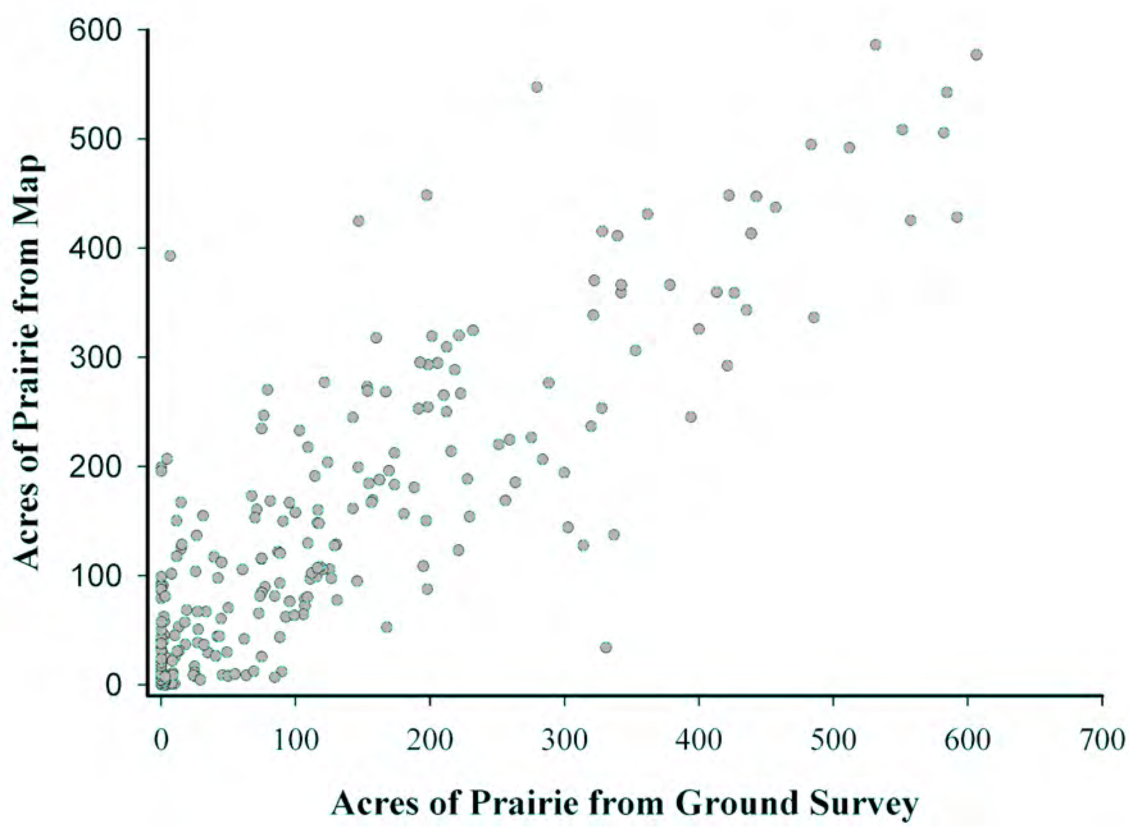


Fig 2.6. Relationship between map and ground estimates of area of prairie at the sample unit scale.

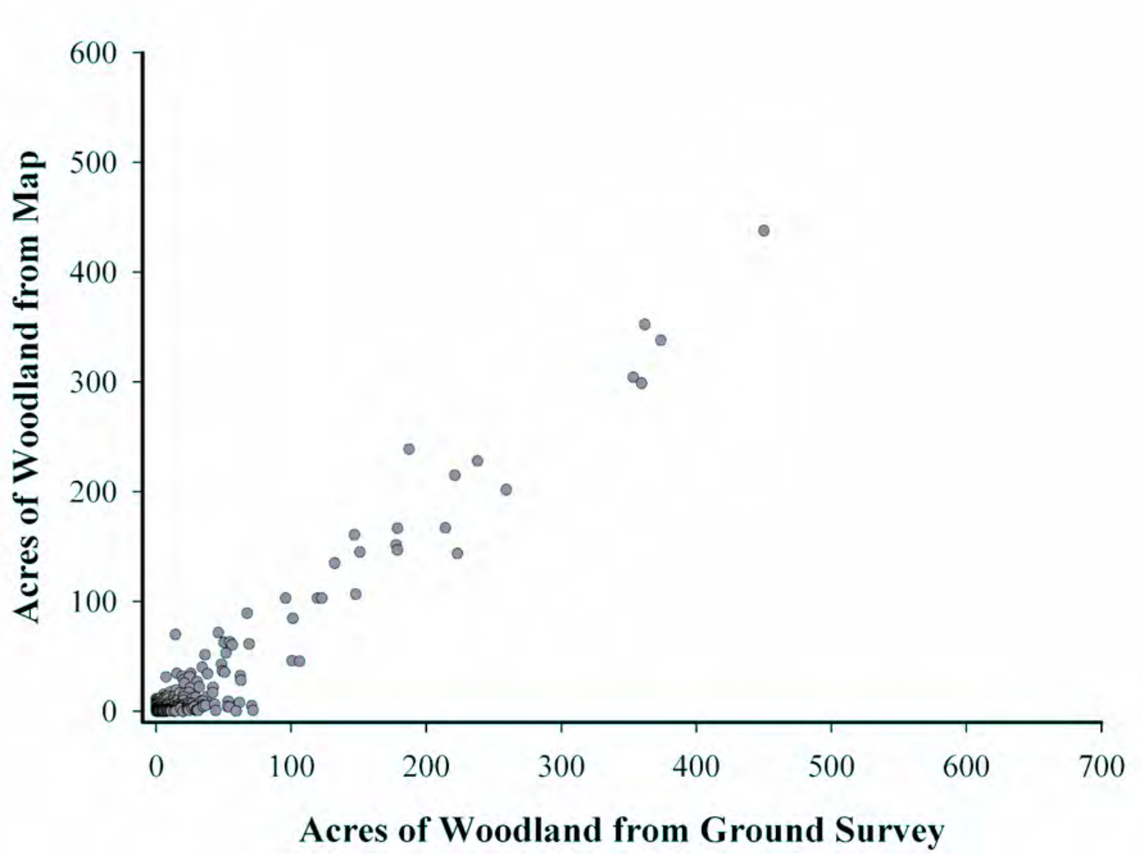


Fig 2.7. Relationship between map and ground estimates of area of woodland at the sample unit scale.

Table 2.10. Confidence intervals for the proportion of prairie by four physiographic regions.

PRegion	Map Proportion	L95CL	U95CL	TRUE Proportion	sq mi low	sq mi high
Missouri Coteau	0.248	0.131	0.218	0.174	2152	3583
Missouri Plateau	0.322	0.276	0.364	0.320	5927	7822
Drift Prairie	0.104	0.059	0.140	0.100	1612	3792
Glacial Lake Agassiz	0.057	0.006	0.134	0.070	42	960

land cover map. Natural vegetation categories were defined by physiognomic characteristics at the upper level and by floristic characteristics at the lower level. Even at the level of the eight physionomically defined land cover categories, we had difficulty consistently mapping a shrubland category. The shrubland category was not mapped for some portions of the state due to spectral similarity of shrublands with prairie. Shrublands are inclusions within the prairie land cover category for those portions of the map without a shrubland category. Inspection of the error matrix from the accuracy assessment (Table 2.6) reveals that prairie accounts for 54% of the omission errors for shrublands. The planted herbaceous perennials, wetland, and woodland categories account for 16%, 5%, and 5% of the omission errors for shrubland, respectively. Previous small-scale vegetation maps for ND have not included a shrubland category. Only some of the recent land cover maps for ND developed using remotely sensed imagery have a shrubland land cover category. Vogelman (2001) also apparently had difficulty mapping shrublands as the category is missing from large portions of the state in their 1992 ND National Land Cover Map. Refinement of the shrubland category should be a high priority for future land cover maps of ND.

We combined the forest and woodland physiognomic classes of the NVCS into a single woodland category for the ND-GAP land cover map. Application of the NVCS tree canopy cover criteria for forest (>60%) and woodland (25–60%) is not meaningful when the classification procedure is performed on a 30-m × 30-m pixel. Distinguishing between forest and woodland would require an evaluation of canopy cover and the spatial extent of the stand. The woodland category in the ND-GAP land cover map identifies areas where trees are a dominant component of a pixel.

Our ability to map floristically defined plant communities at the alliance level of the NVCS varied with physiognomic class in relation to the amount and spatial distribution of training data and the difficulty discriminating among floristically defined plant communities using spectral reflectance measurements. We allocated the greatest effort to prairie land cover categories because of their importance and abundance in ND. We were able to create a relatively complete and consistent map of 10 prairie land cover categories using training data constructed from range surveys on school lands managed by the ND State Land Department. Training data for the woodland land cover category was much sparser than for prairie. As a result of the sparse training data, the floristic detail for woodland land cover categories is not consistent across the state. Aspen and bur oak stands, for example, may be mapped as separate categories in some portions of the state, but elsewhere they are mapped as a generic woodland category.

The overall accuracy for the eight land cover categories at the upper level of the land cover map legend was 62%. Factors influencing the accuracy assessment include (1) temporal changes in land cover between 1992–1999 (when TM images were acquired) and the 2002 when data for the accuracy assessment were collected, (2) spatial registration of the map and the reference data, (3) differences in class generalizations including definitions and inclusions arising from ground and satellite methods for observing land cover, and (4) the accuracy of the reference data. The accuracy assessment revealed that classification accuracy is spatially variable and a single number for an entire map is of limited value. One exciting outcome from our sampling design is the ability to produce maps of the spatial distribution of the accuracy parameters by applying the estimates to the strata maps. The accuracy assessment was conducted at the pixel scale, which is the most stringent test possible. An accuracy assessment is in progress at multiple spatial scales intermediate to the pixel and sample unit (1 mi^2) scales for the 39 land cover categories at the lower level of the map legend.

The use of natural land cover categories is a coarse surrogate for information about plant species and plant communities. Biodiversity conservation plans and actions need to give more consideration to native plant species, the composition of plant communities, and the threats posed by introduced and invasive species. Research is needed on the use of fire and grazing interactions to create and maintain heterogeneity in mixed prairie (Fuhlendorf and Engle 2004). The role of below-ground biological processes including the roles of invertebrates, bacteria, fungi on the population dynamics of native species needs research.

PREDICTED ANIMAL SPECIES DISTRIBUTIONS AND SPECIES RICHNESS

Introduction

All species range maps are predictions about the occurrence of those species within a particular area (Csuti and Crist 1998). Traditionally, the predicted occurrences of most species begin with observations or samples collected at individual point locations. Most species range maps are coarse scale (e.g., >1:10,000,000) and derived primarily from point data to construct field guides that are suitable, at best, for approximating distribution at the regional or county level for example. The purpose of the GAP vertebrate species maps is to provide more precise information about the current predicted distribution of individual native species according to actual habitat characteristics within their general ranges. With this information, better estimates can be made about the amount of existing habitat, its location, and its configuration.

GAP maps are produced at a nominal scale of 1:100,000 or larger and are intended for applications at the landscape or "gamma" scale (i.e., heterogeneous areas generally covering 1,000-1,000,000 ha and consisting of more than one type of natural community). Applications of these data to site- or stand-level analyses (site; a microhabitat, generally 10-100 m^2; stand; a single habitat type, generally 0.1-1,000 ha; Whittaker 1977, also see Stoms and Estes 1993) will likely be compromised by the finer-grained patterns of environmental heterogeneity that are resolved at those levels.

Gap analysis uses the predicted distributions of animal species to evaluate their conservation status relative to existing land management (Scott et al. 1993). In addition, the maps of species distributions may be used to answer a wide variety of management, planning, and research questions relating to individual species or groups of species. In addition to the maps, great utility may be found in the consolidated specimen and observational records and literature that were assembled into databases and used to produce the maps. Perhaps most importantly, as a first effort in developing such detailed distributions, the maps should be viewed as testable hypotheses to be confirmed or refuted by data collected in the field.

Previous to this effort, there were no maps available, digital or otherwise, showing the likely present-day distribution of species by habitat type across their ranges in North Dakota. Because of this, ordinary species (i.e., those that are not threatened with extinction or not managed as game animals) are generally not given sufficient consideration in land-use decisions in the context of large geographic regions or in relation to their actual habitats. Population declines of ordinary species resulting from incremental habitat loss can and often does result in one threatened or endangered species after another. Frequently, the records that do exist for an ordinary species are truncated by political boundaries (e.g., state boundary). Simply creating a consistent spatial framework to store, retrieve, manipulate, analyze, and update the existing knowledge about the status of each vertebrate species is one of the most necessary and basic elements to prevent further erosion of biological resources and diversity.

Mapping Standards

Potential distribution maps for terrestrial vertebrate species were prepared in accordance with procedures outlined in the vertebrate analysis chapter of the GAP Handbook (Csuti and Crist 1998) and described by Csuti (1996) and Boone and Krohn (2000).

Methods

Overview

The modeling approach used to predict vertebrate distributions in North Dakota consisted of seven steps. First, criteria were developed to identify the species to be included in the analysis, and then a list of species was developed. Second, sources of species location records were identified, and the data were collated and organized into a geospatial database. Third, the range of each species was defined by recording the species presence or absence within a hexagon grid system developed by the U.S. Environmental Protection Agency (White et al. 1992). Fourth, a Wildlife-Habitat Relationships (WHR) database was developed to define the affinities of terrestrial vertebrate species in relation to habitat features including land cover types, ecotones between land cover types, land cover juxtaposition, and soil characteristics. Fifth, the hexagon and WHR databases were used in a GIS-modeling process to produce potential distribution maps for each species. Sixth, range maps, WHR models, and potential distribution maps for the species were reviewed by biologists familiar with the distribution of North Dakota's wildlife. Finally, we conducted an accuracy assessment of the potential distribution maps.

Species List

A list of 281 vertebrate species was compiled for the North Dakota GAP using published literature, including the *Revised Checklist of North Dakota Birds* (Faanes and Stewart 1982), *Reptiles and Amphibians of North Dakota* (Hoberg and Gause 1992) and *Mammals of the Northern Great Plains* (Jones et al. 1983) (Appendix 3.1). Bird, mammal and herptile lists were reviewed, and species that occur only rarely (< 5 confirmed records), transients, extirpated species, or introduced exotics were not modeled. The bird species list was limited to breeding birds with five or more confirmed observations during the last 20 years. The taxonomy and nomenclature used to describe species were the Integrated Taxonomic Information System (http://www.itis.usda.gov/index.html) for herptiles and mammals and American Ornithologists' Union, seventh edition, for birds (AOU 1998).

Mapping Range Extent

Several sources of information were used to document the distribution of terrestrial vertebrate species in North Dakota (Appendix 3.2). We mapped the distributional limits of species using 648 km^2 hexagons, which are part of a global hexagonal grid system developed by the EPA (White et al.1992). Advantages to using the hexagon grid system include its equal-area sampling structure, its independence from political and administrative boundaries (resulting in more consistent mapping of animal distributions), and its hierarchical structure which can facilitate increasing or decreasing grid densities in future analyses (White et al. 1992).

Three primary sources of information were used to document the occurrence (or expected occurrence) of a species within a hexagon: (1) species locality records, (2) published range maps, and (3) the knowledge of experts. Each species location dataset was converted to point vector. Many of the species locations were recorded by township, range, and section using the Public Land Survey System; in these cases the centroid of the section was used as the point location for these records. All location datasets were then transferred to a polygon vector of the hexagon grid. Hexagons encompassing a locality record were coded as “confirmed”. Hexagons occurring adjacent to a confirmed hexagon were coded as “probable”.

Some species of mammals (Table 3.1) and all herptile species had insufficient locality records to generate a comprehensive range map. Range maps published by Jones et al. (1983), Conant and Collins (1991), and Hoberg and Gause (1992) were used to create range maps for these species. The geographic range of each species was manually transferred to the hexagon grid system by selecting the hexagons that overlapped with existing range maps. Hexagons populated in this manner were coded as probable.

A range map for each species was provided to experts that were cognizant of the species and their ranges in North Dakota (Appendix 3.3). These experts were asked to review, and if necessary, identify omission and commission errors for the hexagons that defined a species range. Reviewers also were given the opportunity to provide comments. Reviewer revisions and comments were incorporated into the final range map for a species.

Wildlife Habitat Relationships

No database of WHR existed for North Dakota at the start of this project. Primary sources of habitat information came from the *Birds of North America* series, the American Society of Mammalogists *Mammalian Species* accounts, Conant and Collins (1998) and Collins (1993) for herptiles, and additional peer-reviewed publications for individual species or groups of species in the region and the state. North Dakota GAP

Table. 3.1 List of 21 mammal species that had an insufficient number of locality records to construct a range map. Hexagon grid representations of species ranges for these species and all herptile species were created using published range maps.

Scientific Name	Common Name
Sorex arcticus	Arctic Shrew
Microsorex hoyi	Pigmy Shrew
Myotis evotis	Long-eared Myotis
Myotis keenii	Keen's Myotis
Myotis leibii	Small-footed Myotis
Myotis lucifugus	Little Brown Bat
Myotis volans	Long-legged Myotis
Lasionycteris noctivagans	Silver-haired Bat
Lasiurus borealis	Eastern Red Bat
Lasiurus cinereus	Hoary Bat
Sylvilagus audubonii	Desert Cottontail
Eutamius minimus	Least Chipmunk
Marmota monax	Woodchuck
Spermophilus richardsonii	Richardson's Ground Squirrel
Glaucomys sabrinus	Northern Flying Squirrel
Perognathus fasciatus	Plains Pocket Mouse
Neotoma cinerea	Bushy-tailed Woodrat
Microtus ochrogaster	Prairie Vole
Urocyon cinereoargenteus	Common Gray Fox
Mustela erminea	Ermine
Spirogale putorius	Eastern Spotted Skunk
Lutra Canadensis	River Otter

collaborated with Iowa GAP and South Dakota GAP on the WHR models to reduce the redundancy of effort for species found in all three states and to increase the consistency of WHR models across states in the Central and Northern Great Plains. The species lists that were assembled by the three states were combined, and the species that were present in all three states were equally divided among the vertebrate modelers in each state. Species that occurred in only one or two states were modeled by those respective states. We used the database system that was developed by Kansas GAP (Cully et al. 2002) in Microsoft Access to enter, organize, and assign species habitat affinities described in the literature to vegetation alliances defined in the NVCS and other habitat features including anthropogenic land cover categories, ecotones, soil texture characteristics, and juxtaposition of habitats. By modeling at the alliance level, species could be modeled, and the models could be reviewed before completion of the final land cover map for the state.

Models for both regional and local species were peer reviewed by local reviewers or reviewers that were familiar with the habitat requirements or the species range within the three states. Each reviewer was provided with the range maps, WHR models (NDBIRDMOD.XLS, NDHERPTILEMOD.XLS, NDMAMMALMOD.XLS), a subset of the NVCS that describes vegetation alliances and associations in North Dakota (NatureServe 2001), and a table showing the relationship of vegetation alliances to land cover categories in the provisional land cover classification system for the North Dakota GAP land cover map.

Distribution Modeling

Creating potential distribution maps for each vertebrate species required a geospatial representation of the habitat characteristics included in the WHR models. Modeling of each species was conducted using raster representations of the habitat. The North Dakota GAP land cover data, with a minimum mapping unit of 0.09 ha (30×30 m pixels) was the primary source of data for vertebrate modeling. A raster was created for each land cover category in the North Dakota GAP land cover map (Map 2.1 and Table 2.3). Two additional rasters were created to represent ecotones between woodland and grassland (prairie and planted herbaceous land covers combined) and shrubland and grassland land covers. Ecotone rasters were created from the intersection of the land cover category rasters after applying an outside buffer of 90 m. For example, the woodland-grassland ecotone was six pixels wide representing three pixels into the woodland and three pixels into the grassland.

Some species required the creation of rasters representing the juxtaposition of land cover types. For example, the WHR models identified habitat requirements for the waterfowl genus *Anas* as wetlands and adjacent grasslands and shrublands within 1.5 miles of the wetlands. The comment field in the databases NDBIRDMOD.XLS, NDHERPTILEMOD.XLS and NDMAMMALMOD.XLS contains the details of habitat juxtaposition rasters created for a species distribution model.

The North Dakota STATSGO soil vector was used to produce two soil rasters with 30-m grid cells for use in mapping the distribution of fossorial mammals and herptiles. Both rasters were created using the surface soil texture variable (surftex) in the STATSGO components table. The components table identifies the soil components or types in a soil map unit. The first raster identified map units where the surface soil texture was sand, loam, or sandy loam for the soil component with the largest area in the map unit. To create the second raster which identified map units with a surface soil texture containing greater than 50% sand, the surface soil texture categories were assigned a value for percent silt, sand and clay based on data presented in Cosby et al. (1984). An estimate of percent sand, silt, and clay for each map unit was calculated as a weighted average of the soil types in each map unit using the areas of soil types in the map unit as the weights.

National Hydrography data (NHD) were used to create a raster for riparian habitat (http://nhd.usgs.gov/). Reach data including artificial canals and drains, were analyzed and assigned a stream order attribute. The line file was buffered by reach order to the following values: orders 2 and 3 at 90 m, orders 4 and 5 at 60 m and order 6 and above at 30 meters. Then the line file was converted to a 30 m raster representing riparian habitat. Values for the buffer distance were determined from visual inspection of a sample of the

NHD data using Digital Orthoquarterquads and a follow-up comparison using a slope raster derived from the National Elevational Dataset (NED).

A raster was created that showed the range extent for each species whose range within the state was smaller than the entire state. To minimize the effect of having a predicted distribution stop abruptly at an artificial range boundary, GAP has in the past adopted the practice of extending a species distribution beyond the range boundary to include patches of suitable habitat partially within the species' range. This practice was adopted when the majority of GAP land cover maps were created with minimum mapping units that were 100 ha. The land cover minimum mapping unit for North Dakota GAP was 0.09 ha and rendered the procedure unnecessary for distribution maps for most species. However, there are a few vertebrate species whose distribution maps have an abrupt boundary at Lake Sakakewea, a large manmade reservoir. Extending the distribution map to include the contiguous water habitat would have extended these species distributions beyond their accepted ranges. Therefore, distribution maps for all species were terminated at the range boundary even if a habitat extended outside the range boundary.

Species potential distribution maps were created using the rasters in TNTmips Spatial Manipulation Language (SML) (MicroImages 2003). With the completion of the North Dakota GAP land cover map, the correspondance of vegetation alliances to the final categories in land cover map (NDVERTALLIANCEXREF.XLS) was developed in the WHR data base. The WHR models were exported from Microsoft Access and imported into a SAS program that built an SML script to automate creation of the species potential distribution maps. Species distribution maps were initially created at a 30-m pixel size. To reduce the number of compact disks required to distribute the data, the species distribution maps were resampled using the nearest neighbor method to 90-m pixels.

