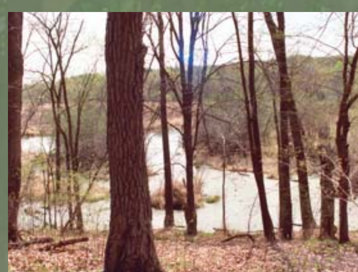
LCCMR

LEGISLATIVE-CITIZEN COMMISSION ON MINNESOTA RESOURCES

FUNDING FROM
THE MINNESOTA ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

MINNESOTA

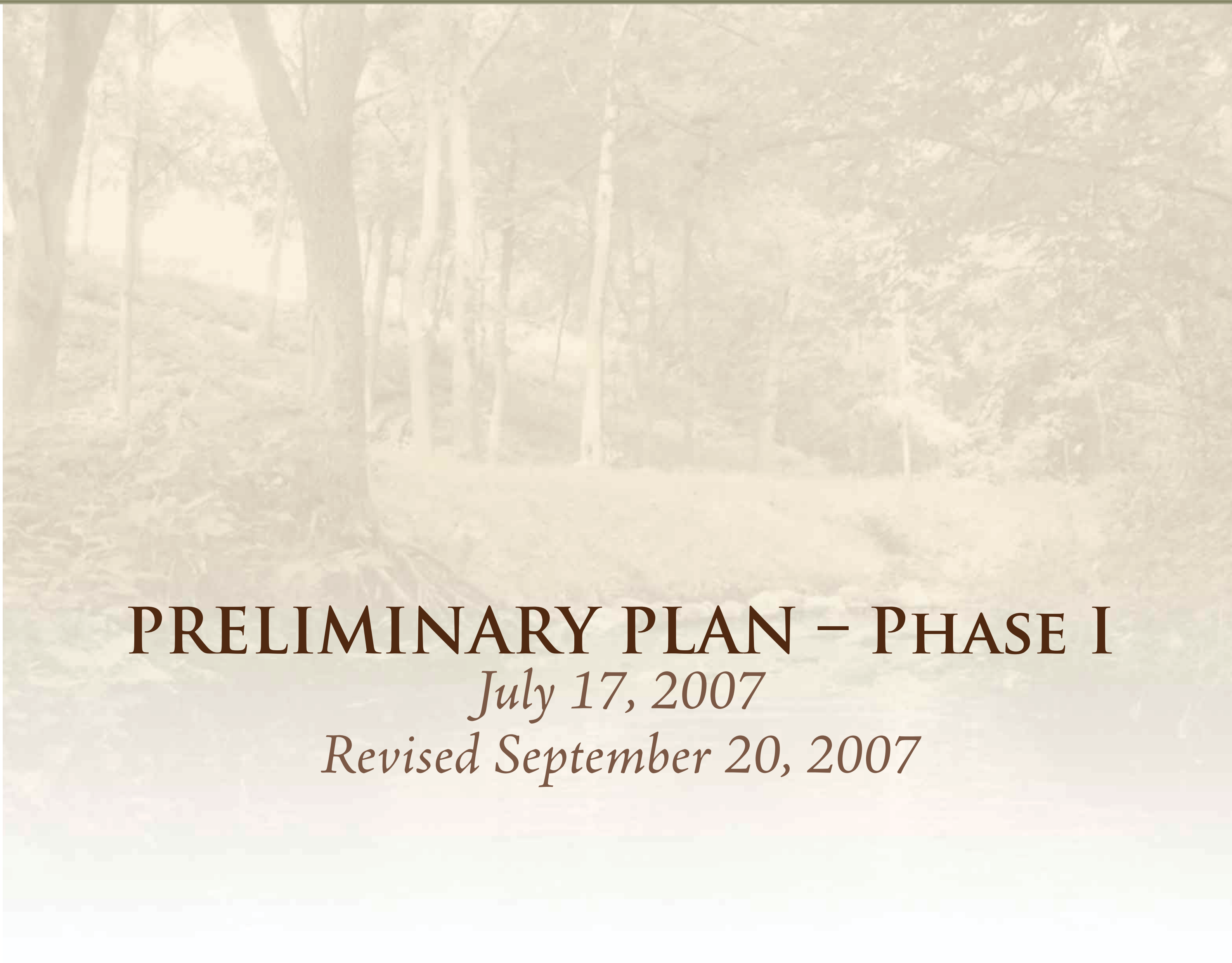
STATEWIDE CONSERVATION AND PRESERVATION PLAN

PRELIMINARY PLAN – PHASE I JULY 17, 2007