Results

Distribution Maps

Potential distribution maps were produced for 281 breeding terrestrial vertebrate species comprised of 184 bird species, 71 mammal species, 15 reptile species, and 11 amphibian species. Land cover was the only variable used in 70-78 % of the models across the three taxonomic groups (Table 3.2). Seventy-three percent of the models for breeding birds used land cover only, 16% used a combination of land cover and ecotones or riparian zones, and 11% used a combination of land cover, ecotone, riparian and juxtaposition of habitats. Seventy-eight percent of the mammal models used land cover only, 6% used land cover and ecotone or riparian zones, 8% used land cover and soils, and 8% used land cover and juxtaposition of habitats. Seventy percent of the herptile models used land cover only, 15% of the models used land cover and soils, and 15% of the models used land cover and juxtaposition of habitats.

Table 3.2 Frequency of species by taxonomic group and variables included in the distribution models.

Taxonomic group	Land cover	Land cover and ecotone or riparian	Land cover and soils	Land cover and juxtaposition
Birds	135	30	0	21
Mammals	55	4	6	6
Amphibians	7	0	2	2
Reptiles	11	0	2	2

Species Richness

An early GAP hypothesis was that mapping of species-rich areas or "hotspots" offered an efficient and cost-effective way to conserve maximum biological diversity in a minimal area (Scott et al. 1987, 1993). Subsequent investigations have evaluated this concept and have changed our understanding of its utility (Jennings 2000). Some of the problems with the concept include: (1) species richness calculations are highly scale-dependent (Stoms 1992), (2) the lack of geographic correspondence between species richness of an indicator taxon and other components of biodiversity (Pendergast et al. 1993), and (3) the assumption that patterns in species richness are correlated in a predictable fashion with processes that are important to species, community, and ecosystem representation and persistence which are the goals of reserve identification, selection, and design (Flather et al. 1997). Although GAP continues to perform this useful pattern analysis, it is only one of many that may be performed with GAP data (Jennings 2000). Richness maps identify locations where the same number of elements, e.g., species, co-occur. Richest areas may or may not indicate the best conservation opportunities. These areas may provide a useful starting point to examine conservation opportunities in combination with other analyses or information. They do not provide consideration of unique assemblies of species or rare environments that are important for individual species. We calculated species richness both by land cover category and the 648-km^2 hexagon scale used to create species range maps.

By Land Cover Category

Species richness within land cover categories or alpha diversity (Whittaker 1960, Whittaker 1977) is the number of species predicted to occur across all pixels of a land cover category. This location- independent indicator of species richness is useful in identifying habitats with a large number of species but also is sensitive to the resolution or scale of the land cover legend. Calculation of species richness in each of the eight general land cover categories (Table 3.3) and the 39 finer-scale land cover categories (Table 3.4) reveal the scale dependence of species richness calculations. For example, at the level of eight general land cover categories, mammal and bird species richness calculations are greatest for the woodland category. However, Little Bluestem Prairie and Needlegrass Prairie have mammal species richness comparable to or exceeding that of some woodland habitats when species richness is calculated using the more detailed land cover classification system. For birds, the Floodplain Woodland category had the highest species richness, and deciduous woodland categories had species richness greater than prairies and wetlands which presumably reflects the greater number of niches provided by the vertical structure of woodlands despite their small spatial extent in North Dakota. Species richness calculations for amphibians reveal the importance of wetland and prairie land cover categories.

Table 3.3 Vertebrate species richness by eight general land cover categories.

Land cover category	Bird species richness	Mammal species richness	Reptile species richness	Amphibian species richness
Woodland	134	57	8	7
Prairie	82	50	11	10
Shrubland	87	47	9	9
Planted Herbaceous Perennials	62	32	3	4
Sparse Vegetation	27	27	9	4
Cropland	37	22	2	1
Wetland	76	22	9	11
Urban	59	22	2	1

By 648 km^2 Hexagons

Species richness calculations at the hexagon scale are a reflection of landscape and regional diversity. Whittaker (1977) used the term "gamma diversity" to describe the number of species in a landscape containing more than one community type and "epsilon diversity" to describe geographic extents that incorporate more than one landscape. Species richness calculations at this scale are potentially useful to identify geographic locations that contain a large number of species, however, there are some potential problems with analysis at this scale. Hexagons lying on the edge of the state will tend to have fewer species because only a portion of these hexagons occurs within the state and thus they have a smaller physical area in which species may occur. Second, there is a tendency for analysis at this scale to emphasize areas where range boundaries overlap such as at the edge of ecoregions. Richness at the hexagon scale is depicted by taxonomic groups in Figures 3.1 - 3.4. Amphibian richness ranged from 4-10 species per hexagon with a mean of 7.33. Reptile richness was 5-11 species per hexagon with a mean of 7.49. Mammal richness was 31-57 species per hexagon with a mean of 47.45. Breeding bird richness was 87-166 species per hexagon with a mean of 133.1. At this scale, local patterns of habitat availability are suppressed, and the maps emphasize regional variation in species richness. For example, bird, mammal and amphibian species richness maps identify the eastern half of North Dakota as having relatively high species richness in spite of the small amount and fragmentation of natural habitats. The aggregation of wetland and prairie habitats at the hexagon scale accounts for the high bird

Table 3.4 Vertebrate species richness by 35 detailed land cover categories.

Land cover category	Bird species richness	Mammal species richness	Reptile species richness	Amphibian species richness
Cropland	37	22	2	1
Planted Herbaceous Perennials	62	32	3	4
Wet-Mesic Tallgrass Prairie	38	29	5	5
Mesic Tallgrass Prairie	37	33	3	4
Mesic Tall and Mixed grass Prairie	63	33	4	5
Bluestem-Needlegrass-Wheatgrass Prairie	31	26	3	3
Wheatgrass Prairie	61	39	7	5
Needlegrass Prairie	60	43	6	4
Little Bluestem Prairie	56	44	8	4
Fescue Prairie	52	25	4	4
Sand Prairie	50	30	8	3
Saline Prairie	39	16	6	9
Upland Deciduous Shrubland	62	34	6	3
Lowland Deciduous Shrubland	59	27	6	9
Sagebrush Shrubland	30	29	4	0
Ponderosa Pine Woodland	50	41	4	0
Limber Pine Woodland	49	33	5	0
Rocky Mountain Juniper Woodland	49	27	6	1
Mixed Conifer and Deciduous Woodland	89	35	6	4
Floodplain Woodland	101	37	6	7
Deciduous Woodland	76	36	6	2
Green Ash Woodland	84	43	6	2
Aspen Woodland	79	43	6	1
Bur Oak Woodland	77	41	6	2
Aspen-Bur Oak Woodland	79	43	6	2
Lacustrine Wetland	60	10	5	10
Riverine Wetland	53	8	4	10
Palustrine Temporary Wetland	35	18	6	10
Palustrine Seasonal Wetland	50	16	6	9
Palustrine Semi-permanent Wetland	59	14	7	9
Sparse Vegetation - Others	26	27	9	4
Sparse Vegetation - Badlands	26	27	9	4
Sparse Vegetation - Riverine	2	0	0	4
High Density Residential and Commercial	17	3	0	1
Low Density Residential and Recreation	59	22	2	1

species richness in the Drift Plain and Missouri Coteau physiographic regions. Species richness maps calculated by ecoregions, for example Omernik's level IV ecoregions (Bryce et al. 1998), may by a more effective means to reveal regional patterns of species richness than analysis at an arbitrary hexagon cell size.

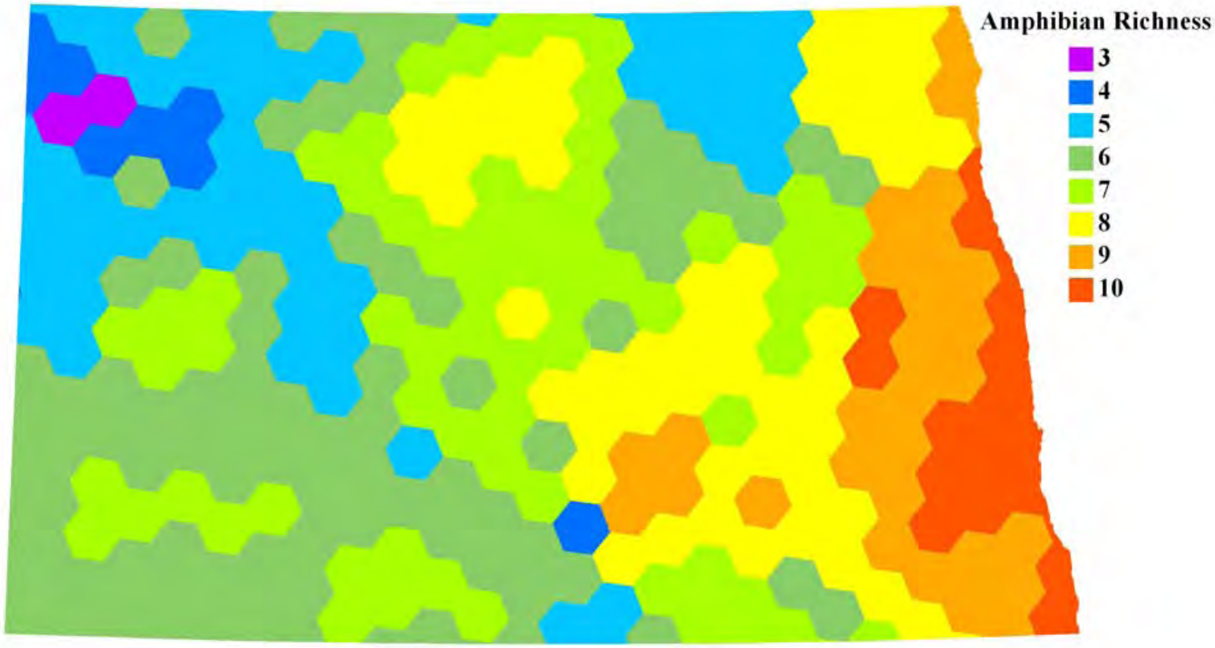


Fig 3.1. Amphibian species richness by 648 km^2 hexagons.

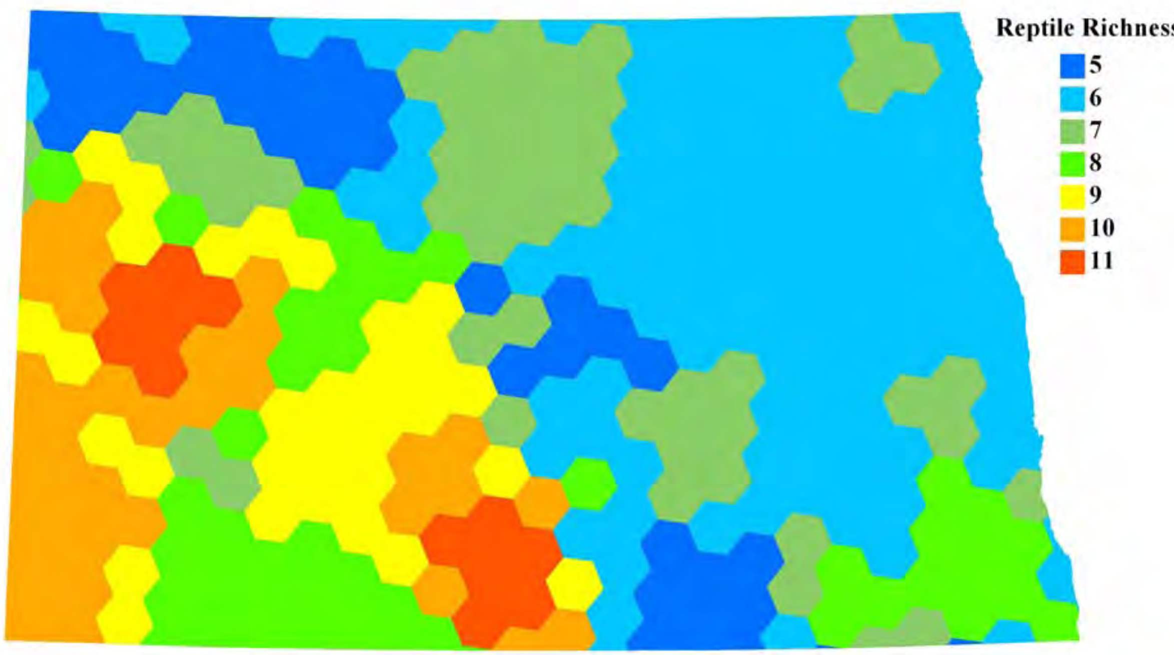


Fig 3.2. Reptile species richness by 648 km^2 hexagons.

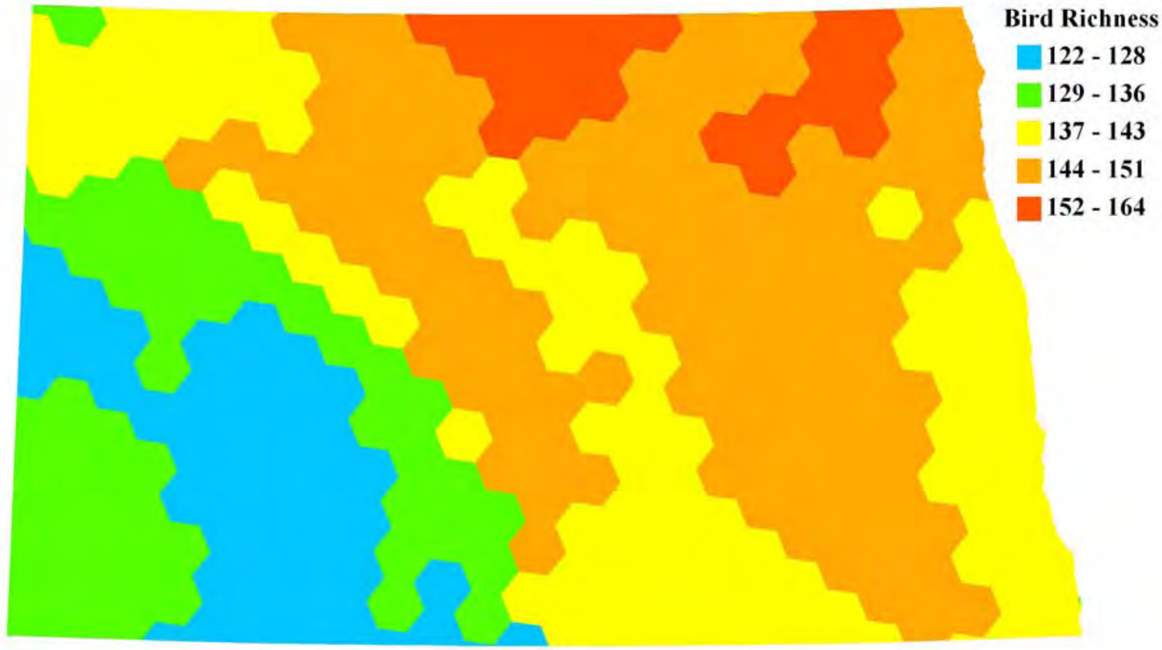


Fig 3.3. Bird species richness by 648 km^2 hexagons.

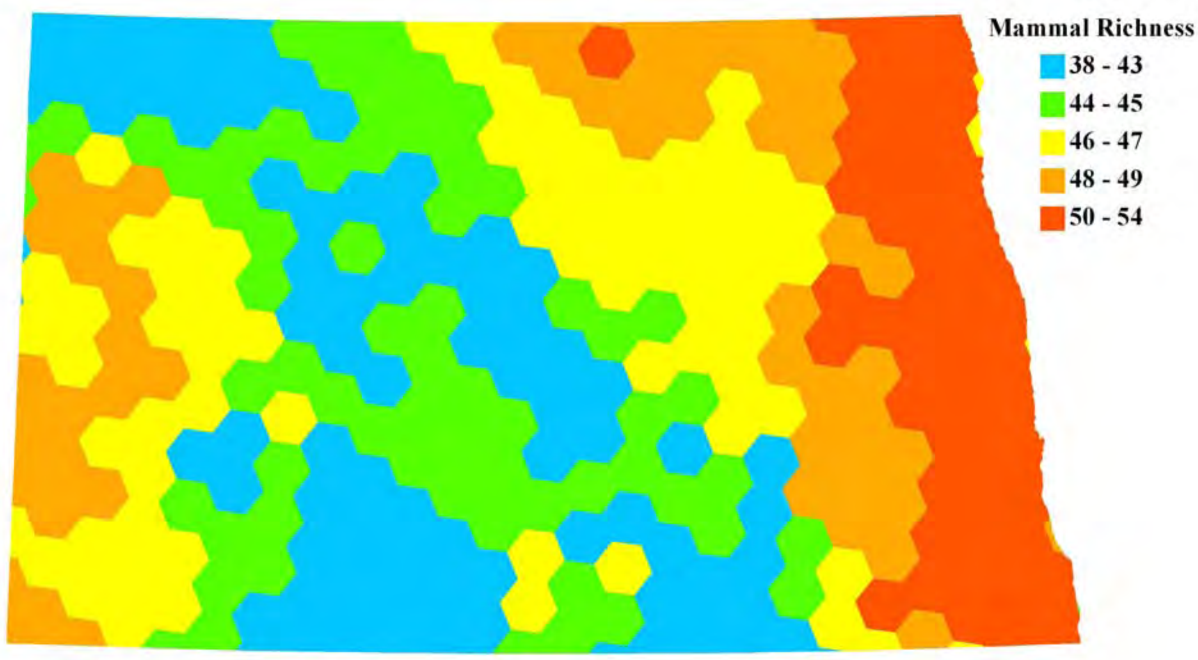


Fig 3.4. Mammal species richness by 648 km^2 hexagons.

Accuracy Assessment

Introduction

Assessing the accuracy of the predicted vertebrate distributions is subject to many of the same problems as assessing land cover maps, as well as a host of more serious challenges related to both the behavioral aspects of species and the logistics of detecting them (Boone and Krohn 1999, 2000; Edwards et al. 1996). These are described further in the Background section of the GAP Handbook on the national GAP web page. We do, however, feel it is important to provide users with a statement about the accuracy of GAP predicted vertebrate distributions within the limitations of available resources and practicalities of such an endeavor. We acknowledge that distribution maps are never finished products but are continually updated as new information is gathered. This reflects not only an improvement over the modeling process but also the opportunity to map changes in species distributions over time. However, we feel that assessing the accuracy of the current maps provides useful information about their reliability to potential users.

Our goal was to produce maps that predict distribution of terrestrial vertebrates and, from that, species richness and species composition with an accuracy of 80% or higher. Failure to achieve this level of accuracy indicates the need to refine the data sets and models used to predict distribution. There is a conscious effort in the GAP process, however, to err on the side of commission, (e.g., coding hexagons adjacent to hexagons with known location records as “probable” when creating species range maps; That is to attribute species as possibly present when they are not). There are two primary reasons for doing so: (1) few species have systematic, unbiased known ranges, and we believe science is best served by identifying a greater potential for sampling and investigation than using a conservative approach that may miss such opportunities; (2) in conducting the analysis of conservation representation (see the Analysis section), we believe it most appropriate to identify a species that may need additional conservation attention that is latter reclassified by further investigation rather than identifying a species as sufficiently protected that is latter reclassified as declining or extirpated.

Methods

Our approach to assessing the accuracy of the North Dakota GAP vertebrate distribution models was similar to that of other GAP projects (Edwards et al. 1996). We had difficulty identifying natural areas in North Dakota with long-term and accurate species lists. Systematic monitoring of vertebrate species is not a standard practice on many natural areas, and the general consensus was that most species lists were incomplete. Published lists also become outdated as species distributions change. We used published species checklists from four USFWS National Wildlife Refuges, The Nature Conservancy’s Cross Ranch Nature Preserve, and Theodore Roosevelt National Park to examine the accuracy of the potential vertebrate distribution models (Table 3.5 and Fig. 3.5). The existing species lists were evaluated by expert reviewers and natural area biologists, and these revised species lists were compared with a species list assembled for

Table 3.5 Six natural areas used to assess the accuracy of North Dakota GAP vertebrate distribution models.

Natural area	Area (ha)	Birds	Mammals	Herptiles
Cross Ranch Nature Preserve	2382		x	
Tewaukon National Wildlife Refuge	3442	x	x	x
Arrowwood National Wildlife Refuge	6422	x		
Long Lake National Wildlife Refuge	8748	x		
Lostwood National Wildlife Refuge	11884	x	x	x
Theodore Roosevelt National Park	28467	x		x

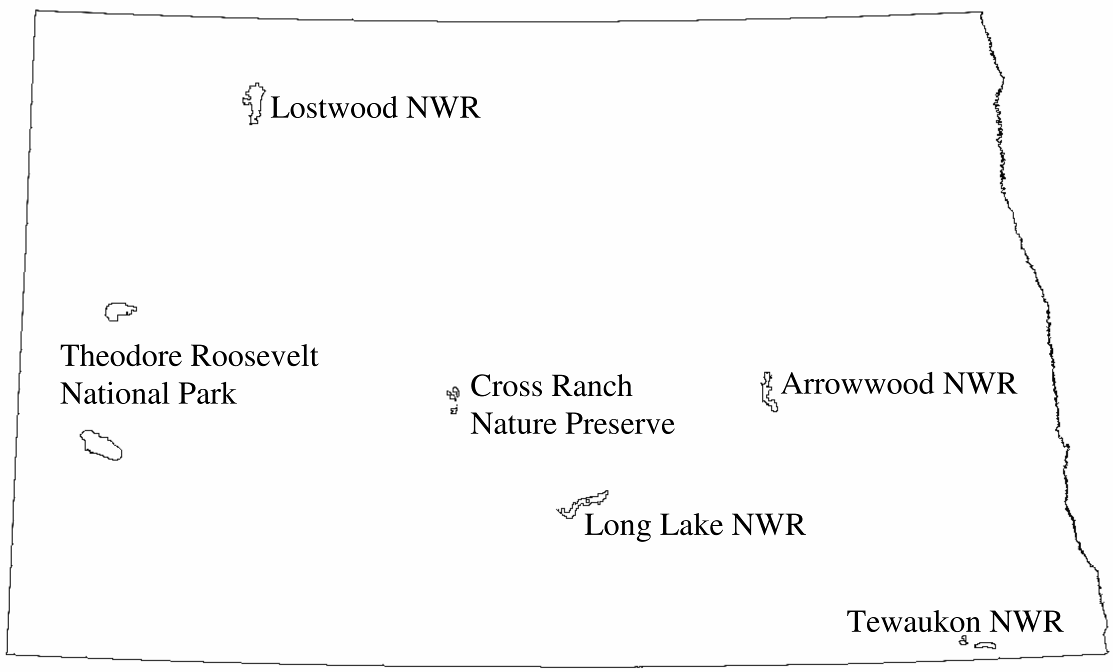


Fig 3.5 Location of six natural areas used to assess the accuracy of vertebrate distribution models.

the area using the predicted vertebrate distribution maps. The checklists were not used in the construction of species range maps. A North Dakota GAP species list for each area was created from the vertebrate distribution maps by extracting within the boundary lines of each natural area the results of the hypergrid analysis performed in conjunction within the investigation of species richness.