REVISED SEPTEMBER 20, 2007

Minnesota Statewide Conservation and Preservation Plan



PRELIMINARY PLAN – Phase I

July 17, 2007

Revised September 20, 2007

INSTITUTE ON THE ENVIRONMENT

UNIVERSITY OF MINNESOTA

CR Planning

Bonestroo

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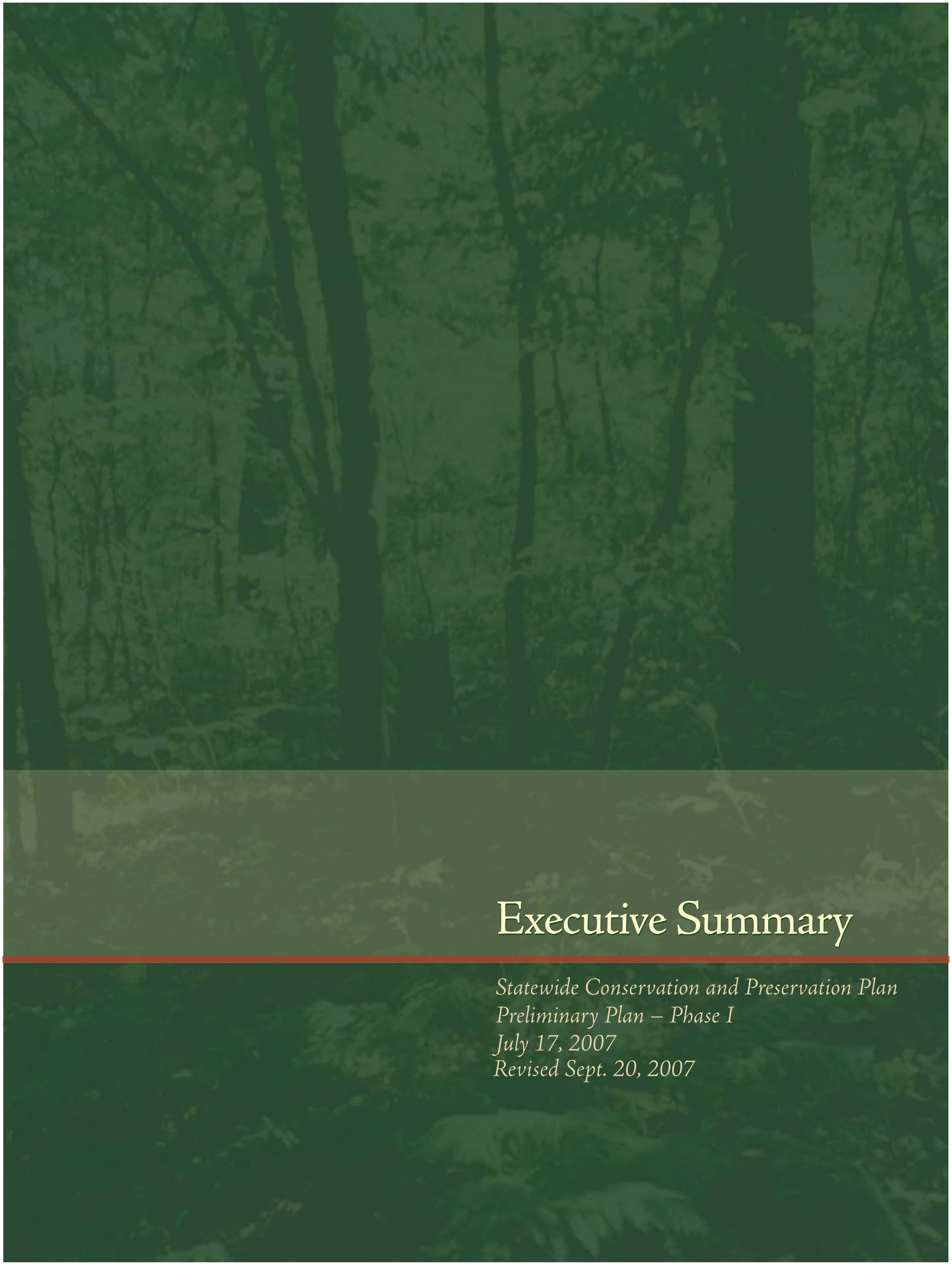