<u>Results</u>

Published bird species lists were available for four of the five areas, and published lists for mammal and herptile species were available for three of the five locations. The complete accuracy assessment tables for each taxonomic group are in Appendices 3.4–3.7. Omission errors were smaller than commission errors for each taxonomic group at all locations (Table 3.6). Percent agreement for birds averaged 94% with a range of 84-98 %. Omission errors for birds averaged less than 1% with a range of 0-2%. Commission errors for birds averaged 5.4% with a range of 2-14%. One half of the commission errors in the birds of Theodore Roosevelt National Park are wetland birds including grebes and some species of waterfowl, which were predicted to occur because of the presence of riverine wetland habitat. Other congener species have been recorded as breeding in the park. Percent agreement for mammals averaged 89.6% with a range of 86-94%. Omission errors for mammals averaged 2% with a range of 0-3% whereas commission errors averaged 8.3% with a range of 3-14%. Percent agreement for herptiles averaged 92% with a range of 85-100%. Omission errors for herptiles averaged 2.6% with a range of 0-8% whereas commission errors averaged 5.3% with a range of 0-8%. Most of the commission errors are small mammals that have not been collected or well studied but are suspected to occur in the selected area and bird species seen but not yet recorded as breeding in the selected areas. Lists of the species identified as omission or commission errors at any of the six natural areas are presented in Tables 3.7–3.9 for birds, mammals, and herptiles, respectively. There was no relationship between percent agreement or omission and commission errors with natural-area size.

Table 3.6. Number of agreements and commission and omission errors from a comparison of vertebrate potential distribution maps with species checklists for six public natural areas.

Taxonomic Group	Arrowwood NWR	Long Lake NWR	Lostwood NWR	Tewaukon NWR	Theodore Roosevelt National Park	Cross Ranch Nature Preserve
			Birds			
Agreement	179(97%)	175(95%)	181(98%)	181(98%)	154(84%)	
Commission	5(3%)	9(5%)	3(2%)	3(2%)	27(14%)	
Omission	0	0	0	0	3(2%)	
			Mammals			
Agreement			67(94%)	61(86%)		63(89%)
Commission			2(3%)	10(14%)		6(8%)
Omission			2(3%)	0		2(3%)
			Reptiles			
Agreement			14(93%)	15(100%)	14(93%)	
Commission			1(7%)	0	0	
Omission			0	0	1(7%)	
			Amphibians			
Agreement			10(91%)	11(100%)	8(73%)	
Commission			1(9%)	0	2(18%)	
Omission			0	0	1(9%)	

Table 3.7. A list of bird species identified as omission (O) or commission (C) errors at one or more of five natural areas used to examine the accuracy of vertebrate distribution models. An A indicates agreement between species potential distribution maps and species checklists for the public natural area.

TNCcode	Common name	Scientific name	Arrow-wood NWR	Long Lake NWR	Lost-wood NWR	Tewaukon NWR	Theodore Roosevelt NP
ABNCA02010	Pied-Billed Grebe	Podilymbus podiceps	A	A	A	A	C
ABNCA03030	Eared Grebe	Podiceps nigricollis	A	A	A	A	C
ABNCA04010	Western Grebe	Aechmophorus occidentalis	A	A	A	A	C
ABNFD01020	Double-Crested Cormorant	Phalacrocorax auritus	A	A	A	A	C
ABNGA01020	American Bittern	Botaurus lentiginosus	A	A	A	A	C
ABNJB09010	Wood Duck	Aix sponsa	A	A	A	A	C
ABNJB10140	Cinnamon Teal	Anas cyanoptera	A	A	A	C	A
ABNJB10150	Northern Shoveler	Anas clypeata	A	A	A	A	C
ABNJB11030	Redhead	Aythya americana	A	A	A	A	C
ABNJB11070	Lesser Scaup	Aythya affinis	A	A	A	A	C
ABNJB18010	Common Goldeneye	Bucephala clangula	A	A	A	A	O
ABNJB22010	Ruddy Duck	Oxyura jamaicensis	A	A	A	A	C
ABNKC10010	Bald Eagle	Haliaeetus leucocephalus	A	C	A	A	A
ABNKC19050	Broad-Winged Hawk	Buteo platypterus	C	A	A	A	A
ABNKC22010	Golden Eagle	Aquila chrysaetos	A	C	C	A	A
ABNLC11010	Ruffed Grouse	Bonasa umbellus	A	A	A	A	C
ABNME05030	Virginia Rail	Rallus limicola	A	A	A	A	C
ABNME08020	Sora	Porzana carolina	A	A	A	A	A
ABNME14020	American Coot	Fulica americana	A	A	A	A	C
ABNND02010	American Avocet	Recurvirostra americana	A	A	A	A	C
ABNNF02010	Willet	Catoptrophorus semipalmatus	A	A	A	A	C
ABNNF04020	Spotted Sandpiper	Actitis macularia	A	A	A	A	C
ABNNF08040	Marbled Godwit	Limosa fedoa	A	A	A	A	C
ABNNF18010	Common Snipe	Gallinago gallinago	A	A	A	A	C
ABNNF20010	Wilson's Phalarope	Phalaropus tricolor	A	A	A	A	C
ABNSB10010	Burrowing Owl	Athene cunicularia	A	A	A	C	A
ABNUA03010	Chimney Swift	Chaetura pelagica	A	A	A	A	C
ABPAE43070	Great Crested Flycatcher	Myiarchus crinitus	A	C	A	A	A
ABPAT02010	Horned Lark	Eremophila alpestris	C	A	A	A	A
ABPAV02020	Blue Jay	Cyanocitta cristata	A	A	C	A	A
ABPBK03010	Northern Mockingbird	Mimus polyglottos	A	A	A	A	C
ABPBX24010	Yellow-Breasted Chat	Icteria virens	A	C	A	A	A
ABPBX45040	Scarlet Tanager	Piranga olivacea	A	C	A	A	A
ABPBX61030	Rose-Breasted Grosbeak	Pheucticus ludovicianus	C	A	A	A	O
ABPBX64020	Lazuli Bunting	Passerina amoena	A	C	A	A	A
ABPBX64030	Indigo Bunting	Passerina cyanea	A	C	A	A	A
ABPBX65010	Dickcissel	Spiza americana	C	A	A	A	C
ABPBX74080	Spotted Towhee	Pipilo maculatus	A	C	A	A	A
ABPBX94020	Chipping Sparrow	Spizella passerina	A	A	A	C	A
ABPBX94050	Field Sparrow	Spizella pusilla	A	C	C	A	A

Table 3.7 (continued). A list of bird species identified as omission or commission errors at one or more of five natural areas used to examine the accuracy of vertebrate distribution models.

TNCcode	Common name	Scientific name	Arrow-wood NWR	Long Lake NWR	Lost-wood NWR	Tewaukon NWR	Theodore Roosevelt NP
ABPBX95010	Vesper Sparrow	Pooecetes gramineus	C	A	A	A	A
ABPBXA0040	Le Conte's Sparrow	Ammodramus leconteii	A	A	A	A	C
ABPBXA6010	Mccown's Longspur	Calcarius mccownii	A	A	A	A	O
ABPBXB9190	Baltimore Oriole	Icterus galbula	A	A	A	A	C
ABPBXB9220	Bullock's Oriole	Icterus bullockii	A	A	A	A	C
ABPBY04040	House Finch	Carpodacus mexicanus	A	A	A	A	C
ABPBY05010	Red Crossbill	Loxia curvirostra	A	A	A	A	C

Table 3.8. A list of mammal species identified as omission or commission errors at one or more of three natural areas used to examine the accuracy of vertebrate distribution models.

TNC code	Common name	Scientific name	Lostwood NWR	Tewaukon NWR	Cross Ranch Nature Preserve
AMABA01190	Arctic Shrew	*Sorex arcticus*	A	C	A
AMABA03010	Northern Short-tailed Shrew	*Blarina brevicauda*	A	A	C
AMACC01060	Keen's Myotis	*Myotis keenii*	A	C	C
AMACC04010	Big Brown Bat	*Eptesicus fuscus*	A	C	A
AMAEB03010	Snowshoe Hare	*Lepus americanus*	A	A	C
AMAFB02230	Eastern Chipmunk	*Tamias striatus*	A	C	A
AMAFB06010	Black-tailed Prairie Dog	*Cynomys ludovicianus*	A	A	C
AMAFB07010	Gray Squirrel	*Sciurus carolinensis*	A	C	A
AMAFB09020	Northern Flying Squirrel	*Glaucomys sabrinus*	A	C	A
AMAFC01040	Northern Pocket Gopher	*Thomomys talpoides*	C	A	A
AMAFD01010	Olived-backed Pocket Mouse	*Perognathus fasciatus*	A	C	A
AMAFD01020	Plains Pocket Mouse	*Perognathus flavescens*	C	A	O
AMAFF02010	Plains Harvest Mouse	*Reithrodontomys montanus*	A	C	C
AMAFF08090	Bushy-tailed Woodrat	*Neotoma cinerea*	A	A	O
AMAFF11140	Prairie Vole	*Microtus ochrogaster*	A	C	A
AMAJF02010	Ermine	*Mustela erminea*	O	A	A
AMAJH03020	Bobcat	*Felis rufus*	A	C	A
AMALD01010	Pronghorn	*Antilocapridae americana*	O	A	A
AMALE04010	Bighorn Sheep	*Ovis canadensis*	A	A	C

Table 3.9. A list of herptile species identified as omission or commission errors at one or more of three natural areas used to examine the accuracy of vertebrate distribution models.

TNC code	Common name	Scientific name	Lostwood NWR	Tewaukon NWR	Theodore Roosevelt NP
AAABB01080	Canadian Toad	*Bufo hemiophrys*	C	A	C
AAABF01010	Plains Spadefoot Toad	*Scaphiopus bombifrons*	A	A	O
AAABH01200	Wood Frog	*Rana sylvatica*	A	A	C
ARAAB01012	Common Snapping Turtle	*Chelydra s. serpentina*	C	A	A
ARAAG01022	Midland Smooth Softshell Turtle	*Apalone m. mutica*	A	A	O

Limitations and Discussion

A database that encompasses the type and large amount of information that is incorporated into a Gap analysis is certain to have some errors and thus some uncertainty. The combined effect of errors in the land cover map, the species range representations, and the WHR models on species potential distribution maps are unknown.

The validity of the results of accuracy assessments of WHR models have been shown to be dependent on the size of the assessment sites, the duration of surveys, the biology and ecology of the fauna, as well as the quality of species predicted distribution models (Boone and Krohn 2000). Our analysis did not assess the accuracy of species habitat affinities but rather assessed presence or absence of a species in a geographic area. Because the accuracy assessment was not a probability-based sample, care must be taken with regards to inferences drawn from the results. Accuracy assessments are only applicable at the spatial and temporal scales at which they are conducted. For example, to infer from our results the accuracy of prediction for a 10-ha prairie surveyed one season would be inappropriate. Although the results from our accuracy assessment were encouraging, the vertebrate distribution maps have a number of limitations that users should consider.

Our simple WHR models do not account for community and ecosystem processes that may be important determinants of species occurrences. A species fundamental niche which corresponds to suitable or potential habitat, is often broader than its realized niche where it actually occurs. Biological and ecological factors, such as interactions with predators and competitors, influence the distribution of species. Thus, WHR models, which are based primarily upon affinities with land cover categories, in many cases will tend to over-estimate the actual distribution of a species and therefore species richness.

Model results depend on the scale and the generalization of the land cover map (Stoms 1992). From the well-known species-area relationship, we would expect fewer species to be found in a 1-ha patch than a 100-ha patch of the same habitat type. However, our simple WHR models do not incorporate the area or size of land cover patches into model predictions. For example, species distributions for woodland dependent species are likely overestimated as many small woodland patches depicted in the land cover map probably cannot sustain a breeding population. There is a tradeoff of predicting species presence in patches too small to sustain a viable population (errors of commission) and not predicting species that inhabit small but critical habitat patches (errors of omission).

Over-prediction of the total area potentially occupied by the animals also can occur when a species affinity is with a subset of habitat characteristics of a broadly defined land cover category. A good example of this problem are the distribution maps for bats, cavity nesting birds, and other species requiring specific structural elements below the resolution of the land cover map.

WHR model predictions for colonial wetland birds overestimate the amount of occupied nesting habitat. Although nesting may not occur at many of the predicted habitat locations, adult or subadult birds can be present or even common during the breeding season. Many of these species have subpopulations of non-breeding adults or subadults, which wander throughout parts of North Dakota. For some species, such as the American White Pelican, nesting adults travel great distances from their colony to forage.

For accidental breeders, sporadic or irruptive breeders, or species nesting outside of their typical breeding range, the models exaggerate the species' distribution within the state. Even if suitable habitat is present, the species may not occur at a location in most years. Examples of accidental breeders include Least Bittern, American Black Duck, Cinnamon Teal, Merlin, Northern Mockingbird, Bell's Vireo, and Blue Grosbeak. Some of these species might be expanding their ranges into ND (e.g., Northern Mockingbird, Cattle Egret) or recolonizing portions of their former range (e.g., Merlin). Sporadic or irruptive breeders include Long-eared Owl, Ruby-throated Hummingbird, Pine Siskin, and Red Crossbill.

Finally, most species' distributions are not static but rather ebb and flow with changing climatic and biological conditions. For example, the potential distribution map for the Burrowing Owl includes a significant area of natural prairie that occurs east and north of the Missouri River. However, recent efforts to determine the status of the Burrowing Owl have concluded the species changed from common or uncommon to rare in the best potential habitat that remains and has disappeared from the eastern one-third of the state (Murphy et al. 2001).

LAND STEWARDSHIP

Introduction

To fulfill the analytical mission of GAP, it is necessary to compare the mapped distribution of elements of biodiversity with their representation in different categories of land stewardship and management. We use the term "stewardship" in place of “ownership” in recognition that legal ownership does not necessarily equate to the entity charged with management of the land, e.g., lands owned by the Army Corps of Engineers but managed by the North Dakota Game and Fish Department. We use management status to distinguish administrative units with different land management objectives and degrees of management for biodiversity. For example, a steward such as the U.S. Forest Service may manage administrative units with different management objectives within a National Grassland, e.g., Research Natural Areas, and Rangelands with Broad Resource Emphasis.

The purpose of comparing biotic distribution with stewardship is to provide a method by which land stewards can assess their relative amount of responsibility for the management of a species or plant community and identify other stewards sharing that responsibility. This information can reveal opportunities for cooperative management of that resource, which directly supports the primary mission of GAP to provide objective, scientific information to decision makers and managers to make informed decisions regarding biodiversity. It also is not unlikely that a steward that has previously borne the major responsibility for managing a species may, through such analyses, identify a more equitable distribution of that responsibility. We emphasize, however, that GAP only identifies private land as a homogeneous category and does not differentiate individual tracts or owners, unless the information was provided voluntarily to recognize a long-term commitment to biodiversity maintenance.

After comparison to stewardship, it is also necessary to compare biotic occurrence to categories of management status. The purpose of this comparison is to identify the need for change in management status for the distribution of individual elements or areas containing high degrees of diversity. Such changes can be accomplished in many ways that do not affect the stewardship status. While it will eventually be desirable to identify specific management practices for each tract, and whether they are beneficial or harmful to each element, GAP currently uses a scale of 1 to 4 to denote relative degree of maintenance of biodiversity for each tract. A status of "1" denotes the highest, most permanent level of maintenance, and "4" represents the lowest level of biodiversity management, or unknown status. This is a highly subjective area, and we recognize a variety of limitations in our approach, although we maintain certain principles in assigning the status level. Our first principle is that land ownership is not the primary determinant in assigning status. The second principle is that while data are imperfect, and all land is subject to changes in ownership and management, we can use the intent of a land steward as evidenced by legal and institutional factors to assign status. In other words, if a land steward institutes a program backed by legal and institutional arrangements that are intended for permanent biodiversity maintenance, we use that as the guide for assigning status.

The characteristics used to determine status are as follows:

- Permanence of protection from conversion of natural land cover to unnatural (human-induced barren, exotic-dominated, arrested succession).
- Relative amount of the tract managed for natural land cover.
- Inclusiveness of the management, i.e., single feature or species versus all biota.
- Type of management and degree that it is mandated through legal and institutional arrangements.

The four status categories can generally be defined as follows (after Scott et al. 1993, Edwards et al. 1995, Crist et al. 1995):

Status 1: An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a natural state within which disturbance events (of natural type, frequency, and intensity) are allowed to proceed without interference or are mimicked through management.

Status 2: An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a primarily natural state, but which may receive use or management practices that degrade the quality of existing natural communities.

Status 3: An area having permanent protection from conversion of natural land cover for the majority of the area, but subject to extractive uses of either a broad, low-intensity type or localized intense type. It also confers protection to federally listed endangered and threatened species throughout the area.

Status 4: Lack of irrevocable easement or mandate to prevent conversion of natural habitat types to anthropogenic habitat types. Allows for intensive use throughout the tract. Also includes those tracts for which the existence of such restrictions or sufficient information to establish a higher status is unknown.

Mapping Standards

When the NDGAP began to organize in 1998, very little digital boundary data existed for public lands in ND. The North Dakota Department of Transportation (NDDOT) was in the process of converting their mapping responsibilities for ND from a manual process to a digital process. One of the NDDOT products is a state base map which contains boundaries for many of the federal and state public lands in ND. Organizations with stewardship responsibilities for public lands in North Dakota were contacted and queried about the availability of digital and analog maps, realty records, and management plans for their lands. Few organizations had digital boundary data for all their lands but many agencies had partial data sets and plans to create digital land ownership vectors for their lands. The scale of the boundary data being developed by the agencies ranged from 1:24,000 to 1:100,000. Based on this information, a decision was made that the NDGAP would acquire digital boundary data from public land managers in ND and would assemble the data for individual agencies into a single vector. If boundary data were not available from the agency that owned or managed the lands, the NDGAP would use the NDDOT digital state base map for those lands, and if not available in the NDDOT product the NDGAP would create the data. A useful starting point for addressing the inclusiveness of the stewardship vector for ND was a paper 1:500,000 scale land status map for North Dakota produced by the Bureau of Land Management in 1993.

Nearly all public land boundary data were acquired from the owner or manager of the land in digital format. Digital vectors of land ownership or stewardship boundaries in ND were acquired from 11 organizations (Table 4.1). Methods used to create the data included digitizing and GPS surveys. The cartographic scale of the source layers for the digitized data ranged from 1:12,000 to 1:100,000 with the majority of the data having a scale of 1:24,000. A U.S. Census Bureau TIGER vector developed from U.S. Geological Survey 1:100,000 digital line graphs was used for the ND state boundary.

The projection parameters and datum of the acquired vectors varied with the majority of the data in UTM 14, NAD 27 or NAD 83. All acquired vectors were reprojected to the NDGAP standard projection parameters of Albers Conical Equal Area, GRS 1980, NAD 83. Land boundary data for the two Military Bases and a ND National Guard Base were obtained from the NDDOT digital base map. Boundary data for lands managed by the ND Forest Service, ND Agricultural Experiment Stations, and the Audubon Society were created by the NDGAP by on-screen digitizing using 1:24,000 PLSS and DOQQ reference data. When a vector did not have metadata, we contacted the agency and obtained information on the methods used to create the data.

The vectors for American Indian Reservations do not depict land ownership in the same manner as vectors from other sources. The American Indian Reservation boundaries enclose lands under the jurisdiction of tribal governments recognized by the U.S. Government. Public lands within the Reservation boundaries are shown in the stewardship vector. The remaining lands within the reservation boundaries have a very complex ownership consisting of privately owned lands and tribal and individual Indian trusts managed by the USBIA. The management of individual Indian trust lands is the

Table 4.1. Organizations that provided digital land boundary data used to create the stewardship vector for the ND GAP. Data sources are listed in reserve of the order that they were used in the Arc-Info update function to create a single, all inclusive stewardship vector for ND. For example, the USFWS vector was used in the last iteration of the update function and its spatial topology and attributes superseded the previous vectors where overlap occurred.

Data Sources	Acronym
U.S. Fish and Wildlife Service	USFWS
ND Game and Fish Department	NDGF
U.S. Army Corps of Engineers	USACE
U.S. Forest Service	USFS
U.S. Bureau of Reclamation	USBR
U.S. National Park Service	USNPS
U.S. Bureau of Land Management	USBLM
U.S. Bureau of Indian Affairs	USBIA
The Nature Conservancy	TNC
ND Department of Transportation	NDDOT
ND State School Land	NDGS[a]

[a]The ND Geological Survey provided a vector of lands managed by the ND State Land Department.

subject of an on-going class action lawsuit, Cobell v. Norton, filed in 1996. All lands within reservation boundaries with the exception of public lands were assigned an owner and manager code of 2000.

We did not include water features in the stewardship vector unless they were present in the vectors obtained from the various agencies. Only water polygons belonging to large reservoirs were coded using the GAP water owner and manager numeric code (8000). The small number of water body polygons not belonging to a large reservoir (n =20) from all source vectors were coded with the owner and manager codes for the land unit that contained them. This was done for consistency since many lakes much larger than these were not included in the stewardship layer. Ownership, managing entities, and water rights are complex issues that will be addressed in the future by the aquatic component of GAP.

ND-GAP did not use a standard Minimum Mapping Unit (MMU). Instead, we followed the recommendation within the GAP handbook for mapping and categorizing land stewardship and maintained the resolution at which the digital data were acquired. About one quarter (24 percent) of the total number of ND GAP land units were less than 40 acres, with 60 percent of these land units owned by the USACE. Many of these USACE-owned land units were primarily small islands, or secondarily land bordered on one side by water and the other by different landowners. Many of the remaining less than 40-acre land units were owned or managed by the USFWS, the USFS, or the NDGF.

Methods

Stewardship Mapping:

In most cases, the data received from an agency consisted of more than one vector. For example, the USFWS data set consisted of three data layers: fee title refuges, easement refuges, and waterfowl production areas, and the USFS and USACE data sets consisted of separate vectors for each management district. When the agency used the same procedure to create each vector, the individual vectors were united to create a single vector with all of the agency's lands in ND.