Executive Summary

Statewide Conservation and Preservation Plan
Preliminary Plan – Phase I
July 17, 2007
Revised Sept. 20, 2007

Executive Summary

Executive Summary

Minnesota's quality of life and economic vitality depend on clean air and water, abundant fish and wildlife, healthy forests, and access to quality outdoor recreation. Complex and rapid changes affecting our landscapes and watersheds are leading to degradation and loss of these resources across a broad front, and these changes can no longer be addressed in a piecemeal fashion: there is an overarching need to forge a more interconnected understanding of the state's environment, economy and natural resources, and to build this understanding into a strategic plan for managing those resources going forward.

To achieve this goal, the LCCMR has funded a partnership of leading natural resource scholars, practitioners and planners to create a Statewide Conservation and Preservation Plan. This partnership involves more than 40 research scientists from the University of Minnesota, and natural resource experts from the consulting firms of Bonestroo and CR Planning.

The plan's objective is to provide a blueprint for ensuring that healthy and abundant natural resources are available for future generations of Minnesotans.

During the first half of this year, the project's team of experts has worked diligently to summarize past and current status of Minnesota's resources. More importantly, the project team identified and prioritized the drivers of change affecting Minnesota's resources. Both proximate and higher order drivers were considered. Proximate drivers affect the resource more directly, such as nutrient loading, but tend to be harder to manage. Higher order drivers, such as agricultural policy, tend to have indirect but signigicant effects on the resources. The result of this analysis is this report.

This first phase of planning focused on compiling information on the statutory resource areas separately, but at the end of the phase the team began looking at how some higher order drivers of change affect multiple resources. Three of the most important of these are:

- Demographic Changes, including an aging and increasingly diverse and urban population, which result in changing perspectives on conservation, preservation and resource use;
- Land use decisions, which are often the "driver behind the driver" since the consequences of these decisions tend to propagate throughout the system; and
- Climate change, which will have broad and varied effects on Minnesota's natural resources, and will tend to exacerbate the negative effects of other drivers.

The project team's recommendations for key issues to investigate in the next phase of this project focus on those higher order drivers of change that have the broadest influence on multiple resources and are most amenable to management through policy and investment decisions. These drivers are:

- land and water habitat fragmentation, degradation, loss and conversion;
- land use practices;
- impacts of resource consumption;
- transportation;
- energy production and use;
- invasive species;
- and toxic contaminants.

Project Progress To Date

Statewide Conservation and Preservation Plan
Preliminary Plan – Phase I
July 17, 2007
Revised Sept. 20, 2007

KEY PROJECT TEAM MEMBERS

The Statewide Conservation and Preservation Plan project team is composed of many leading experts in science, natural resources, data analysis and modeling, planning, land use, policy implementation and facilitation of large, complex projects.

Many of the University of Minnesota faculty involved are recognized locally, regionally, nationally, and internationally for their scientific expertise. In addition to holding prominent leadership and research positions at the University of Minnesota, they have served on advisory committees to the U.S. Federal government, in joint Canadian-U.S. scientific and policy groups, and have contributed their time and experience to advisory groups to the United Nations. They sit on the editorial panels for leading scientific journals, and several hold highly prestigious international fellowships.

The private consultant team members are widely recognized within the industry for their experience and applied knowledge, and all bring a strong regional, and in some cases national, reputation for skill and excellence. Two are current or past owners of their own planning firms, and several are widely published. Many have been members or board members of regional, local, and national professional organizations, and have served leadership roles in those organizations.

Members of the project Core Management Team and resource team leads are listed below. There are more than 30 additional academic and professional staff who have participated in the project to date.

University of Minnesota:

Todd Arnold, PhD; Associate Professor, Department of Fisheries, Wildlife and Conservation Biology

George Host, PhD; Senior Research Associate & Landscape Ecologist, Natural Resources Research Institute; Director, Natural Resources Geographic Information System Laboratory, Duluth

Anne R. Kapuscinski, PhD; Professor, Department of Fisheries, Wildlife and Conservation Biology; Co-director, Ecosystem Science and Sustainability Initiative

Lance Neckar, MLA; Professor, Department of Landscape Architecture

Gerald Niemi, PhD; Professor of Biology; Director of the Center for Water and the Environment, Natural Resources Research Institute, Duluth

Ingrid Schneider, PhD; Associate Professor, Forest Resources; Director of the University's Tourism Center.

Matt F. Simcik, Ph.D. Associate Professor, Environmental Health Sciences

Sangwon Suh, PhD; Assistant Professor, Department of Bioproducts and Biosystems Engineering

Deborah Swackhamer, PhD; Professor, Environmental Health Sciences; Interim Director, Institute on the Environment

Mary Vogel, MA; Co-director, Center for Changing Landscapes

CR Planning:

Jean Coleman JD, MA; Attorney and Land Use Planner; owner, CR Planning, Inc.

Bonestroo:

Paul Bockenstedt, MA; Senior Ecologist and Project Manager

Elizabeth Gould, B.S.; Project Scientist and ecologist

John Shardlow, BS; Senior Principal and Director of Planning; past-president and owner, DSU

Randy Neprash, PE; Civil Engineer, Water and Natural Resources Group

Ciara Schlichting, MS, AICP; Senior Planner

Project Progress To Date

Project Overview

With funding from the LCCMR, the Statewide Conservation and Preservation Plan (SCPP) is being developed by a public-private partnership consisting of faculty from the University of Minnesota-Twin Cities and the Natural Resources Research Institute at the University of Minnesota-Duluth, and the consulting firms of Bonestroo and CR Planning, Inc. (see facing page) The SCPP is being developed in two phases: a Preliminary Plan (this report) and a Final Plan (to be completed in June, 2008).

The primary objective of this Preliminary Plan is to provide the LCCMR with an update on overall progress, and to present preliminary conclusions that would help inform the LCCMR's funding strategy for the coming fiscal year.

Project Structure

Research and Analysis Teams made up of faculty and consultant advisors were formed to examine six natural resource categories: air, land, wildlife, water, fish, and outdoor recreation. These six teams identified pertinent data and studies for assessing the status of resources and drivers of change for each natural resource category. They also identified and gathered a preliminary set of existing plans and policies related to natural resource conservation and preservation at all levels of government. Using this cumulative information, the resource teams identified and prioritized key issues or drivers of change. Based on strategic criteria developed at a meeting with the full LCCMR, the core management team formed recommendations for key issues to be investigated in the second phase of the project, the final plan.

An *Information Systems Team* has created a project intranet to facilitate inter-team communication and act as an archive for data and policy documents and project outputs, and has created maps and data representations to illustrate and document project team findings.

An *External Communications Team* laid the groundwork for connecting the project to stakeholder groups and the general public (see Public Engagement section below).

A *Cost/Benefit Analysis Team* has been formed, and contributed to the analysis of drivers that was the foundation for the project's funding recommendations to the LCCMR.