There were a small number of cases where internal administrative and management boundaries separating land units with different GAP status codes were not included in a vector acquired from an agency. When this occurred we created the internal management unit boundary after consultation with agency personnel.

Once a vector with the state-wide extent of an agency's land was created, the next step was the creation and population of a polygon attribute table with the GAP stewardship attributes. The attributes included owner, manager, and status for all polygons, and division, unit, date of establishment, and source of management information for lands assigned GAP status codes of 1 or 2 or for other lands if the information was available. Owner, manager and status were recorded using the numeric codes for the attributes found in the GAP Stewardship Handbook.

The next step in the development of the NDGAP stewardship vector was to combine the individual agency vectors into a single vector. Combining individual vectors from different sources and scales into a single vector is potentially difficult because of problems with coincident lines and the creation of spurious polygons when the boundaries of polygons on the source vectors are highly correlated (Burrough and McDonnell 1998: p 237). Large numbers of small spurious or sliver polygons can be created when what theoretically should be coincident lines in the source vectors are not. The greatest problem was the removal of the spurious polygons to avoid nonsense in the state stewardship vector. To minimize the spurious polygon problem, we constructed a hierarchy of data sets on the basis of the scale of the source data, the procedures used to create the vector, and the agency-imposed use constraints accompanying the data (Table 4.1). The hierarchy defined the order that data sets would be included in the Arc Info V7.2 update function. The update function combines vectors by overlaying the update vector over the input vector, with the spatial topology and attributes of the update vector superseding the input vector where overlaps occur. The importance of the hierarchy was to define the order that the different agency data sets were included in the repetitive use of the update function to construct a single, all-inclusive stewardship vector for ND. Agency data sets were introduced into the update function starting with the lowest level in the hierarchy, the boundary layer for ND, and continuing to the FWS Fee Title Refuge

vector which was assigned to the highest level the hierarchy. The update function minimized the amount of sliver and island edits that were required, while giving precedence to data sets of finer scale and accuracy.
At the conclusion of the iterative use of the update function, spurious sliver and island polygons were identified using an area to perimeter ratio and visually. Following the data set hierarchy, arcs and the sliver and island polygons were edited or eliminated as needed if determined to be trivial. Polygon attributes were checked and reattributed when necessary and excess data fields were deleted.

Land ownership and stewardship is dynamic. We terminated data collection for the NDGAP stewardship vector with the delivery of the USFWS vector in the spring 2003.

<u>Management Status Categorization</u>:

The NDGAP generally used the dichotomous key and the criteria in the GAP Stewardship Handbook to categorize the biodiversity management status of land units. A primary difficulty categorizing the status for some land units in ND using the GAP criteria was reconciling the requirement for natural land cover with legislation and management objectives. Many public lands in ND, in particular FWS Waterfowl Production Areas (WPA), have only fragments of natural land cover remaining but have wildlife or biodiversity conservation objectives. Strict conformance to the natural land cover requirement in the description of the four biodiversity status categories would require these lands being assigned a status 4 because natural land cover in has been replaced by planted grassland. In accordance with the GAP principles for assigning status categories (see introduction), lands that had a wildlife or biodiversity management objective were assigned a minimum status category of 3 even if natural land cover of the land unit had been replaced by a planted land cover.

Published management plans, such as the USFS Northern Great Plains Management Plan Revision, USFWS Comprehensive Conservation Plans, and the USACE Master Plan, greatly facilitated the categorization of the biodiversity management status of land units (Table 4.2). When management plans were not available, the categorization of biodiversity management status was more difficult and made on the basis of information provided by the land manager, legal mandates, and the management objective as implied by the land unit designation specified by the land owner. Because Comprehensive Conservation Plans required by the National Wildlife Refuge System Improvement Act of 1997 are not yet available for most FWS lands in ND, we requested information on the land cover composition, unique resources, and management objectives for WPAs from FWS personnel. WPAs with natural land cover greater than or equal to 95% were coded as status 2 and WPAs with natural land cover less than 95% or WPA without land cover composition information were coded as status 3. In a similar manner, we used knowledge of the land use history and the absence of natural land cover to assign a status code of 2 rather than 1 to the two Wilderness areas on FWS NWRs.

Table 4.2 Management Entity and area (sq. km) of status 1 and 2 lands in North Dakota

Managing Entity and Internal Management Division	Total Area sq. km	Information Sources used to Assign Management Status
U.S. Fish and Wildlife Service		
National Wildlife Refuge	856.98	1. Year 2000 North Dakota Briefing Book[1],
Waterfowl Production Area	133.13	2. Land Cover and Management Objective Spreadsheet[2],
Wilderness Area	39.43	3. personal communications
U.S. Forest Service		
Research Natural Area	81.44	1. Northern Great Plains Management Plan Revision[3],
General Forest Lands	484.90	2. Record of Decision for Dakota Prairie Grasslands[4]
National Park Service		
National Historic Site	6.90	1. Theodore Roosevelt National Park Zones Vector[5],
National Park	162.45	2. National Park Service website[6]
Wilderness Area	123.10	
Audubon Society Preserves	8.60	1. Personal communication, Donna Schneider, Audubon Society North Dakota
TNC Preserves	50.98	Personal communications: 1. Eric Rosenquist, TNC Preserve Manager, 2. Robert Self, TNC Preserve Manager, 3. Brian Winter, Regional Stewardship Director
University of North Dakota	1.29	Personal communication, Dr. Richard Crawford, UND
Totals	1949.2	

1. USFWS, Mountain-Prairie Region website, (http://mountain-prairie.fws.gov/reference/briefing_book_nd_2000.pdf).
2. Informational spreadsheet developed by ND-GAP and completed by USFWS Wetland Management District Personnel.
3. Northern Great Plains Management Plan Revision, CDs 1 and 2, Northern Great Plains Planning, USDA Forest Service, Chadron, NE.
4. Record of Decision for Dakota Prairie Grasslands, July 2002, Dakota Prairie Grasslands Office, Bismarck, ND.
5. Data supplied by the Theodore Roosevelt National Park GIS Lab.
6. National Park Service website, Theodore Roosevelt National Park, (http://www.nps.gov/thro/).

We also created two subcategories for status 4 lands owned by the ND State Land Department. The status subcategory 4a identifies land units where the natural land cover is intact and anthropogenic disturbance of the soils has been minimal. The land units do not warrant a higher status rating because they are not subject to an institutional management plan which would prevent conversion of natural land cover to anthropogenic land covers. Status subcategory 4b identifies land units owned by the ND State Land Department where the natural land cover has been destroyed by disturbances such as cropland tillage or mining. The status subcategories were created because status 4a lands owned by the ND State Land Department are pivotal to future prairie biodiversity conservation efforts on public lands in ND because of their area, geographical distribution, and diversity.

Reservoirs assigned GAP owner and manager codes of 8000 were assigned a status code of zero.

Results

Lands managed by public agencies comprise approximately 6.4% of ND lands with 4.3% under federal and 2% under state jurisdiction (Table 4.3, Map 4.1). Approximately 4.2% of the land in ND occurs within the boundaries of lands governed by five Native American Tribal Governments. Lands managed by non-profit conservation organizations account for less than half of one percent of the land in ND. Private land owners are responsible for the management of more than 89% of the land in ND (portions of Native American Reservations are privately owned).

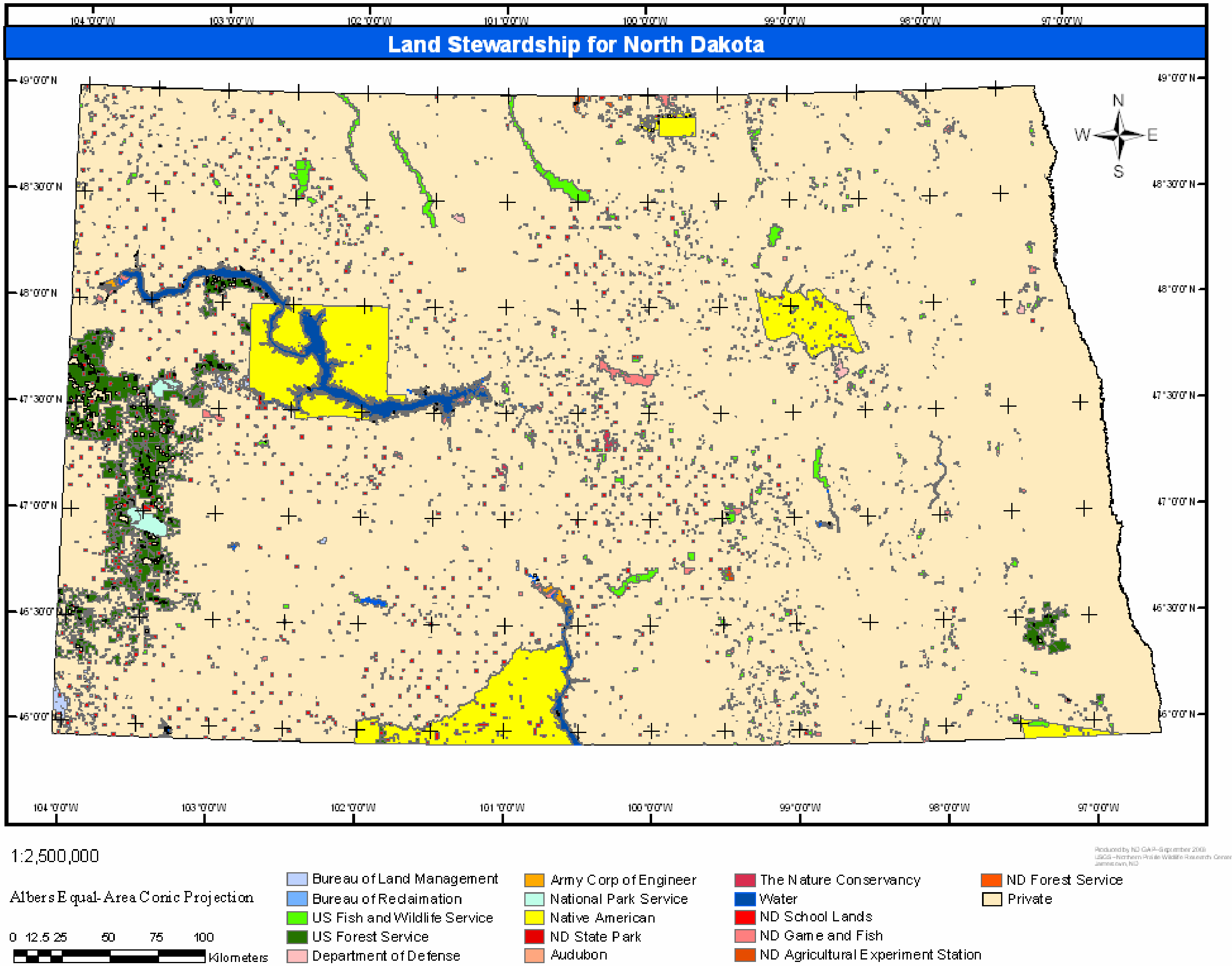
The USFS administers the largest amount of federal lands, 4467.34 sq. km, which is about double the amount of land managed by the USFWS, the second largest manager of federal lands in ND. USFS lands consist of the Little Missouri and Cedar River National Grasslands in western ND and the Sheyene National Grasslands in southeastern ND. The majority of USFWS lands are located east and north of the Missouri River in the Prairie Pothole Region of ND. More USFWS National Wildlife Refuges occur in ND than in any other state, although many of the 62 refuges are small and under easement from private land owners to provide resting and production areas for migratory birds (Bihrle 2003). The North Dakota State Land Department has management responsibility for the 2904.74 sq km of school lands which is 79% of lands under state jurisdiction.

Lands assigned to GAP status categories 1, 2, or 3 comprise less than 5% of land area of ND with only 1% in status categories 1 and 2 (Table 4.3, Map 4.2). Theodore Roosevelt National Park located in western ND accounts for 74% of the status 1 lands in ND. USFS Research Natural Areas, lands managed by the National Audubon Society, the Nature Conservancy, and the University of North Dakota account for the remainder of lands classified as status 1. The USFWS and the USFS has management responsibility for approximately 66 and 31%, respectively of the lands categorized as status 2 with the remainder under the management of the USNPS and private conservation organizations. Seven federal government agencies have responsibility for 5917.78 sq km or 87.8 % of the land classified as status 3 with the USFS, USFWS, USACE, and USBLM managing 65%, 21%, 8%, and 4% respectively, of these federal lands. Lands under state jurisdiction account for 11.6% of the lands classified as status 3 with the NDGF managing 654.4 sq. km or 83% of these lands. Status 4 lands are managed by private land owners (93.8%), Native American Tribal Governments (4.4%), and the ND State Land Department (1.7%).

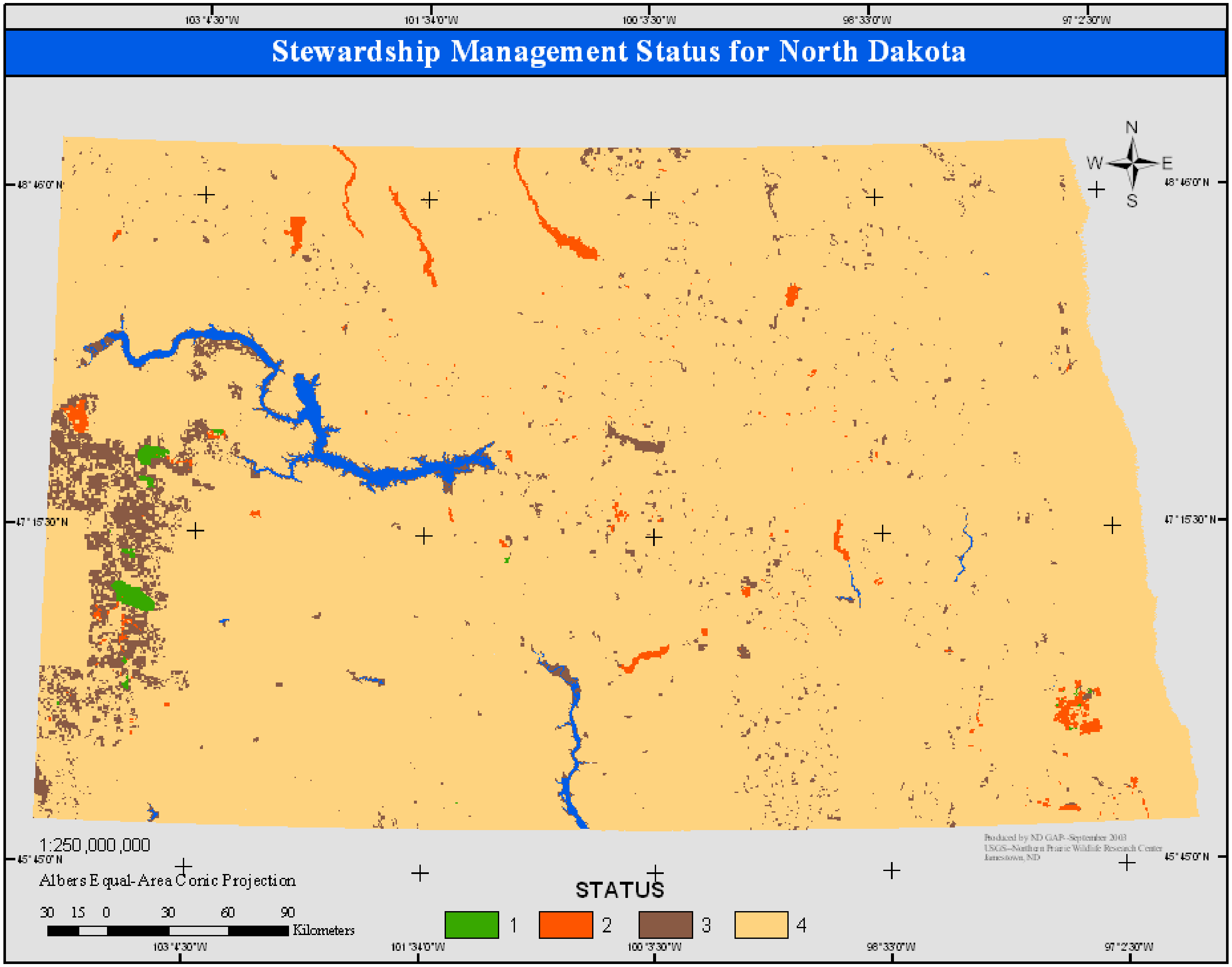
Eighty percent of the 2063 state school land units were given a status _sub category ranking of 4a because these land units have a high percentage of natural land cover and there has not been large scale anthropogenic disturbance of the soil. These land units do not warrant a higher status rating because they are not subject to an institutional management plan to prevent conversion of natural habitat types to anthropogenic habitat types.

Table 4.3 Area (sq. km) and percent of land by ND GAP stewardship and conservation status categories.

Manager/Steward	Land in Status 1		Land in Status 2		Land in Status 3		Land in Status 4		Total Area	Total Land Area
	sq. km	%	sq. km	%	sq.km	%	sq.km	%	sq.km	%
Federal	**371.16**	**97.16**	**1517.17**	**96.89**	**5917.78**	**87.78**	**73.49**	**0.04**	**7879.6**	**4.346**
U.S. Bureau of Reclamation					14.52	0.22			14.52	0.008
U.S. Bureau of Land Management					242.64	3.60			242.64	0.134
U.S. Fish and Wildlife Service			1029.54	65.75	1260.73	18.70	0.81	0.00	2291.08	1.264
U.S. National Park Service	284.08	74.37	8.38	0.54	1.56	0.02			294.02	0.162
U.S. Forest Service	87.08	22.80	479.25	30.61	3901.01	57.86			4467.34	2.464
U.S. Army Corps of Engineers					493.27	7.32			493.27	0.272
U.S. Department of Defense					4.05	0.06	72.68	0.04	76.73	0.042
Native American					**1.91**	**0.03**	**7572.37**	**4.39**	**7574.28**	**4.178**
Standing Rock Sioux							2677.31	1.55	2677.31	1.477
Three Affiliated Tribes					1.91	0.03	3158.31	1.83	3160.22	1.743
Turtle Mountain Chippewa							310.46	0.18	310.46	0.171
Spirit Lake Sioux							1177.82	0.68	1177.82	0.650
Sisseton-Wahpeton Sioux							248.47	0.14	248.47	0.137
State	**1.29**	**0.00**			**784.55**	**11.64**	**2914.69**	**1.69**	**3699.24**	**2.040**
University of North Dakota	1.29	0.00								
North Dakota State Parks					55.78	0.83			55.78	0.031
North Dakota Game and Fish					654.4	9.71			654.4	0.361
North Dakota School Lands							2904.74	1.68	2904.74	1.602
North Dakota Forest Service					55.31	0.82			55.31	0.031
North Dakota Agricultural Experiment Stations					19.06	0.28	9.95	0.01	29.01	0.016
Municipal					**19.6**	**0.29**			**19.6**	**0.011**
Non-Profit Conservation	**10.84**	**2.84**	**48.74**	**3.11**	**18.04**	**0.27**			**77.62**	**0.043**
National Audubon Society			8.6	0.55					8.6	0.005
The Nature Conservancy	10.84	2.84	40.14	2.56	18.04	0.27			69.02	0.038
Private							**162044.5**	**93.88**	**162044.5**	**89.382**
Open Water									1807.14	0.997
Total sq. kilometers of Land by Status Category	**383**		**1565.91**		**6741.88**		**172606.34**		**181297.13**	**100.000**
Total Status Land as a Pecentage of Total Land Area	0.21		0.86		3.72		95.21		100.00	
Total Area of North Dakota									183103.27	



Map 4.1. Land stewardship for North Dakota



Map 4.2. Gap stewardship management status for North Dakota

Limitations and Discussion

There are additional lands that could not be included in the stewardship vector but play an important role in biodiversity conservation in ND. In 2004, there are 3349 km^2 of wetlands and 620 km^2 of natural and semi-natural grassland protected by USFWS perpetual easements (Personnel Communication, Stu Wacker, USFWS). Conservation programs that are part of the National Farm Bill such as the Conservation Reserve Program (CRP) are also important to biodiversity conservation. Although lands enrolled in the CRP program have relatively short conservation contracts (typically 10 – 15 years) the program is beneficial in the short-term because of the large number of acres and the creation of an idle grassland land cover which is relatively scarce on other lands.

The stewardship vector is a compilation of ownership vectors provided by a variety of sources that are individually responsible for their accuracy. It was created solely for the purpose of conducting the analyses described in this report and is not suitable for locating boundaries on the ground or determining precise area measurements of individual tracts.

ANALYSIS BASED ON STEWARDSHIP AND MANAGEMENT STATUS

Introduction

As described in the Introduction of this report, a primary objective of GAP is to provide information on the distribution and status for two elements of biological diversity: natural land cover categories and terrestrial vertebrate species. This is accomplished by first producing maps of land cover (see Chapter 2), predicted distributions for selected animal species (see Chapter 3), and land stewardship and management status (see Chapter 4). Intersecting the land stewardship and management status map with the distribution of the elements allows the creation of tables that summarize the area and percent of total mapped distribution of each element in different land stewardship and management status categories. With these tables, a user can determine the representation of each element in the different stewardship and management status categories as appropriate to their needs. These comparisons do not measure viability, but are a start to assessing the likelihood of future threat to a biotic element through habitat conversion--the primary cause of biodiversity decline. These tables serve GAP's mission to provide land owners and managers with the information necessary to conduct informed policy development, planning, and management for biodiversity maintenance.

Although GAP "seeks to identify land cover types and species not adequately represented in the current network of biodiversity management areas" (GAP Handbook, Preface, Version 1, p. I), it is unrealistic to create a standard definition of "adequate representation" for either land cover types or individual species (Noss et al. 1995). A practical solution to this problem is to report both percentages and absolute area of each element in biodiversity management areas and allow the user to determine which types are adequately protected. There are many other factors that should be considered in such determinations such as (a) historic loss or gain in distribution, (b) nature of the spatial distribution, (c) immediate versus long-term risk, and (d) degree of local adaptation among populations of the biotic elements that are worthy of individual conservation consideration. Such analyses are beyond the scope of this project, but we encourage their application as well as field confirmation of the mapped distributions. As a coarse indicator of the status of the elements, gap analyses traditionally provide a breakdown along five levels of representation (<1%, 1–10%, 10–20%, 20–50%, >50%). The <1% level indicates those elements with essentially none of their distribution in a protected status while levels of 10%, 20%, and 50% have been recommended in the literature as necessary amounts of conservation (Noss and Cooperrider 1994; Noss 1991; Odum and Odum 1972; Specht et al. 1974; Ride 1975; Miller 1994).

The network of Conservation Data Centers (CDCs) and Natural Heritage Programs (NHPs) established cooperatively by The Nature Conservancy and various state agencies maintain detailed databases on the locations of rare elements of biodiversity. GAP cooperatively uses these data to develop predicted distributions of potentially suitable habitat for these elements, which may be valuable for identifying research needs and preliminary considerations for restoration or reintroduction. Conservation of such elements, however, is best accomplished through the fine-filter approach of the above organizations as described in the introduction. It is not the role of GAP to duplicate or disseminate Heritage Program or CDC Element Occurrence Records. Users interested in more specific information about the location, status, and ecology of populations of such species are directed to the ND Natural Heritage Program.

Currently, land cover types and terrestrial vertebrates are the primary focus of GAP's mapping efforts; however, other components of biodiversity, such as aquatic organisms or selected groups of invertebrates may be incorporated into GAP distributional data sets. Where appropriate, GAP data also may be analyzed to identify the location of a set of areas in which most or all land cover types or species are predicted to be represented. The use of "complementarity" analysis, which additively identifies a selection of locations that may represent biodiversity, may prove most effective for guiding biodiversity maintenance efforts than "hot spots of species richness". Several quantitative techniques have been developed recently that facilitate this process (see Pressey et al. 1993, Williams et al. 1996, Csuti et al. 1997, for details). These areas become candidates for field validation and may be incorporated into a system of areas managed for the long-term maintenance of biological diversity.

Methods

The analysis of land cover by stewardship and management status was performed using the raster properties function in the vector attributes process of MicroImage's Map and Image Processing System software. The function computes a histogram of cell values from the land cover raster for each polygon in the stewardship vector and saves the results as an attribute table attached to the vector. The attribute table was exported to SAS and the relationship of land cover to steward and management status categories summarized.

The analysis of vertebrate distributions was performed only relative to the management status categories. The stewardship vector was converted to a raster where the cells corresponding to each polygon were assigned the management status category of the polygon. The proportion of each species potential distribution in each of the four status categories was calculated from the vertebrate distribution rasters and the raster representation of the management status categories using ArcGIS software and the sprich.aml provided by GAP.

Results

Land Cover Analysis by Steward

The area of land cover categories and the proportion of land cover categories within each stewardship category are presented in Tables 5.1 and 5.2, respectively. With more than 90% of the land area in ND under private ownership, it is not surprising that all of the general land cover categories and 32 of the 39 detailed land cover categories are most abundant on private lands.

The USFS, NDSL, and USFWS manage 5.9%, 5.1%, and 1.7% of the prairie land cover category, respectively. Lands governed by the NASRS and NATAT accounted for 4.5% and 2.0% of the prairie land cover category. Nine stewards have less than 1% of the prairie land cover category on the lands they manage. Approximately 79% of the prairie land cover category occurred on private lands.

Private land owners are responsible for the stewardship of approximately 77% of the wetland land cover category. Ten percent of the wetland land cover category occurred within the open water category (i.e., large reservoirs) of the stewardship vector. The USFWS has responsibility for 5.9% of the wetland land cover category. Two percent of wetlands occur within lands governed by the NASLT and 1.5% of the wetland occurred on NDSL. Thirteen stewards individually have responsibility for less than 1 % and together 3.5% of the wetland land cover category.

Sixty-nine percent of the shrubland land cover category occurred on private lands. The USFS, NATAT, and the NDSL manage approximately 13.4%, 6.5%, and 3.5 %, respectively, of the shrubland land cover category. The BLM, FWS, NPS, ACE and NASLT each have about 1% of the shrubland land cover category on lands they manage. Stewardship responsibilities for shrublands may be distorted due to shrubland omissions related to the difficulty mapping shrublands for some portions of the state (see Chapter 2).

Seventy percent of the woodland land cover category occurs on private lands. This figure is probably an overestimate of the proportion of natural woodlands on private land since many of the woodlands in ND are planted. The USFS, NATAT, NATMC, NDGF, USFWS and ACE are stewards for 7.2%, 6.1%, 2.9%, 2.5%, 2.0% and 1.4%, respectively, of the woodland land cover category. The ACE, NDGF, and the USFWS are stewards for 4.4%, 4.2%, and 2.8 %, respectively, of the floodplain woodland land cover category.

The sparse vegetation land cover category includes the badlands topography in western ND. Approximately 28.5% of the land cover category is managed by the USFS. The NDSL, NPS, BLM and the NATAT are stewards for 3.9%, 3.7%, 3.1% and 2.5% percent of the sparsely vegetated land cover category, respectively. Fifty-one percent of the sparsely vegetated land cover category is privately managed.

Six of the 32 detailed natural and semi-natural land cover categories have more than 50% of their area occurring in stewardship categories other than private. Four of these six land cover categories (Rocky Mountain juniper, limber pine, mixed conifer/ deciduous woodlands, and sparsely vegetated badlands) have distributions restricted to western ND. The two remaining land cover categories with less than 50% of their area occurring on private lands are riverine sparse vegetation and lacustrine wetland which have their greatest abundance in the open water category of the stewardship vector.

Table 5.1. Area (sq. km) of land cover categories by land stewards.

Land Cover Category	Land Stewards[1]																	
	BLM	BOR	FWS	NPS	USDA	ACE	NASRS	NATAT	NASLT	NATMC	NASWT	NDGF	NDO	NDSL	TNC	AUD	PRIVATE	WATER	LCSUM
prairie total	**61.29**	**2.66**	**605.50**	**71.21**	**2103.38**	**145.48**	**1626.69**	**700.16**	**171.25**	**47.53**	**22.79**	**130.15**	**23.85**	**1820.06**	**31.16**	**1.68**	**28211.70**	**3.15**	**35779.70**
wet- mesic tall grass prairie		0.07	48.76		42.81	2.41	27.10		20.87	11.08	4.11	13.16	2.42	43.71	3.42		1216.15	0.03	1436.10
mesic tall grass prairie			2.13		36.74						3.30	0.62	0.20	0.93	0.28		111.87		156.06
mesic tall and mixed grass prairie	5.69	0.23	8.06	6.43	168.52	10.46	54.03	78.90		0.29		4.89	0.92	100.50	1.00		1610.18	0.60	2050.72
bluestem-needlegrass-wheatgrass prairie	0.52	0.22	213.85	0.11	44.02	26.94	65.75	4.88	65.30	9.66	9.78	22.60	4.24	231.69	6.28	1.36	5175.61	0.71	5883.51
wheatgrass prairie	19.57	0.81	72.65	15.14	485.48	29.16	586.59	132.74	18.68	6.52	3.80	19.29	6.50	472.25	7.73	0.19	6414.37	0.39	8291.86
needlegrass prairie	10.21	0.54	137.28	17.20	423.00	30.43	293.34	254.51	34.63	8.23		19.74	3.86	430.46	3.55	0.13	5725.61	0.43	7393.16
little bluestem prairie	13.71	0.30	21.16	19.27	483.24	20.19	340.01	103.44	5.66	3.34		11.68	2.17	217.60	2.42		3048.12	0.29	4292.61
fescue prairie	0.03		29.53		0.00					0.45		0.36	0.00	48.68			364.86		443.90
sand prairie	11.44	0.23	36.92	12.84	417.53	21.87	160.46	124.84	12.10	5.13	1.80	21.71	2.48	214.28	3.99		3215.36	0.47	4263.45
saline prairire	0.13	0.26	35.16	0.21	2.05	4.01	99.41	0.86	14.00	2.82		16.08	1.06	59.97	2.50		1329.58	0.23	1568.33
shrubland total	**62.84**	**0.87**	**68.13**	**69.17**	**706.37**	**68.62**	**9.04**	**344.04**	**53.47**	**2.54**	**0.03**	**34.07**	**8.04**	**184.24**	**2.76**	**1.01**	**3634.53**	**15.41**	**5265.17**
upland deciduous shrubland	13.25	0.84	66.08	47.45	414.54	50.33	8.56	309.07	50.94	1.93		27.73	5.99	139.55	2.71	1.01	3148.71	2.37	4291.07
sagebrush shrubland	48.22	0.03	0.11	21.71	291.43	10.47		34.30		0.19		1.94	1.24	43.07			443.67	0.65	897.04
lowland deciduous shrubland	1.37		1.94	0.01	0.39	7.82	0.48	0.67	2.53	0.42	0.03	4.40	0.81	1.62	0.05		42.15	12.39	77.06
woodland total	**20.79**	**0.49**	**85.05**	**44.23**	**309.86**	**59.44**	**33.51**	**261.87**	**77.20**	**125.84**	**6.39**	**107.42**	**56.07**	**78.64**	**5.25**	**0.19**	**2988.25**	**16.64**	**4277.13**
ponderosa pine woodland	0.22				2.98								0.00	0.29			6.10		9.60
limber pine woodland					0.15								0.00				0.10		0.25
rocky mountain juniper woodland	4.69	0.06	0.17	15.60	81.79	4.69		16.46		0.00		0.91	0.87	8.55			58.56	0.12	192.47
mixed conifer and deciduous woodland	8.21	0.12	0.16	12.15	116.70	10.12		95.01		0.02		2.94	2.76	16.11			183.90	0.14	448.34
floodplain woodland	1.92		19.35	9.57	10.28	30.34	8.49	2.68	1.82	0.21	0.89	28.53	3.77	3.94	4.54		542.38	15.95	684.65
deciduous woodland	2.07	0.08	41.00	1.38	35.25	8.28	17.09	49.55	21.55	6.29	5.51	30.19	6.95	18.37	0.64	0.18	1356.35	0.35	1601.09
green ash woodland	3.67	0.23	1.08	5.54	62.70	4.71	0.38	98.16	2.16	0.18		4.17	1.01	12.61	0.00	0.00	300.87	0.06	497.52
aspen woodland			10.86			0.18	2.55		8.73	37.74		19.35	7.18	6.19	0.04		197.67	0.00	290.49
bur oak woodland			5.93			0.97	1.75		35.10	20.23		9.38	6.64	3.66	0.01	0.00	151.80	0.01	235.49
aspen and bur oak woodland			6.50			0.16	3.25		7.85	61.17		11.96	26.88	8.93	0.01		190.53	0.01	317.24
wetlands total	**3.30**	**4.84**	**954.95**	**5.71**	**88.27**	**82.31**	**56.86**	**98.74**	**323.21**	**42.55**	**27.82**	**136.41**	**14.24**	**239.29**	**10.57**	**1.00**	**12327.77**	**1640.83**	**16058.68**
Lacustrine wetlands	0.22	3.54	371.95	0.01	0.07	45.03	1.35	9.49	198.65	8.87	0.55	49.81	3.36	29.42	1.86	0.31	1106.51	1614.64	3445.63
Riverine wetlands	0.90	0.03	6.77	5.01	13.72	1.65	8.80	0.87	1.07	0.10	0.59	2.36	0.70	7.81	0.30		383.82	3.18	437.68
Paustrine temporary wetland	1.14	0.05	66.38	0.23	41.34	3.57	16.87	39.10	25.98	0.98	6.30	15.86	0.51	49.11	1.78	0.13	2814.95	1.49	3085.78
Palustrine seasonal wetland	0.40	0.36	91.08	0.02	24.77	6.64	21.76	41.43	38.77	18.13	6.90	18.09	6.14	83.16	2.51	0.16	4799.49	1.67	5161.48
Palustrine semipermanent wetland	0.30	0.08	357.51	0.02	4.34	13.17	7.38	7.39	34.87	13.92	10.81	41.21	3.20	54.32	2.92	0.18	2238.80	2.35	2792.75
water	0.35	0.78	61.26	0.42	4.04	12.25	0.68	0.46	23.86	0.54	2.67	9.08	0.33	15.48	1.21	0.22	984.20	17.51	1135.35
sparse vegetation total	**58.60**	**0.18**	**1.59**	**68.42**	**532.98**	**27.14**	**24.05**	**46.19**	**0.00**	**0.37**	**0.00**	**11.94**	**2.51**	**72.19**	**0.34**	**0.00**	**946.31**	**80.01**	**1872.81**
sparse vegetation - others	0.25	0.14	1.49	0.09	0.06	2.47	5.08	0.87		0.15		2.68	0.15	3.21	0.34		290.46	1.03	308.47
sparse vegetation - badlands	58.35	0.04	0.10	68.33	532.90	16.76	18.96	44.56		0.21		3.32	2.33	68.97			653.53	1.29	1469.65
sparse vegetation - riverine	0.00			0.00	0.02	7.91		0.76				5.94	0.03	0.01			2.32	77.70	94.69
cropland	4.23	0.90	162.91	8.50	117.45	32.80	342.46	1339.82	360.62	35.48	150.24	74.56	12.24	128.17	1.62	1.88	85431.76	2.62	88208.26
planted perrenial herbaceous cover	23.31	3.25	391.53	24.84	574.42	89.67	584.93	360.49	191.45	44.93	41.13	143.90	21.75	368.07	16.65	2.83	27635.23	6.08	30524.47
high intensity residental			0.10	0.00	0.01	1.58	0.51	0.74	0.17	0.20		0.00	0.07	0.03			85.87	0.02	89.28
low intensity residental	0.00		0.63	0.08	0.47	4.52	1.14	2.54	1.05	1.10		0.05	0.80	0.10			266.70	0.23	279.39
commercial/industrial/transportation	0.00	0.32	10.84	1.12	3.37	9.33	0.92	3.54	2.10	9.36	0.15	1.62	0.58	2.10	0.28	0.01	429.40	0.37	475.41
urban grasslands		0.67	0.18		0.02	17.32	0.01	1.10	0.03			0.04	0.04	0.10			88.87	0.10	108.47
STEWARD SUM	234.37	14.17	2281.41	293.28	4436.60	538.21	2680.10	3159.24	1180.54	309.89	248.56	640.16	140.19	2893.00	68.64	8.60	162046.38	1765.46	182938.77

[1]BLM-Bureau of Land Management, BOR-Bureau of Reclamation, FWS-U.S. Fish and Wildlife Service, NPS-National Park Service, ACE-Army Corps of Engineers, NASRS-Native American Standing Rock Sioux, NATAT-Native American Three Affiliated Tribes, NASLT-Native American Spirit Lake Tribe, NATMC-Native American Turtle Mountain Chippewa, NASWT-Native American Sisseton-Wahpeton Sioux Tribe, NDGF-North Dakota Game and Fish, ND0-Other ND state government agencies, NDSL-North Dakota School Lands, TNC-The Nature Conservancy, AUD-The Audubon Society, PRIVATE-private land owners, WATER-large water bodies included in the stewardship vector, LCSUM-sum of the area of the land cover category across stewards.

Table 5.2. Percent of land cover categories by land stewards.

	Land Stewards[1]																	
Land Cover Category	BLM	BOR	FWS	NPS	USDA	ACE	NASRS	NATAT	NASLT	NATMC	NASWT	NDGF	NDO	NDSL	TNC	AUD	PRIVATE	WATER
prairie total	**0.2**	**0.0**	**1.7**	**0.2**	**5.9**	**0.4**	**4.5**	**2.0**	**0.5**	**0.1**	**0.1**	**0.4**	**0.1**	**5.1**	**0.1**	**0.0**	**78.8**	**0.0**
wet- mesic tall grass prairie		0.0	3.4		3.0	0.2	1.9		1.5	0.8	0.3	0.9	0.2	3.0	0.2		84.7	0.0
mesic tall grass prairie			1.4		23.5						2.1	0.4	0.1	0.6	0.2		71.7	
mesic tall and mixed grass prairie	0.3	0.0	0.4	0.3	8.2	0.5	2.6	3.8		0.0		0.2	0.0	4.9	0.0		78.5	0.0
bluestem-needlegrass-wheatgrass prairie	0.0	0.0	3.6	0.0	0.7	0.5	1.1	0.1	1.1	0.2	0.2	0.4	0.1	3.9	0.1	0.0	88.0	0.0
wheatgrass prairie	0.2	0.0	0.9	0.2	5.9	0.4	7.1	1.6	0.2	0.1	0.0	0.2	0.1	5.7	0.1	0.0	77.4	0.0
needlegrass prairie	0.1	0.0	1.9	0.2	5.7	0.4	4.0	3.4	0.5	0.1		0.3	0.1	5.8	0.0	0.0	77.4	0.0
little bluestem prairie	0.3	0.0	0.5	0.4	11.3	0.5	7.9	2.4	0.1	0.1		0.3	0.1	5.1	0.1		71.0	0.0
fescue prairie	0.0		6.7							0.1		0.1		11.0			82.2	
sand prairie	0.3	0.0	0.9	0.3	9.8	0.5	3.8	2.9	0.3	0.1	0.0	0.5	0.1	5.0	0.1		75.4	0.0
saline prairire	0.0	0.0	2.2	0.0	0.1	0.3	6.3	0.1	0.9	0.2		1.0	0.1	3.8	0.2		84.8	0.0
shrubland total	**1.2**	**0.0**	**1.3**	**1.3**	**13.4**	**1.3**	**0.2**	**6.5**	**1.0**	**0.0**	**0.0**	**0.6**	**0.2**	**3.5**	**0.1**	**0.0**	**69.0**	**0.3**
upland deciduous shrubland	0.3	0.0	1.5	1.1	9.7	1.2	0.2	7.2	1.2	0.0		0.6	0.1	3.3	0.1	0.0	73.4	0.1
sagebrush shrubland	5.4	0.0	0.0	2.4	32.5	1.2		3.8		0.0		0.2	0.1	4.8			49.5	0.1
lowland deciduous shrubland	1.8		2.5	0.0	0.5	10.1	0.6	0.9	3.3	0.5	0.0	5.7	1.0	2.1	0.1		54.7	16.1
woodland total	**0.5**	**0.0**	**2.0**	**1.0**	**7.2**	**1.4**	**0.8**	**6.1**	**1.8**	**2.9**	**0.1**	**2.5**	**1.3**	**1.8**	**0.1**	**0.0**	**69.9**	**0.4**
ponderosa pine woodland	2.3				31.1									3.0			63.5	
limber pine woodland					60.2												39.8	
rocky mountain juniper woodland	2.4	0.0	0.1	8.1	42.5	2.4		8.6		0.0		0.5	0.5	4.4			30.4	0.1
mixed conifer and deciduous woodland	1.8	0.0	0.0	2.7	26.0	2.3		21.2		0.0		0.7	0.6	3.6			41.0	0.0
floodplain woodland	0.3		2.8	1.4	1.5	4.4	1.2	0.4	0.3	0.0	0.1	4.2	0.6	0.6	0.7		79.2	2.3
deciduous woodland	0.1	0.0	2.6	0.1	2.2	0.5	1.1	3.1	1.3	0.4	0.3	1.9	0.4	1.1	0.0	0.0	84.7	0.0
green ash woodland	0.7	0.0	0.2	1.1	12.6	0.9	0.1	19.7	0.4	0.0		0.8	0.2	2.5	0.0	0.0	60.5	0.0
aspen woodland			3.7			0.1	0.9		3.0	13.0		6.7	2.5	2.1	0.0		68.0	0.0
bur oak woodland			2.5			0.4	0.7		14.9	8.6		4.0	2.8	1.6	0.0	0.0	64.5	0.0
aspen and bur oak woodland			2.0			0.0	1.0		2.5	19.3		3.8	8.5	2.8	0.0		60.1	0.0
wetlands total	**0.0**	**0.0**	**5.9**	**0.0**	**0.5**	**0.5**	**0.4**	**0.6**	**2.0**	**0.3**	**0.2**	**0.8**	**0.1**	**1.5**	**0.1**	**0.0**	**76.8**	**10.2**
Lacustrine wetlands	0.0	0.1	10.8	0.0	0.0	1.3	0.0	0.3	5.8	0.3	0.0	1.4	0.1	0.9	0.1	0.0	32.1	46.9
Riverine wetlands	0.2	0.0	1.5	1.1	3.1	0.4	2.0	0.2	0.2	0.0	0.1	0.5	0.2	1.8	0.1		87.7	0.7
Paustrine temporary wetland	0.0	0.0	2.2	0.0	1.3	0.1	0.5	1.3	0.8	0.0	0.2	0.5	0.0	1.6	0.1	0.0	91.2	0.0
Palustrine seasonal wetland	0.0	0.0	1.8	0.0	0.5	0.1	0.4	0.8	0.8	0.4	0.1	0.4	0.1	1.6	0.0	0.0	93.0	0.0
Palustrine semipermanent wetland	0.0	0.0	12.8	0.0	0.2	0.5	0.3	0.3	1.2	0.5	0.4	1.5	0.1	1.9	0.1	0.0	80.2	0.1
water	0.0	0.1	5.4	0.0	0.4	1.1	0.1	0.0	2.1	0.0	0.2	0.8	0.0	1.4	0.1	0.0	86.7	1.5
sparse vegetation total	**3.1**	**0.0**	**0.1**	**3.7**	**28.5**	**1.4**	**1.3**	**2.5**		**0.0**		**0.6**	**0.1**	**3.9**	**0.0**		**50.5**	**4.3**
sparse vegetation - others	0.1	0.0	0.5	0.0	0.0	0.8	1.6	0.3		0.1		0.9	0.0	1.0	0.1		94.2	0.3
sparse vegetation - badlands	4.0	0.0	0.0	4.6	36.3	1.1	1.3	3.0		0.0		0.2	0.2	4.7			44.5	0.1
sparse vegetation - riverine	0.0			0.0	0.0	8.4		0.8				6.3	0.0	0.0			2.5	82.1
cropland	0.0	0.0	0.2	0.0	0.1	0.0	0.4	1.5	0.4	0.0	0.2	0.1	0.0	0.1	0.0	0.0	96.9	0.0
planted perrenial herbaceous cover	0.1	0.0	1.3	0.1	1.9	0.3	1.9	1.2	0.6	0.1	0.1	0.5	0.1	1.2	0.1	0.0	90.5	0.0
high intensity residental			0.1	0.0	0.0	1.8	0.6	0.8	0.2	0.2		0.0	0.1	0.0			96.2	0.0
low intensity residental	0.0		0.2	0.0	0.2	1.6	0.4	0.9	0.4	0.4		0.0	0.3	0.0			95.5	0.1
commercial/industrial/transportation	0.0	0.1	2.3	0.2	0.7	2.0	0.2	0.7	0.4	2.0	0.0	0.3	0.1	0.4	0.1	0.0	90.3	0.1
urban grasslands		0.6	0.2		0.0	16.0	0.0	1.0	0.0			0.0	0.0	0.1			81.9	0.1

[1]See Table 5.1 for acronyms.

Careful inspection of the data in Tables 5.1 and 5.2 by an observer familiar with the vegetation of ND will reveal limitations of the land cover map (see Chapter 2). An example is the omission of aspen, bur oak and aspen-bur oak woodlands on lands managed by the BLM, USFS, NPS, and NATAT in western ND. As explained in the land cover chapter, these woodland land cover categories were not individually mapped for path 34 rows 26, 27 or 28 due to spectral confusion among the forest types and the small amount of training data available for these types. These woodland land cover categories are combined into a single generic deciduous woodland land cover category for that portion of the land cover map. We observed stands of aspen and bur oak woodlands on lands managed by the USFS and the NATAT during collection of data for the accuracy assessment of the land cover map and aspen woodlands have been mapped for Theodore Roosevelt National Park (Von Loh et al. 2002).

Land Cover Analysis by Management Status Categories

Five of the 32 detailed natural and semi-natural land cover categories have more than 10% of their total area on lands classified as status 1 or 2 (Table 5.3). Sixty percent of the limber pine woodlands in ND are managed as a special interest area by the USFS. Twenty-three percent of the area mapped as ponderosa pine woodland occurs on Research Natural Areas or Special Interest Areas managed by the USFS. Twenty-four percent of the area mapped as mesic tall grass prairie occurs on lands classified as status 1 or 2 with the USFS Sheyene National Grassland, the USFWS, and the TNC responsible for 95%, 4%, and 1% of these lands, respectively. Fourteen percent of the area mapped as Rocky Mountain juniper occurs on lands classified as status 1 or 2 with the NPS and USFS having responsibly for 60% and 39% of these lands, respectively. Twelve percent of lacustrine wetlands occur on lands classified as status 1 and 2 with the USFWS responsible for more than 99% of these wetlands.

Four natural vegetation land cover categories have more than 5% but less than 10% of their area on lands classified as status 1 or 2. These four land cover categories include fescue prairie, mixed conifer/deciduous woodland, palustrine semipermanent wetland, and sparse vegetation-badlands. Twenty natural vegetation land cover categories have more than 1% but less than 5% of their area on lands classified as status 1 or 2. Only one natural vegetation land cover category, saline prairie, has less than 1% of its area (0.9%) on lands classified as status 1 and 2. The table indicates small amounts of cropland, planted perennial herbaceous vegetation, and transportation land cover categories on lands classified as status 1 and 2. Most of these areas are errors in the land cover map. For example, areas mapped as cropland within Theodore Roosevelt National Park are actually prairie dog towns or sparsely vegetated badlands.

Table 5.3 Area (sq. km) and percent of land cover categories by four management status categories.										
Land cover category	Status 1		Status 2		Percent in status 1 + 2	Status 3		Status 4		Total area km^2
	km^2	%	km^2	%		km^2	%	km^2	%	
prairie	**96.53**	**0.3**	**638.71**	**1.8**	**2.1**	**2419.21**	**6.8**	**32625.25**	**91.2**	**35779.70**
wet-mesic tall grass prairie	1.59	0.1	66.80	4.7	4.8	44.61	3.1	1323.11	92.1	1436.10
mesic tall grass prairie	0.75	0.5	36.76	23.6	24.0	2.46	1.6	116.09	74.4	156.06
mesic tall and mixed grass prairie	8.14	0.4	14.08	0.7	1.1	183.81	9.0	1844.69	90.0	2050.72
bluestem-needlegrass-wheatgrass prairie	1.74	0.0	144.79	2.5	2.5	157.09	2.7	5579.89	94.8	5883.51
wheatgrass prairie	20.73	0.3	83.72	1.0	1.3	551.46	6.7	7635.94	92.1	8291.86
needlegrass prairie	21.01	0.3	123.05	1.7	1.9	496.91	6.7	6752.18	91.3	7393.16
little bluestem prairie	23.20	0.5	40.95	1.0	1.5	510.21	11.9	3718.24	86.6	4292.61
fescue prairie		0.0	23.87	5.4	5.4	6.04	1.4	413.99	93.3	443.90
sand prairie	18.73	0.4	91.08	2.1	2.6	419.41	9.8	3734.23	87.6	4263.45
saline prairie	0.64	0.0	13.61	0.9	0.9	47.21	3.0	1506.88	96.1	1568.33
shrubland	**84.58**	**1.6**	**59.59**	**1.1**	**2.7**	**874.38**	**16.7**	**4246.62**	**80.7**	**5265.17**
upland deciduous shrubland	57.63	1.3	42.90	1.0	2.3	525.97	12.3	3664.56	85.4	4291.07
sagebrush shrubland	26.87	3.0	15.86	1.8	4.8	332.56	37.1	521.74	58.2	897.04
lowland deciduous shrubland	0.07	0.1	0.83	1.3	1.4	15.84	24.5	60.31	78.3	77.06
woodland	**63.81**	**1.5**	**94.89**	**2.2**	**3.7**	**529.20**	**12.4**	**3589.23**	**83.9**	**4277.13**
ponderosa pine woodland	2.17	22.6	0.01	0.1	22.7	1.03	10.7	6.39	66.6	9.60
limber pine woodland	0.15	60.2		0.0	60.2		0.0	0.10	39.8	0.25
rocky mountain juniper woodland	21.09	11.0	4.89	2.5	13.5	82.84	43.1	83.65	43.5	192.47
Mixed conifer and deciduous woodland	19.03	4.2	6.75	1.5	5.8	127.53	28.5	295.02	65.8	448.34
floodplain woodland	10.29	1.5	18.85	2.8	4.4	79.29	11.9	576.22	84.2	684.65
green ash woodland	7.35	1.5	3.65	0.7	2.2	72.12	14.5	414.69	83.3	497.81
deciduous woodland	3.63	0.2	44.55	2.8	3.0	77.08	4.8	1475.53	92.2	1600.80
aspen woodland	0.01	0.0	8.29	2.9	2.9	29.31	10.1	252.88	87.1	290.49
bur oak woodland	0.09	0.0	4.55	1.9	2.0	17.84	7.6	213.01	90.5	235.49
aspen and bur oak woodland		0.0	3.34	1.1	1.1	42.16	13.3	271.74	85.7	317.24
wetlands	**9.44**	**0.1**	**508.08**	**3.5**	**3.6**	**777.79**	**5.4**	**14763.37**	**91.9**	**16058.68**
lacustrine wetlands	0.01	0.0	217.64	11.9	11.9	257.14	14.0	2970.84	86.2	3445.63
riverine wetlands	4.86	1.1	5.96	1.4	2.5	20.61	4.7	406.24	92.8	437.68
palustrine temporary wetland	2.26	0.1	59.31	1.9	2.0	68.16	2.2	2956.05	95.8	3085.78
palustrine seasonal wetland	1.55	0.0	53.65	1.0	1.1	93.57	1.8	5012.71	97.1	5161.48
palustrine semipermanent wetland	0.05	0.0	147.19	5.3	5.3	273.77	9.8	2371.75	84.9	2792.75
water	0.71	0.1	24.33	2.2	2.2	64.54	5.8	1045.77	92.1	1135.35
sparse vegetation	**86.74**	**4.8**	**23.95**	**1.3**	**6.2**	**593.17**	**33.1**	**1168.95**	**62.4**	**1872.81**
sparse vegetation - others	0.00	0.0	0.31	0.1	0.1	7.36	2.4	300.80	97.5	308.47
sparse vegetation - badlands	86.74	5.9	23.64	1.6	7.5	571.87	38.9	787.41	53.6	1469.65
sparse vegetation - riverine		0.0		0.0	0.0	13.95	82.1	80.74	85.3	94.69
cropland	8.92	0.0	46.39	0.1	0.1	353.41	0.4	87799.54	99.5	88208.26
planted perrenial herbaceous cover	30.23	0.1	180.99	0.6	0.7	1072.63	3.5	29240.62	95.8	30524.47
high intensity residental	0.00	0.0	0.01	0.0	0.0	0.23	0.3	89.04	99.7	89.28
low intensity residental	0.08	0.0	0.07	0.0	0.1	3.17	1.1	276.07	98.8	279.39
commercial/industrial/transportati	0.89	0.2	7.66	1.6	1.8	11.04	2.3	455.83	95.9	475.41
urban grasslands		0.0	0.04	0.0	0.0	0.99	0.9	107.44	99.1	108.47
										182938.77

Vertebrate Distribution Analysis by Management Status Categories

A summary table is not provided due to the large number of species analyzed, but some generalizations and examples of species results by the various thresholds discussed in the chapter introduction are provided below. The complete vertebrate species distribution analysis table in Appendix 5.1 provides the area in hectares of the species' mapped distribution by status category, and the percent of the species' total distribution in each category. For example, the Burrowing Owl has 54,892 ha of potential habitat in lands that are ranked Status 1 or Status 2, which represents 1.7 % of that species' potential distribution.

Species with <1% of potential distribution in status 1 or 2 lands: 62 species total; 1 amphibian, 37 birds, 21 mammals, 3 reptiles. – Some of these are common species, e.g., sharp-tailed grouse, killdeer, white-tailed deer, coyote, red fox, and plains garter snake, which have large ranges and use a variety of habitats. The low percent of protected habitats is a reflection of the high percentage of ND that is privately owned. Other species such as McCown's longspur, Nashville warbler, purple finch, Ord's kangaroo rat, hispid pocket mouse, and eastern spotted skunk are near the edge of their range in ND. The false map turtle and midland smooth softshell turtle have distributions limited to the lower Missouri River in ND. None of their predicted habitat is protected in status 1 and 2 lands but 15–20% of their predicted distribution is in lands classified as status 3. These species may be negatively affected by unnatural stream flows since the creation of dams on the river. Five species, Franklin's gull, chestnut-collared longspur, grasshopper sparrow, Swainson's hawk, and lark bunting are members of a list of 25 species identified by the ND Game and Fish Department as having a high level of conservation priority.

Species with 1-5% of potential distribution in status 1 or 2 lands: 194 species total; 10 amphibians, 128 birds, 47 mammals, 9 reptiles. – This range of protection status includes 67% of the breeding terrestrial vertebrates in ND. Forty-three of these species were identified as having high (n=19) and moderate (n=24) levels of conservation concern by the ND Game and Fish Department. Particularly notable among these is the least tern, an endangered species, with 2.3% of its predicted habitat in status 1 or 2 lands.

Species with 5-10% of potential distribution in status 1 or 2 lands: 22 species total; 17 birds, 3 mammals, 2 reptiles. – Many of the bird species are associated with lacustrine and semi-permanent wetlands (e.g., American white pelican, pied-billed grebe, canvasback) or with woody borders of wetlands (e.g., northern waterthrush, belted kingfisher) that are well represented on National Wildlife Refuges. The long-eared myotis, Nutalls's cottontail, and bushy-tailed woodrat, and northern sagebrush lizard have distributions limited to western ND where the largest amount of public lands in status 1 and 2 occur. The common snapping turtle is associated with lacustrine and semi-permanent wetlands.

Species with l0%-20% of potential distribution in status 1 or 2 lands: 1 species total; 1 bird species. – The bufflehead is a small cavity-nesting duck associated with lacustrine and semi-permanent wetlands that are well represented on National Wildlife Refuges within its limited breeding distribution in ND.

Species with 20% -<50% of potential distribution in status 1 or 2 lands: 2 species total; 1 bird, 1 reptile. – The red-breasted nuthatch is a rare and irregular species in ND associated with ponderosa pine woodlands a portion of which are managed as a Research Natural Area by the USFS. The northern prairie skink is associated with sandy areas in the eastern one-third of ND which includes Research Natural Areas in the Sheyene National Grasslands.

Species with at least 50% of potential distribution in status 1 and 2 lands: None

Species of Concern in ND

The US Fish and Wildlife Service have listed 23 vertebrate species that occur in ND as candidate, threatened or endangered species.

Birds

- Least Tern (*Sterna antillarum*)
- Bald Eagle (*Haliaeetus leucocephalus*)
- Whooping Crane (*Grus americana*)
- Peregrine Falcon (*Falco peregrinus anatum*)
- Piping Plover (*Charadrius melodus*)
- Western Burrowing Owl (*Athene cunicularia hypugea*)
- Black Tern (*Chlidonias niger*)
- Baird's Sparrow (*Ammodramus bairdii*)
- Northern Goshawk (*Accipiter gentilis*)
- Loggerhead Shrike (*Lanius ludovicianus*)
- Ferruginous Hawk (*Buteo regalis*)

Reptiles

- False Map Turtle (*Graptemys pseudogeographica pseudogeographica*)
- Eastern Short-Horned Lizard (*Phrynosoma douglassii brevirostra*)
- Northern Sagebrush Lizard (*Sceloporus graciosus graciosus*)

Mammals

- Black-Footed Ferret (*Mustela nigripes*) (currently extirpated)
- Gray Wolf (*Canis lupus*) (currently extirpated but transient)
- Swift Fox (*Vulpes velox*) (currently extirpated)
- Lynx (*Felis lynx*) (currently extirpated but transient)
- Wolverine (*Gulo gulo*) (currently extirpated)
- Pale Townsend's Big-Eared Bat (*Plecotus townsendii pallescens*)
- Long-Eared Myotis (*Myotis evotis*)
- Long-Legged Myotis (*Myotis volans*)
- Small-Footed Myotis (*Myotis ciliolabrum*)

The ND Game and Fish Department recently compiled a list of 100 species of concern (Dyke et al. 2004). Twenty-five terrestrial vertebrate species were listed as having a high level of conservation priority because of declining status either in ND or across their range, or because ND constituted the core of the species' breeding range and non-State Wildlife Grant funding is not readily available for them.

Birds

Horned Grebe (*Podicips auritus*)
American White Pelican (*Pelecanus erythrorhynchos*)
American Bittern (*Botaurus lentiginosus*)
Swainson's Hawk (*Buteo swainsoni*)
Ferruginous Hawk (*Buteo regalis*)
Yellow Rail (*Coturnicops noveboracensis*)
Willet (*Catoptrophorus semipalmatus*)
Upland Sandpiper (*Bartramia longicauda*)
Long-Billed Curlew (*Numenius americanus*)
Marbled Godwit (*Limosa fedoa*)
Wilson's Phalarope (*Phalaropus tricolor*)
Franklin's Gull (*Larus pipixcan*)
Black Tern (*Chlidonias niger*)
Black-Billed Cuckoo (*Coccyzus erythrophalmus*)
Sprague's Pipit (*Anthus spragueii*)
Grasshopper Sparrow (*Ammodramus savannarum*)
Baird's Sparrow (*Ammodramus bairdii*)
Nelson's Sharp-Tailed Sparrow (*Ammodramus nelsoni*)
Lark Bunting (*Calamospiza melanocorys*)
Chesnut-Collared Longspur (*Calcarius ornatus*)

Herptiles

Canadian Toad (*Bufo hemiophrys*)
Plains Spadefoot Toad (*Scaphiopus bombifrons*)
Smooth Green Snake (*Opheodrys vernalis*)
Western Hognose Snake (*Heterodon nasicus*)

Mammals

Black-Tailed Prairie Dog (*Cynomys ludovicianus*)

Limitations and Discussion

A basic assumption of the analysis is that processes important to species, community, and ecosystem representation and persistence are correlated in a predictable way with status rankings. This assumption is untested. Some of the areas assigned to status 1 and 2 have small spatial extents and the full complement of ecosystem processes may not occur naturally in these areas. The analysis based on stewardship and management status did not consider the connectedness and juxtaposition of stewardship lands.

We were not able to include digital data for the distribution and spatial extent of private land easements in the stewardship vector. Thus, the analysis does not include the contribution of private land easements to the conservation of natural land cover categories and vertebrate species.

From a more technical perspective, it is critical that the following limitations are considered when using the results of our analyses: 1) the limitations described for each of the component parts (land cover mapping, animal species mapping, stewardship mapping) of the analyses, 2) the spatial accuracy and thematic accuracy of the components, and 3) the suitability of the results for the intended application (see Product Use and Availability Chapter). Refer to Chapters 2, 3, and 4 and the Limitations and Discussions sections of those Chapters for more information.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

On the 200th anniversary of the Lewis and Clark Expedition, there is no place in the Northern Great Plains where one can see the vast herbivore concentrations and associated carnivores described in the stories of Native Americans or the writing of Lewis and Clark and other early explorers. In ND, most of the natural prairie has been converted to cropland, tens of thousand of wetlands have been drained and farmed, and magnificent stands of floodplain forest along the Missouri and other rivers have been greatly reduced by water development projects and agriculture. Natural ecological processes have been greatly modified or eliminated by changes in the configuration of the landscape and the composition of the biota. The disruption of natural ecological processes is so great that temperate prairies may be North America's most endangered biome.

The conservation of biodiversity in the Northern Great Plains is a huge challenge both scientifically and socially (Johnson et al. 1994, Sieg et al. 1999). At a minimum, the challenge is to preserve and manage the small amount of remaining natural land cover and to sustain viable populations of the remaining endemic and native species while critical resources for their survival fluctuate in response to climatic, ecological, social, and economic forces. The evolution of prairie ecosystems took place under climates with periodic droughts, herbivory, and fire that resulted in spatial and temporal variability in the relative importance of limiting factors such as water, nutrients, and light. This dynamic environment forms the template for a complex web of biological interactions including competition, predation and mutualism. Ultimately the biodiversity of prairie ecosystems depends on the continued operation of these ecological processes at many temporal, spatial, and organizational scales (Huston 1994).

A strategy for conservation of biodiversity requires decisions of what is to be sustained, at what level, for how long, by whom, and for whom (Moir and Mowrer 1994). Before biodiversity conservation strategies can succeed, clear quantifiable objectives must be defined and evaluation methods developed (Johnson et al. 1994). The geospatial datasets for actual land cover, potential vertebrate species distributions, and land stewardship created by the ND-GAP provide an excellent starting point for land managers, planners, scientists, and policy makers to develop proactive habitat-based conservation plans. Conservation plans that take into consideration the overlapping habitat requirements of multiple species within functional communities and ecosystems (i.e., consideration of ecological and evolutionary processes) are a logical step towards the conservation of biodiversity given our incomplete knowledge of the subject (Noss et al. 1997). The geospatial framework should facilitate coordination of disparate habitat conservation efforts to affect unified, comprehensive conservation actions to reduce the impacts of the myriad of anthropogenic threats that fragment habitats.

Area requirements and habitat fragmentation effects are poorly understood for grassland bird species (Johnson 2001; Johnson and Igl 2001) and largely unknown for other less-studied animal and plant species in the Northern Great Plains (Sovada et al 2000). Wildlife investigations of lands enrolled in the Conservation Reserve Program have demonstrated the importance of matrix habitat quality, landscape composition, and landscape configuration for waterfowl and grassland birds (Johnson 2000, Reynolds et al. 2001). There are no simple answers to the design of landscape configurations for biodiversity conservation. Approaches that scale species attributes (e.g., area requirements, dispersal ability, resource acquisition strategies) to realistic landscape representations (e.g., multiple land cover categories with temporal and spatial variation in habitat quality) will be needed (Lambeck 1997, Vos et al. 2001, Jonzen et al. 2004, Wiegand et al. 2005).

Most of the remaining natural land cover in ND exists as relatively small, isolated patches. The State of North Dakota manages 1.29 km^2 of lands as research biological areas (protection status 1), 785 km^2 as wildlife management areas, state parks and forests (protection status 3) and 2905 km^2 of school lands (protection status 4). The Federal Government manages 1888 km^2 as wilderness areas, national parks, national wildlife refuges, waterfowl production areas, research natural areas, and tallgrass prairie restoration areas (protection status 1 or 2), and 5918 km^2 as multiple use lands (status 3). Non-Profit Conservation organizations manage 59.58 km^2 as nature preserves (protection status 1 or 2) and 18 km^2 (protection status 3).

With more than 90% of ND in private ownership, a major challenge facing biodiversity conservation is learning how to achieve desired goals compatible with and supported by local residents and private landowners (Clark 1996). Developing actions that foster a healthy environment and a healthy economy will be critical to success. A growing body of literature demonstrates there is not a trade-off of environmental amenities and economic development and in fact environmental amenities play a significant role in people's decision to move and establish businesses in an area. A lack of natural amenities that support recreation and eco-tourism corresponded to rapid loss of population from rural counties in the United States during 1970-2000 (McGanahan and Beale 2002, McGranahan 1999). Studies also have found that communities located near natural areas have healthier economies than communities that are not so located (Rudzitis and Johansen 1991, Rasker and Hackman 1996). Natural areas generate economic activity by attracting and retaining residents including business owners and retirees who want to be located near natural areas for recreation and attracting tourists and recreationists. In some high-amenity areas, growth has been so rapid that the challenge is not economic development but growth management (Theobald 2001).

Success in biodiversity conservation and restoration will depend upon the skilled presentation of conservation opportunities. Positive incentives, local leadership, and public participation are important characteristics for successful conservation programs (Anonymous 2001). The private sector can be drawn to habitat-based conservation planning by stream-lined regulations and providing a clear picture of future obligations

(Noss et al. 1997). By fulfilling the needs of many species at once, habitat-based conservation planning may keep some species off the endangered species list.

PRODUCT USE AND AVAILABILITY

How to Obtain the Products

It is the goal of the Gap Analysis Program and the USGS Biological Resources Division (BRD) to make the data and associated information as widely available as possible. Use of the data requires specialized software called geographic information systems (GIS) and substantial computing power. Additional information on how to use the data or obtain GIS services is provided below and on the GAP home page (URL below). While a CD-ROM of the data will be the most convenient way to obtain the data, it may also be downloaded via the Internet from the national GAP home page at:

http://www.gap.uidaho.edu/

The home page will also provide, over the long term, the status of our state's project, future updates, data availability, and contacts. Within a few months of this project's completion, CD-ROMs of the final report and data should be available at a nominal cost--the above home page will provide ordering information. To find information on the ND-GAP project's status and data, follow the links to "Current Projects" and then to the particular state of interest.

Disclaimer

Following is the official Biological Resources Division (BRD) disclaimer as of 29 January 1996, followed by additional disclaimers from GAP. Prior to using the data, you should consult the GAP home page (see How to Obtain the Products, above) for the current disclaimer.

Although these data have been processed successfully on a computer system at the BRD, no warranty expressed or implied is made regarding the accuracy or utility of the data on any other system or for general or scientific purposes, nor shall the act of distribution constitute any such warranty. This disclaimer applies both to individual use of the data and aggregate use with other data. It is strongly recommended that these data are directly acquired from a BRD server [see above for approved data providers] and not indirectly through other sources which may have changed the data in some way. It is also strongly recommended that careful attention be paid to the content of the metadata file associated with these data. The Biological Resources Division shall not be held liable for improper or incorrect use of the data described and/or contained herein.

These data were compiled with regard to the following standards. Please be aware of the limitations of the data. These data are meant to be used at a scale of 1:100,000 or smaller (such as 1:250,000 or 1:500,000) for the purpose of assessing the conservation status of animals and vegetation types over large geographic regions. The data may or may not have been assessed for statistical accuracy. Data evaluation and improvement may be ongoing. The Biological Resources Division makes no claim as to the data's suitability for other purposes. This is writable data which may have been altered from the original product if not obtained from a designated data distributor identified above.

Minimum GIS System Required for Data Use

The land cover and vertebrate species predicted habitats are in ArcGIS GRID format. All other GIS data are in ArcGIS vector format. These data may be successfully used with ESRI ArcGIS 8.x or other software that can import these formats.

Metadata

Proper documentation of information sources and processes used to assemble GAP data layers is central to the successful application of GAP data. Metadata documents the legacy of the data for new users. The Federal Geographic Data Committee (FGDC 1994, 1995) has published standards for metadata and NBII (<http://www.nbii.gov>) has updated those standards to include biological profiles. Executive Order 12906 requires that any spatial data sets generated with federal dollars will have FGDC-compliant metadata. Each spatial data layer provided is accompanied by its metadata.

Appropriate and Inappropriate Use of These Data

All information is created with a specific end use or uses in mind. This is especially true for GIS data, which is expensive to produce and must be directed to meet the immediate program needs. For GAP, minimum standards were set (see A Handbook for Gap Analysis, Scott et al. 1993) to meet program objectives. These standards include: scale or resolution (1:100,000 or 100 hectare minimum mapping unit), accuracy (80% accurate at 95% confidence), and format (ARC/INFO coverage tiled to the 30' x 60' USGS quadrangle).

Recognizing, however, that GAP would be the first, and for many years likely the only, source of statewide biological GIS maps, the data were created with the expectation that they would be used for other applications. Therefore, we list below both appropriate and inappropriate uses. This list is in no way exhaustive but should serve as a guide to assess whether a proposed use can or cannot be supported by GAP data. For most uses, it is unlikely that GAP will provide the only data needed, and for uses with a regulatory outcome, field surveys should verify the result. In the end, it will be the responsibility of each data user to determine if GAP data can answer the question being asked, and if they are the best tool to answer that question.

<u>Scale:</u> First we must address the issue of appropriate scale to which these data may be applied. The data were produced with an intended application at the ecoregion level, that

is, geographic areas from several hundred thousand to millions of hectares in size. The data provide a coarse-filter approach to analysis, meaning that not every occurrence of every plant community or animal species habitat is mapped, only larger, more generalized distributions. The data are also based on the USGS 1:100,000 scale of mapping in both detail and precision. When determining whether to apply GAP data to a particular use, there are two primary questions: do you want to use the data as a map for the particular geographic area, or do you wish to use the data to provide context for a particular area? The distinction can be made with the following example: You could use GAP land cover to determine the approximate amount of oak woodland occurring in a county, or you could map oak woodland with aerial photography to determine the exact amount. You then could use GAP data to determine the approximate percentage of all oak woodland in the region or state that occurs in the county, and thus gain a sense of how important the county's distribution is to maintaining that plant community.

Appropriate Uses: The above example illustrates two appropriate uses of the data: as a coarse map for a large area such as a county, and to provide context for finer-level maps. Specific case-study examples are provided in appendix 7.1, but following is a general list of applications:

- Statewide biodiversity planning
- Regional (Councils of Government) planning
- Regional habitat conservation planning
- County comprehensive planning
- Large-area resource management planning
- Coarse-filter evaluation of potential impacts or benefits of major projects or plan initiatives on biodiversity, such as utility or transportation corridors, wilderness proposals, regional open space and recreation proposals, etc.
- Determining relative amounts of management responsibility for specific biological resources among land stewards to facilitate cooperative management and planning.
- Basic research on regional distributions of plants and animals and to help target both specific species and geographic areas for needed research.
- Environmental impact assessment for large projects or military activities.
- Estimation of potential economic impacts from loss of biological resource-based activities.
- Education at all levels and for both students and citizens.

Inappropriate Uses: It is far easier to identify appropriate uses than inappropriate ones, however, there is a "fuzzy line" that is eventually crossed when the differences in resolution of the data, size of geographic area being analyzed, and precision of the answer required for the question are no longer compatible. Examples include:

- Using the data to map small areas (less than thousands of hectares), typically requiring mapping resolution at 1:24,000 scale and using aerial photographs or ground surveys.
- Combining GAP data with other data finer than 1:100,000 scale to produce new hybrid maps or answer queries.
- Generating specific areal measurements from the data finer than the nearest thousand hectares (minimum mapping unit size and accuracy affect this precision).

- Establishing exact boundaries for regulation or acquisition.
- Establishing definite occurrence or non-occurrence of any feature for an exact geographic area (for land cover, the percent accuracy will provide a measure of probability).
- Determining abundance, health, or condition of any feature.
- Establishing a measure of accuracy of any other data by comparison with GAP data.
- Altering the data in any way and redistributing them as a GAP data product.
- Using the data without acquiring and reviewing the metadata and this report.

LITERATURE CITED

American Ornithologists' Union. 1998. Check-list of North American birds, 7th ed. Washington, DC: American Ornithologists Union. 829 p.

Anonymous. 2001. Ranch Conversations: A blueprint for conserving species and rural livestyles. A publication of the Western Governors' Association, the High Plains Partership for Species at Risk, and the Lesser Prairie Chicken Interstate Working Group. 15 p. http://www.westgov.org/wga/initiatives/HighPlains/Ranch%20Conversation%20final.pdf

Austin, M.P. 1991. Vegetation: Data collection and analysis. Pages 37-41 in C.R. Margules and M.P. Austin, editors, Nature conservation: Cost effective biological surveys and data analysis. Australia CSIRO, East Melbourne.

Axelrod, D. I. 1985. Rise of the grassland biome. Botanical Review 51:163-201.

Bachand, R.R. 2001. The American prairie: going, going, gone? National Wildlife Federation. Boulder, CO.

Bailey, V. 1926. A biological survey of North Dakota. U.S. Dept. of Agriculture, North American Fauna No. 49. 226 p.

Bihrle, C. 2003. 100 Years of Refuges. North Dakota Outdoors. March: 3-9.

Bluemle, J.P. 2000. The face of North Dakota. Third Edition. North Dakota Geological Survey. Eductational Series 26.

Boe, K.K. and D.M. Lenz. 1999. Tallgrass prairie inventory in Sargent and Barnes Counties, North Dakota. Final Report to the Nature Conservancy of the Dakotas, North Dakota Parks and Recreation Department, Bismarck, ND.

Boone, R.B. and W.B. Krohn. 1999. Modeling the occurrence of bird species: are errors predictable? Ecological Applications 9:835-848.

Boone, R.B. and W.B. Krohn. 2000. Predicting broad-scale occurrences of vertebrates in patchy landscapes. Landscape Ecology 15:63-74.

Bouzaher, A. and S. R. Johnson, eds. 1995. Conservation of Great Plains ecosystems: Current science, future options. Kluwer Academic Publishers, Netherlands.

Brand, M.D., M.M. Moore, and R.P. Williams. 1988. Management of North Dakota's School Lands. Rangelands 10:51-52.

Brown, R. J., F. J. Ahern, K.P. Thomson, K. Staenz, J. Cihlar, C.M. Pearce, and S.G. Klumph. 1983. Alberta rangeland assessment using remotely sensed data. Canada Centere for Remote Sensing Research Report 83-1. 128 p.

Bryce, Sandra. James M. Omernik, David E. Pater, Michael Ulmer, Jerome Schaar, Jerry Freeouf, Rex Johnson, Pat Kuck, and Sandra H. Azevedo. 1998. Ecoregions of North Dakota and South Dakota. [Two sided color poster with map, descriptive text, summary tables, and photographs.] Reston, Virginia: U.S. Geological Survey (scale 1:1,500,000). ISBN 0-607-89384-2.

Burrough, P.A. and R.A. McDonnell. 1998. Principles of Geographical Information Systems. Oxford Univ. Press, New York.

Card, D. H. 1982. Using known map category marginal frequencies to improver estimates of thematic map accuracy. Photogrammetric Engineering and Remote Sensing 48(3):431-439.

Carneggie, D.M., B.J. Schrumpf, and D.A. Mouat. 1983. Rangeland Applications. Pages 2325-2384 *in* J.E. Estes and G.A. Thorley, eds., Manual of remote sensing Vol. II. Amer. Society of Photgrammetry, Falls Church, VI.

Clark, J.S. 1996. The Great Plains partnership. Pages 169-173 in F.B. Samson and FL. Knopf, eds. Prairie Conservation, Island Press,Washington, D.C.

Clawson, M. 1968. The land system of the United States. Univ. of Nebraska Press, Lincoln, NE.

Clayton, L., S.R. Moran, J.P. Bluemle, and C.G. Carlson. 1980. Geological Map of North Dakota. North Dakota Geological Survey.

Clements, F.E. 1920. Plant indicators: The relation of plant communities to process and practice. Carnegie Institution of Washington, Publication No. 290.

Collins, J.T. 1993. Amphibians and reptiles in Kansas. Univ. of Nebraska Press, Lincoln, NE.

Conant, R., and J.T. Collins. 1991 and 1998. Reptiles and Amphibians, Eastern/Central North America. Houghton Mifflin, Boston, Massachusetts.

Cosby, B.J., G.M. Hornberger, R.B. Clapp, and T.R. Ginn. 1984. A statistical exploration of the relationships of soil moisture characteristics to the physical properties of soils. Water Resources Research 20:682-690.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetland and deepwater habitats of the United States. U.S. Dept. of Interior, Fish and Wildlife Service FWS/OBS-79/31. 103 p.

Cowardin, Lewis M., Terry L. Shaffer, and Phillip M. Arnold. 1995. Evaluations of duck habitat and estimation of duck population sizes with a remote-sensing-based system. National Biological Service, Biological Science Report 2. 26pp.

Crist, P., B. Thompson, and J. Prior-Magee. 1995. A dichotomous key of land management categorization, unpublished. New Mexico Cooperative Fish and Wildlife Research Unit, Las Cruces, New Mexico.

Csuti, B. 1996. Mapping animal distribution areas for gap analysis. In: Gap Analysis: a landscape approach to biodiversity planning. J.M. Scott, T.H Tear, and F.W. Davis, eds., pp. 135-145. American Society of Photogrammetry and Remote Sensing, Bethesda, Maryland.

Csuti, B., S. Polasky, P.H. Williams, R.L. Pressey, J.D. Camm, M. Kershaw, A.R. Kiester, B. Downs, R. Hamilton, M. Huso, and K. Sahr. 1997. A comparison of reserve selection algorithms using data on terrestrial vertebrates in Oregon. *Biological Conservation* 80:83-97

Csuti, B. and P. Crist. 1998. Methods for developing terrestrial vertebrate distribution maps for Gap Analysis (version 2, 12 March 1998). In: J.M. Scott and M.D. Jennings, editors. A handbook for Gap Analysis. Idaho Cooperative Fish and Wildlife Research Unit, University of Idaho, Moscow.

Cully, J., S. Egbert, J. Harrington, T. Hoernemann, G. Kaufman, C. Lauver, E. Martinko, and K. Price. 2002. A Gap Analysis of Kansas. Kansas Cooperative Fish and Wildlife Research Unit, Manhattan, Kansas.

Dahl, T.E. 1997. Status and trends of wetlands in the conterminous United States 1986 to 1997. U.S. Department of Interior, Fish and Wildlife Service, Washington, D.C. 82pp.

Davis, F.W., P.A. Stine, D.M. Stoms, M.I. Borchert, and A.D. Hollander. 1995. Gap Analysis of the actual vegetation of California - 1. The southwestern region. *Madroño* 42:40-78.

De Bruin, S., A.J.W. De Wit, P.A.J. Van Oort and B.G.H. Gorte. 2004. Using quadtree segmentation to support error modeling in categorical raster data. Int. J. Geographical Information Science 18:151-168.

Diamond, J. 1986. The design of a nature reserve system for Indonesian New Guinea. Pages 485-503 in M.E. Soulé, editor. Conservation biology: The science of scarcity and diversity. Sinauer Associates, Sunderland, Massachusetts.

Dix, R L. 1962. A history of biotic and climatic changes within the North American grassland. Pages 71-89 in Grazing in terrestrial and marine environments: A symposium of the British Ecological Society. Blackwell Scientific Publications, Oxford.

Dix, R.L. and F.E. Smeins. 1996. The prairie, meadow, and marsh vegetation of Nelson County, North Dakota. Canadian J. Botany 45:21-58.

Drake, J. and D. Faber-Langendoen. 1997. An alliance level classification of the vegetation of the midwestern United States. The Nature Conservancy.

Driscoll, R.S., D.L. Merkel, D.L. Radloff, D.E. Snyder, and J.S. Hagihara. 1984. An ecological land classification framework for the United States. Miscellaneous Publication 1439. USDA Forest Service, Washington, DC.

Driscoll, R.S., D.L. Merkel, J.S. Hagihara, and D.L. Radloff. 1983. A component land classification for the United States: Status report. Technical Note 360. U.S. Department of the Interior, Bureau of Land Management, Denver, Colorado.

Dyke, S., S. Hagen, and P. Isakson. 2004. North Dakota's 100 species of conservation priority. North Dakota Outdoors, July:2-21.

EarthSat. 1996. Mapping perennial cover in prairie pothole region. Final report for Ducks Unlimited, Inc. and U.S. Fish and Wildlife Service. 9 pp.

Edwards, T.C., Jr., C.H. Homer, S.D. Bassett, A. Falconer, R.D. Ramsey, and D.W. Wight. 1995. Utah Gap Analysis: An environmental information system. Technical Report 95-1, Utah Cooperative Fish and Wildlife Research Unit, Utah State University, Logan, Utah.

Edwards, T.C., Jr., E.T. Deshler, D. Foster, and G.G. Moisen. 1996. Adequacy of wildlife habitat relation models for estimating spatial distributions of terrestrial vertebrates. Conservation Biology 10:263-270.

Enz, J. W. 2003. North Dakota Topograhic, climatic, and agricultural overview. NorthDakota State Climatologist Online. http://www.soilsci.ndsu.nodak.edu/Enz/enz/reports/ndclimate.pdf

Faanes, C.A. and R.E. Stewart. 1982. Revised checklist of North Dakota birds. Prairie Naturalist 14:81-92.

Federal Geographic Data Committee (FGDC). 1994. Content standards for digital geospatial metadata. 8 June 1994. Federal Geographic Data Committee, Washington, DC.

Federal Geographic Data Committee. 1995. Content standards for digital geospatial metadata workbook, FGDC, Washington, DC.

Federal Geographic Data Committee, Vegetation Subcommittee. 1997. FGDC Vegetation Classification and Information Standards--June 3, 1996 Draft. FGDC Secretariat, Reston, Virginia. 35 pp.

Fenneman, N.M. 1931. Physiography of the western United States. New York, McGraw-Hill Book Co.

Flather, C.H., K.R. Wilson, D.J. Dean, W.C. McComb. 1997. Identifying gaps in conservation networks: of indicators and uncertainty in geographic-based analyses. Ecological Applications 7:531-542.

Forman, R.T.T., and M. Godron. 1986. Landscape ecology. John Wiley and Sons, New York.

Franklin, J.F. 1993. Preserving biodiversity: Species, ecosystems, or landscapes? *Ecological Applications* 3(2):202-205.

Fuhlendorf, S.D. and D.M. Engel. 2004. Application of the fire-grazing interaction to restore a shifting mosaic on tallgrass prairie. J. Applied Ecology 41:6-4-614.

Graetz, R D. 1990. Remote sensing of terrestrial ecosystem structure: an ecologist's pragmatic view. Pages 5-30 in Hobbs, R. J. and Mooney, H A., eds. Remote Sensing of Biosphere Functioning. Springer-Verlag, New York, NY.

Grossman, D.H., D. Faber-Langendoen, A.S. Weakley, M. Anderson, P. Bourgeron, R. Crawford, K. Goodin, S. Landaal, K. Metzler, K. Patterson, M. Pyne, M. Reid, and L. Sneddon. 1998. Terrestrial Vegetation of the United States. Vol 1. The National Vegetation Classification System: Development, Status, and Applications. The Nature Conservancy.

Guntenspergen, G. R., Peterson, S. A., Leibowitz, S. G., and Cowardin, L. M. 2002. Indicators of wetland condition for the Prairie Pothole Region of the United States.Environmental Monitoring and Assessment 78:229-252.

Haugen, D.E, R.J. Piva, N.P. Kingsley, and R.A. Harsel. 1994. North Dakota's forest resources, 1994. USDA Forest Service, Research Paper NC-336. 101p.

Hoberg, T. and C. Gause. 1992. Reptiles and amphibians of North Dakota. North Dakota Outdoors 55:7-19.

Hoffman, R. S. and J.Knox Jones, Jr. 1970. Influence of late-glacial and post-glacial events on the distribution of recent mammals on the Northern Great Plains. Pages 355-394 in W. Dort, Jr., and J. Know Jones, Jr., eds., Pleistocene and recent environments of the Central Great Plains. University Press of Kansas, Special Publication 3.

Homer, C., R. Ramsey, J. T. Edwards, and A. Falconer. 1997. Landscape cover-type modelling using a multi-scene Thematic Mapper mosaic. Photogrammetric Engineering & Remote Sensing 63:59-67.

Huston, M.A. 1994. Biological Diversity: The coexistence of species on changing landscapes. Cambridge University Press. 681p.

Jenkins, R.E. 1985. Information methods: Why the Heritage Programs work. *The Nature Conservancy News* 35(6):21-23.

Jennings, M.D. 2000. Gap Analysis: concepts, methods, and recent results. Landscape Ecology 15:5-20.

Jennings, M. O. Loucks, D. Glenn-Lewin, R. Peet, D. Faber-Langendoen, D. Grossman, A. Damman, M. Barbour, R. Pfister, M. Walker, S. Talbot, J. Walker, G. Hartshorn, G. Waggoner, M. Abrams, A. Hill, D. Roberts, D. Tart, and M.

Rejmanek. 2003. Guidelines for describing associations and alliances of the U.S. National Vegetation Classification. The Ecological Society of America Vegetation Classification Pannel Version 2.0. Http://www.esa.org/wegweb
Johnsgard, P.A. 2003. Great Wildlife of the Great Plains. Univ. Press of Kansas. Lawrence, Kansas.
Johnson, D.H. 2000. Grassland bird use of conservation reserve program fields in the Great Plains. Pages 19-33 in W.L. Homan and D.J. Halloum,eds. A comprehensive review of farm bill contributions to wildlife conservation, 1985-200U.S. Department of Agriculture, Natural Resources Conservation Service, Wildlife Habitat Management Institute, Technical Report.
Johnson, D.H. 2001. Habitat fragmentation effects on birds in grasslands and wetlands: a critique of our knowledge. Great Plains Research 11:211-231.
Johnson, D.H., S. D. Haseltine, and L. M. Cowardin. 1994. Wildlife habitat management on the northern prairie landscape. Landscape and Urban Planning 28:5-21.
Johnson, D.H., and L.D. Igl. 2001. Area requirements of grassland birds: a regional perspective. Auk 118:24-34.
Johnson, W.C. 2002. Dams and riparian forests: a case study from the upper Missouri River. Rivers 3:229-242.
Jones, Jr, J.K., D.M. Armstrong, R.S. Hoffmann, and C. Jones. 1983. Mammals of the Northern Great Plains. Univ. of Nebraska Press, Lincoln, NE.
Jonzen, N., C. Wilcox, and H.P. Possingham. 2004. Habitat selection and population regulation in temporally fluctuating environments. American Naturalist 164:E103-E114.
Kantrud, H A, Krapu, G L, and Swanson, G A. 1989. Prairie basin wetlands of the Dakotas: a community profile. U. S. Fish and Wildl. Serv. Biological Rep. 85. 111 pp.
Kirkpatrick, J.B. 1983. An iterative method for establishing priorities for the selection of nature reserves: An example from Tasmania. *Biological Conservation* 25:127-134.
Knue, J. 1988. Of time…and the Prairie. North Dakota Game and Fish Department. Bismarck, ND.
Krapu, G L and Duebbert, H F. 1989. Prairie wetlands: characteristics, importance to waterfowl, and status. Pages 811-828 in Sharitz, R R and Gibbons, J W., eds., Freshwater Wetlands and Wildlife. United States Department of Energy, Oak Ridge, TN.
Krapu, G.L.,D.A. Brandt, and R.R. Cox, Jr. 2004. Less waster corn, more land in soybeans, and the switch to genetically modified crops: trends with important implications for wildlife management. Wildlife Society Bulletin 32:127-136.
Kuchler, A.W. 1964. Manual to Accompany the Map Potential Natural Vegetation of the Conterminous United States. American Geographical Society, New York, NY.
Küchler, A.W., and I.S. Zonneveld, editors. 1988. Vegetation mapping. Kluwer Academic Publishers, Dordrecht, The Netherlands. 635 pp.
Kuzera, K. and R.G. Pontius, Jr. 2004. Categorical coefficients of agreement for assessing soft-classified maps at multiple resolutions. Sixth international

symposium on spatial accuracy assessment in natural resources and environmental sciences. 28-June – 1 July 2004, Portland, Maine. 11 p.
Lambeck, R.J. 1997. Focal species: a multi-species umbrella for nature conservation. Conservation Biology 11:849-856.
Lee, T. and J.A. Richards. 1985. A low cost classifier for multitemporal applications. Int. J. Remote Sensing 6:1405-1417.
Levin, S.A. 1981. The problem of pattern and scale in ecology. *Ecology* 73:1942-1968.
Lins, K.S., and R.L. Kleckner. 1996. Land cover mapping: An overview and history of the concepts. Pages 57-65 in J.M. Scott, T.H. Tear, and F. Davis, editors, Gap Analysis: A landscape approach to biodiversity planning. American Society for Photogrammetry and Remote Sensing, Bethesda, Maryland.
Lozano-Garcia, D.F. and R. M. Hoffer. 1985. Evaluation of a layered approach for classifying multi-temporal Landsat MSS data. Pages 189-199 in: Proceedings of the PECORA 10 Symposium, Remote Sensing in Forest and Range Resources Management. American Society for Photogrammetry and Remote Sensing.
Loveland, T. R., and Shaw D. M. 1996. Multi-resolution land characterization: building collaborative partnerships. Pages 79-85 in J.M. Scott, T.H. Tear, and F. Davis, editors, Gap Analysis: A landscape approach to biodiversity planning. American Society for Photogrammetry and Remote Sensing, Bethesda, Maryland.
Margules, C.R., A.O. Nicholls, and R.L. Pressey. 1988. Selecting networks of reserves to maximize biological diversity. *Biological Conservation* 43:63-76.
McGranahan, D. A. 1999. Natural amenities drive rural population change. U.S.D.A. Economic Research Service, Agricultrual Economic Report No. 781.
McGranahan, D.A. and C. L. Beale. 2002. Understanding rural population loss. Rural America 17:2-11.
McGwire, K.C. and P. Fisher. 2001 Spatially variable thematic accuracy: beyond the confusion matrix. Pages 308-329 in C.T. Hunsaker, M.F. Goodchild, M.A. Friedl, and T.J. Case, editors, Spatial uncertainty in ecology. Springer, New York.
MicroImages, 2003. Writing scripts with SML. Online. http://www.microimages.com/getstart/pdf/sml.pdf.
Miller, K.R. 1994. In J.A. McNeely and K.R. Miller, editors. National parks conservation and development. Smithsonian Institution, Washington, DC.
Moir, W.H. and H.T. Mowrer. 1994. Unsustainability: the shadow of our future. Pages 143-149 in W.W. Covington and L.F. BeBano, technical coordinators, Sustainable Ecological Systems: Implementing an ecological approach to land management. USDA Forest Service General Technical Report RM-247.
Mueller-Dombois, D., and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley & Sons, New York. 547 pp.
Murphy, R.K., K.W. Hasselblad, C.D. Grondahl, J.G. Sidle, R.E. Martin, and D.W. Freed. 2001. Status of the Burrowing Owl in North Dakota. J. Raptor Res. 35:322-330.
NatureServe 2001. International classification of ecological communities: terrestrial vegetation of the United States. North Dakota GAP subset. Natural Heritage Central Databases. NatureServe, Arlington, VA.

NRCS. 1994. State Soil Geographic (STATSGO) data base. USDS Natural Resources Conservation Service, National Soil Survey Center, Misc. Pub. No. 1492.
NRCS. 2000. Summary Report 1997 Natural Resources Inventory. National Resources Conservation Service Online. http://www.nrcs.usda.gov /technical/NRI/1997/summary_report.
Nicholls, A.O., and Margules. 1993. An upgraded reserve selection algorithm. *Biological Conservation* 64:165-169.
NDASS. 2001. North Dakota at a glance. North Datkota Agricultural Statistical Service Online. Http://www.nass.usda/gov/nd/ atglnd01.pdf
Noss, R.F. 1987. From plant communities to landscapes in conservation inventories: A look at The Nature Conservancy (USA). *Biological Conservation* 41:11-37.
Noss, R.F. 1990. Indicators for monitoring biodiversity: A hierarchical approach. *Conservation Biology* 4:355-364.
Noss, R.F. 1991. Report to the Fund for Animals in Washington, DC.
Noss, R.F., and A.Y. Cooperrider. 1994. Saving nature's legacy. Island Press, Washington, DC.
Noss, R.F., M.A. O'Connell, and D.D. Murphy. 1997. The science of conservation planning: habitat conservation under the Endangered Species Act. Island Press, Washington, D.C.
Noss, R.F., E.T. LaRoe III, and J.M. Scott. 1995. Endangered ecosystems of the United States: A preliminary assessment of loss and degradation. Biological Report 28, National Biological Service, Washington, DC.
Odum, E.D., and H.T. Odum. 1972. Proceedings of the North American Wildlife and Natural Resources Conference 39:178.
Omernik, J.M. 1987. Ecoregions of the conterminous United States. Annals of the Association of American Geographers 77:118-125.
Ozesmi, S. L. and M. E. Bauer. 2002. Satellite remote sensing of wetlands. Wetlands Ecology and Management 10:381-402.
Peterjohn, B.G. and J.R. Sauer. 1999. Population status of North American grassland birds from Breeding Bird Survey, 1966-1996, Stud. Avian Biol. 19:27-44.
Potter, L.D. and D.L. Green. 1964a. Ecology of Ponderosa Pine in Western North Dakota. Ecology 45:10-22.
Potter, L.D. and D.L. Green. 1964b. Ecology of a northeastern outlying stand of Pinus flexilis. Ecology 45:866-868.
Pendergast, J.R., R.M. Auinn, J.H. Lawton, B.C. Eversham, and D.W. Gibbons. 1993. Rare species, the coincidence of diversity hotspots and conservations strategies. Nature 365:335-337.
Pressey, R.L., and A.O. Nicholls. 1989. Application of a numerical algorithm to the selection of reserves in semi-arid New South Wales. *Biological Conservation* 50:263-278.
Pressey, R.L., C.J. Humphries, C.R. Margules, R.I. Vane-Wright, and P.H. Williams. 1993. Beyond opportunism: Key principles for systematic reserve selection. Trends in Ecology and Evolution 8:124-128.
Rasker, R. and A. Hackman. 1996. Economic development and the conservation of large carnivores. Conservation Biology 10:991-1002.

Redmond, R.L., J.C. Winne, T.P. Tady, M. Thornton, J. Troutwine, and Z. Ma. 1997. Existing vegetation and land cover of the Little Missouri, Grand River, and Sheyene National Grasslands. Final Report #53-0343-4-000012. Montana Cooperative Wildlife Research Unit, Missoula, MT. 44pp.

Reynolds, R. E., T. L. Shaffer, R. W. Renner, W. E. Newton, and B. D. J. Batt. 2001. Impact of the Conservation Reserve Program on duck recruitment in the U.S. prairie pothole region. Journal of Wildlife Management 65:765-780.

Ricketts, T.H., E. Dinerstein, D.M. Olson, C.J. Loucks, W. Eichbaum, D. DellaSala, K. Kavanagh, P. Hedao, P.T. Hurley, K.M. Carney, R. Abell and S. Walters. 1999. Terrestrial Ecoregions of North America - A Conservation Assessment. World Wildife Fund. Island Press, Washington, D.C.

Ride, W.L.D. 1975. In F. Fenner, editor. A national system of ecological reserves in Australia. 64 pp.

Robinson, E.B. 1966. History of North Dakota. Univ. of Nebraska Press.

Rudzitis, G. and H.E. Johansen. 1991. How important is wilderness? Results from a United States survey. Environmental Manage. 15:227-233.

Samson, F.B. and F.L. Knopf, eds., 1996. Prairie Conservation. Island Press, Washinton, D.C.

Sargeant, A.B., R.J. Greenwood, M.A. Sovada and T.L. Shaffer. 1993. Distribution and abundance of predators that affect duck production – Prairie Pothole Region. U.S. Fish and Wildl. Service Resour. Publ. 194. 96 pp.

Scott, J.M., B. Csuti, J.D. Jacobi, and J.E. Estes. 1987. Species Richness: a geographic approach to protecting future biological diversity. Bioscience 37:782-788.

Scott, J.M., F. Davis, B. Csuti, R. Noss, B. Butterfield, C. Groves, H. Anderson, S. Caicco, F. D'Erchia, T.C. Edwards, Jr., J. Ulliman, and G. Wright. 1993. Gap analysis: A geographic approach to protection of biological diversity. Wildlife Monographs 123.

Shantz, H.L. 1923. The natural vegetation of the Great Plains region. Annals of the Association of American Geographers. Vol. 13, 81-107.

Shantz, H L. 1924. Natural vegetation: grassland and desert shrub. In: Baker, O E and Taylor, H C. Atlas of American agriculture. U.S. Department of Agriculture, Washington, DC.

Shenk, G.K. and D.M. Lenz. 1998. Tallgrass prairie inventory in Richland and Ransom counties, North Dakota. Final Report to The Nature Conservancy of the Dakotas. North Dakota Parks and Recreation Department. Bismarck, ND.

Sieg, C.H., C.H. Flather, and S. McCanny. 1999. Recent biodiversity patterns in the Great Plains: Implications for restoration and management. Great Plains Research 9:277-313.

Sovada, M.A., M.C. Zicus, R.J. Greenwood, D.P. Rave, W.E. Newton, R.O. Woodward, and J.A. Beiser. 2000. Relationships of habitat patch size to predator community and survival of duck nests. J. Wildlife Manage. 64:820-831.

Specht, R.L. 1975. The report and its recommendations. Pages 11-16 in: F. Fenner, editor, A national system of ecological reserves in Australia. Australian Academy of Sciences Report No. 19. Canberra, Australia.

Specht, R.L., E.M. Roe, and V.H. Boughlon. 1974. Australian Journal of Botany Supplement Series. Supplement No. 7.

Stehman, S. V. 1997. Estimating standard errors of accuracy assessment statistics under cluster sampling. Remote Sensing Environment 60:258-269.

Stehman, S. V. 2000. Practical implications of design-based sampling inference for thematic map accuracy assessment. Remote Sensing Environment 72:35-45.

Stehman, S.V. 2001. Statistical rigor and practical utility in thematic map accuracy assessment. Photogrammetric Engineering and Remote Sensing 67:727-734.

Stehman, S. V. and R. L. Czaplewski. 1998. Design and analysis for thematic map accuracy assessment: Fundamental principles. Remote Sensing of Environment 64:331-344.

Stewart, R.E. 1975. Breeding birds of North Dakota. Tri-College Center for Environmental Studies. Fargo, ND.

Stewart, R.E. and H.A. Kantrud. 1971. Classification of natural ponds and lakes in the glaciated prairie region. USDI FWS Resource Publication 92. 57 p.

Stoms, D.M. 1992. Effects of habitat map generalization in biodiversity assessment. Photogrammetric Engineering and Remote Sensing 58:1587-1591.

Stoms, D. M. 1996. Validating large-area land cover databases with maplets. Geocarto International 11(2):87-95.

Stoms, D., and J. Estes. 1993. A remote sensing research agenda for mapping and monitoring biodiversity. *International Journal of Remote Sensing* 14:1839-1860.

Theobald, D.M. 2001. Land-use dynamics beyond the American urban fringe. The Geographical Review 91:544-564.

Thornthwaite, C.W. 1931. The climates of North America according to a new classification. Geogr. Rev. 21:633-635.

UNESCO. 1973. International classification and mapping of vegetation. Paris.

USDA, Soil Conservation Service. 1976. National Range Handbook. Washington, D.C.

USDA. 1999. 1997 Census of Agriculture, North Dakota State and County Data. Volume 1, Geographic Area Series Part 34. 500p.

Verstraete, M.M., B. Pinty, and R. B. Myneni. 1996. Potential and limitations of information extraction on the terrestrial biosphere from satellite remote sensing. Remote Sensing Environ. 58:201-214.

Vogelmann, J.E., S.M. Howard, L. Yang, C.R. Larson, B.K. Wylie, and J.N. VanDriel. 2001. Completion of the 1990's National Land Cover Data Set for the conterminous United States. Photogrammetric Engineering and Remote Sensing 61:299-305.

Von Loh, J., D. Cogan, J. Butler, D. Faber-Langendoen, D. Crawford, and M.J. Pucherelli. 2000. Theodore Roosevelt National Park, North Dakota. USGS-NPS Vegetation Mapping Program. U.S.D.I. Bureau of Reclamation Technical Memorandum No. 8260-00-04.

Vos, C.C., J. Verboon, P.F.M. Opdam, and C.J.F. Ter Braak. 2001. Towards ecologically scaled landscape indices. American Naturalist 183:24-41.

Weaver, J.E. and T. J. Fitzpatrick. 1934. The prairie. Ecological Monographs 4:110-295.

White, D., A.J. Kimerling, and W.S. Overton. 1992. Cartographic and geometric components of a global sampling design for environmental monitoring. Cartography and Geographic Information Systems 19:5-22.

Whitman, W.C. and W.T. Barker. 1994. Wheatgrass-Bluestem-Needlegrass SRM 606. Page 75 in T.N. Shiflet, ed., Rangeland cover types of the United States. Society for Range Management, Denver, CO.
Wiegand, T., E. Revilla, and K.A. Maloney. 2005. Effects of habitat loss and fragmentation on population dynamics. Conservation Biology 19:108-121.
Wilen, B.O. and M.K. Bates. 1995. The US Fish and Wildlife Service's National Wetlands Inventory Project. Vegetatio 118:153-169.
Williams, P.H., D. Gibbons, C. Margules, A. Rebelo, C. Humphries, and R. Pressey. 1996. A comparison of richness hotspots, rarity hotspots, and complementary areas for conserving diversity of British birds. *Conservation Biology* 10:155-174.
Williams-Sether, T. 1999. From dry to wet, 1988-98, North Dakota. U.S. Geological Survey, Fact Sheet FS-075-99. 4 p.
Whittaker, R.H. 1960. Vegetation of the Siskiyou mountains, Oregon and California. *Ecological Monographs* 30(3):279-338.
Whittaker, R.H. 1965. Dominance and diversity in land plant communities. *Science* 147: 250-259.
Whittaker, R.H. 1977. Species diversity in land communities. *Evolutionary Biology* 10:1-67.
Zhu, A. L. Yang, S. V. Stehman, and R.L. Czaplewski. 2000. Accuracy assessment for the U.S. Geological Survey Regional Land-Cover Mapping Program: New York and New Jersey Region. Photogrammetric Engineering and Remote Sensing 66(12):1425-1435.

GLOSSARY OF TERMS

aerial videography - video images of the land surface taken from an airplane

algorithm - a procedure to solve a problem or model a solution (In GAP typically refers to a GIS procedure used to model animal distributions.)

alliance level - a land unit made up of an "alliance" of natural communities that have the same dominant or co-dominant plant species or, in the absence of vegetation, by the dominant land cover typically described according to the Anderson land cover classification (see "Natural Community Alliance" in Grossman et al. 1995)

alpha diversity - a single within-habitat measure of species diversity regardless of internal pattern, generally over an area of 0.1 to 1,000 hectares (see Whittaker 1960, 1977) -

Anderson Level II - the second hierarchical level in the Anderson land cover classification system (see Anderson et al. 1976)

anthropogenic - caused by man

assemblages - a group of ecologically interrelated plant and animal species

band, spectral - a segment of the electromagnetic spectrum defined by a range of wavelengths (e.g. blue, green, red, near infrared, far infrared) that comprise the Landsat TM imagery

beta diversity - the change in species diversity among different natural communities of a landscape; an index of between-habitat diversity (see Whittaker 1960, 1977)

biodiversity - generally, the variety of life and its interrelated processes

biogeographic - relating to the geographical distribution of plants and animals

biological diversity - see biodiversity

cartographic - pertaining to the art or technique of making maps or charts

classify - to assign objects, features, or areas on an image to spectral classes based upon their appearance as opposed to ‘classification’ referring to a scheme for describing the hierarchies of vegetation or animal species for an area

coarse filter - the general conservation activities that conserve the common elements of the landscape matrix, as opposed to the "fine filter" conservation activities that are aimed at special cases such as rare elements (see Jenkins 1985) community - a group of interacting plants and animals

cover type - a non-technical higher-level floristic and structural description of vegetation cover

cross-walking - matching equivalent land cover categories between two or more classification systems

delineate - identifying the boundaries between more or less homogenous areas on remotely sensed images as visible from differences in tone and texture

delta diversity - the change in species diversity between landscapes along major climatic or physiographic gradients (see Whittaker 1977)

digitization - entering spatial data digitally into a Geographic Information System

ecoregion - a large region, usually spanning several million hectares, characterized by having similar biota, climate, and physiography (topography, hydrology, etc).

ecosystem - a biological community (ranging in scale from a single cave to millions of hectares), its physical environment, and the processes through which matter and energy are transferred among the components

edge-matching - the process of connecting polygons at the boundary between two independently created maps, either between TM scenes or between state GAP data sets

element - a plant community or animal species mapped by GAP. May also be referred to as "element of biodiversity".

error of commission - the occurrence of a species (or other map category) is erroneously predicted in an area where it is in fact absent

error of omission - when a model fails to predict the occurrence of a species that is actually present in an area

exact set coverage - a basic optimization problem to determine the best method for identifying general areas that, when selected sequentially, would have the greatest positive cumulative impact on attaining adequate representation of any or all biotic elements of interest

extinction - disappearance of a species throughout its entire range

extirpation - disappearance of a species from part of its range

fine filter - see "coarse filter"

floristic - pertaining to the plant species that make up the vegetation of a given area.

formation level - the level of land cover categorization between Group and Alliance describing the structural attributes of a land unit, for example, "Evergreen Coniferous Woodlands with Rounded Crowns" (see Jennings 1993b)

gamma diversity - the species diversity of a landscape, generally covering 1,000 to 1,000,000 hectares, made up of more than one kind of natural community (see Whittaker 1977)

gap analysis - a comparison of the distribution of elements of biodiversity with that of areas managed for their long-term viability to identify elements with inadequate representation

geographic information systems - computer hardware and software for storing, retrieving, manipulating, and analyzing spatial data

Global Positioning System (GPS) - an instrument that utilizes satellite signals to pinpoint its location on the earth's surface

greedy heuristic - an algorithm for exact set cover analysis (see Kiester et al., in press)

ground truthing - verifying maps by checking the actual occurrence of plant and animal species in the field at representative sample locations

habitat - the physical structure, vegetational composition, and physiognomy of an area, the characteristics of which determine its suitability for particular animal or plant species

hectare - a metric unit of area of 10,000 square meters and equal to 2.47 acres

hex/hexagon - typically refers to the EPA EMAP hexagonal grid of 635 square kilometer units

hyperclustering - a efficient, interactive method for accurately analyzing and classifying remotely-sensed data that reduces data size and computational requirements while retaining the integrity of the original data

lotic - flowing, e.g., water in a stream or river

metadata - information about data, e.g., their source, lineage, content, structure, and availability

minimum mapping unit - the smallest area that is depicted on a map

neotropics - the zoo-geographic region stretching southward from the tropic of Cancer and including southern Mexico, Central and South America, and the West Indies phenology - the study of periodic biological phenomena, such as flowering, breeding, and migration, especially as related to climate

phenotype - the environmentally and genetically determined observable appearance of an organism, especially as considered with respect to all possible genetically influenced expressions of one specific character

physiognomic - based on physical features

physiographic province - a region having a pattern of relief features or land forms that differ significantly from that of adjacent regions

pixel - the smallest spatial unit in a raster data structure

polygon - an area enclosed by lines in a vector-based Geographic Information System data layer or a region of contiguous homogeneous pixels in a raster system

preprocessing - those operations that prepare data for subsequent analysis, usually by attempts to correct or compensate for systematic, radiometric, and geometric errors

pro-active - acting in anticipation of an event as opposed to reacting after the fact

range - the geographic limit of the species

range unit - a spatial, geographic unit to record and display species geographic range.

reach - a stream or river segment between inflowing tributaries

registration, spatial - matching different images to each other by finding points on the images that can be matched to known points on the ground

remote sensing - deriving information about the earth's surface from images acquired at a distance, usually relying on measurement of electromagnetic radiation reflected or emitted from the feature of interest

resolution - the ability of a remote sensing system to record and display fine detail in a distinguishable manner or: the smallest feature that can be distinguished or resolved on a map or image, such as a TM pixel

scale, map - the ratio of distance on a map to distance in the real word, expressed as a fraction; the smaller the denominator, the larger the scale, e.g. 1:24,000 is larger than 1:100,000

sensitivity analysis - the consideration of a number of factors involved in the mathematical modeling of an ecosystem and its components. These include feedback and control, and the stability and sensitivity of the system as a whole to changes in some part of the system. Predictions can be made from the analysis.

simulated annealing - an algorithm used for set coverage analysis (see Kiester et al., in press)

species richness - the number of species of a particular interest group found in a given area

spectral cluster - a group of adjacent pixels that are uniform with respect to their brightness values

supervised classification - the process of classifying TM pixels of unknown identity by using samples of known identity (i.e., pixels already assigned to informational classes by ground truthing or registration with known land cover) as training data

synoptic - constituting a brief statement or outline of a subject; presenting a summary

tessellation - the division of a map into areas of equal and uniform shape such as the EPA- EMAP hexagon

Thematic Mapper - a sensor on LANDSAT 4 and 5 satellites that records information in seven spectral bands, has a spatial resolution of about 30 m x 30 m, and represents digital values in 256 levels of brightness per band

transect - a transversely cut line along which physical and biological observations are made

trophic structure - the various levels in a food chain, such as producers (plants), primary consumers (herbivores), and secondary consumers (carnivores)

Universal Transverse Mercator - one of several map projections or systems of transformations that enables locations on the spherical earth to be represented systematically on a flat map

Universal Transverse Mercator grid - a geographic reference system used as the basis for worldwide locational coding of information in a GIS or on a map

unsupervised classification - the definition, identification, labeling, and mapping of natural groups, or classes, of spectral values within a scene. These spectral classes are reasonably uniform in brightness in several spectral channels.

vector format - a data structure that uses polygons, arcs (lines), and points as fundamental units for analysis and manipulation in a Geographic Information System virtual reality - a computer-generated simulation of reality with which users can interact using specialized peripherals such as data gloves and head-mounted computer graphic displays

wildlife habitat relationship model - a method of linking patterns of known habitat use by animal species with maps of existing vegetation, thereby identifying the spatial extent of important habitat features for use in conservation and management.

GLOSSARY OF ACRONYMS

ACE Army Corps of Engineers
AML ARC/INFO Macro Language
AUD The Audubon Society
BLM Bureau of Land Management
BOR Bureau of Reclamation
CDC Conservation Data Center
EPA Environmental Protection Agency
EROS National Center for Earth Resources Observation and Science
ESRI Environmental Systems Research Institute
FGDC Federal Geographic Data Committee
FTP file transfer protocol
GAP Gap Analysis Program
GIS Geographic Information System
GPS Global Positioning System
MIPS Map and Image Processing System
MOU Memorandum of Understanding
MMU Minimum mapping unit
NRCS Natural Resources Conservation Service
MRLC Multi-Resolution Land Characteristics Consortium
MSS Multi-Spectral Scanner
NALC North American Landscape Characterization (USEPA, USGS)
NASLT Native American Spirit Lake Tribe
NASRS Native American Standing Rock Sioux
NASWT Native American Sisseton-Wahpeton Sioux Tribe
NATAT Native American Three Affiliated Tribes
NATMC Native American Turtle Mountain Chippewa
NBII National Biological Information Infrastructure
NBS National Biological Service
NDGF North Dakota Game and Fish
NDSL North Dakota School Lands
NMD National Mapping Division
NPS National Park Service
NSDI National Spatial Data Infrastructure
NWI National Wetlands Inventory (USFWS)
OMB Office of Management and Budget (Administration)
SDTS Spatial Data Transfer Standard
RMSE Root mean square error
TIGER Topologically Integrated Geographic Encoding and Referencing system
TM Thematic Mapper
TNC The Nature Conservancy
UNESCO United Nations Educational, Scientific, and Cultural Organization
URL Universal Resource Locator

USDA United States Department of Agriculture
USFS US Forest Service
USFWS US Fish & Wildlife Service
UTM Universal Transverse Mercator
WHR Wildlife-habitat relationships