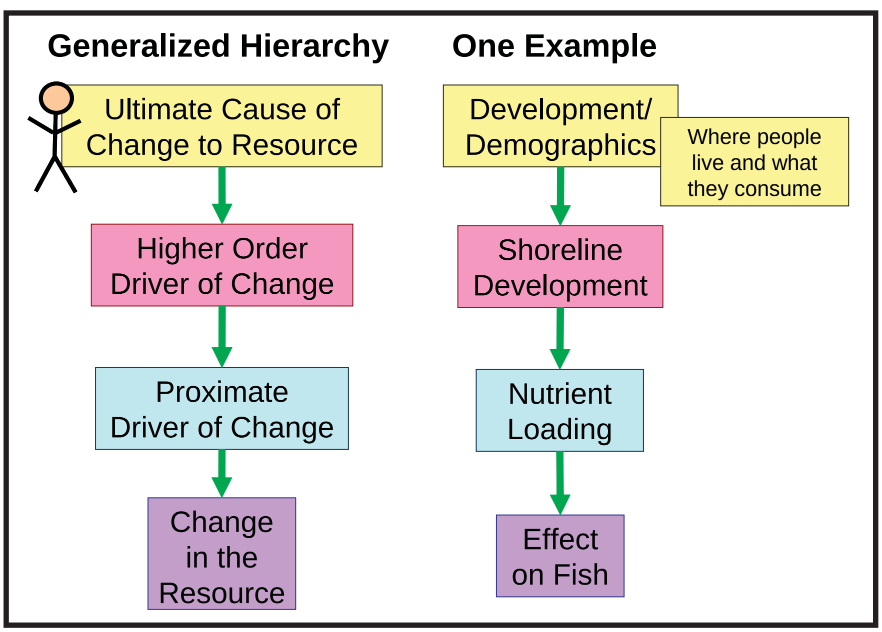

Figure 1: Conceptual hierarchy of drivers. Proximate drivers directly impact the resource. Higher order drivers are often where policy/investment choices operate. Credit: Jean Coleman, CR Planning.

A *Core Management Team* made up of representatives from each of the teams and an LCCMR staff member has overseen the process, ensured cross-communication among the teams and between the Project and the LCCMR.

A *Support Team* comprised of students from the University of Minnesota and staff from CR Planning and Bonestroo provided staff and logistical support to the Research and Analysis Teams.

Identifying and Analyzing Drivers of Change

A major focus of the first phase of the project has been identifying the key drivers of change affecting each natural resource area. Each research team began by identifying proximate drivers, those acting most closely upon the resource, and then mapping them to higher order drivers (see Figure 1, facing page).

The teams, with the assistance of outside experts from relevant state and federal agencies, then ranked these drivers by their relative impact on a common set of "elements of sustainability" (see Table 1 and "Definition of Sustainability" below). As an example, for the Fish resource, the proximate driver Nutrient Loading affects sustainability elements Water Quality (medium), Fish Health (high), and Human Health (low), among others.

Air Quality	Biodiversity
Water Quality	Abundance of Resource
Habitat Quality	Economic Health
Soil/Land Quality	Aesthetics
Fish and Wildlife Health	Cultural/Spiritual Value
Human Health	

Table 1: Sustainability Elements

The rankings were mathematically analyzed to rank the proximate drivers in order of total impact (integrated across elements of sustainability) on the resource. The drivers with the broadest impact were selected for review in this report.

Definition of Sustainability used by the Minnesota 2050 Project[1] *and the Minnesota Statewide Conservation and Preservation Plan*

Sustainability means ensuring that all future Minnesotans have the opportunity to enjoy lives as rich and meaningful as our own, and in a natural environment that is at least as clean, intact, and healthy as that which we enjoy today. We are defining sustainability in the context of the Minnesota 2050 and SCPP projects to mean the persistence of important components and functions of Minnesota's economy, environment and society up to and beyond the year 2050. 'Sustainability' is not an end point or a static state, but rather a dynamic condition that responds to:

- trends in the systems themselves;
- policies that influence those systems; and
- influences external to Minnesota such as climate change, macroeconomic trends, and fossil fuel availability.

Activities that provide future generations with degraded natural resources, reduced economic opportunities or diminished social well-being are inherently less sustainable than policies and actions that maintain or improve these systems. The following are important components and functions of Minnesota's environmental, economic and social systems whose persistence (or absence) determine sustainability:

- air and water quality and quantity that support human health, economic uses, and the health of Minnesota's aquatic and terrestrial ecosystems;
- maintenance or recovery of forest, grassland, savanna and aquatic ecosystem habitat, biodiversity, and productivity functions and the economic and ecological services these functions provide;
- maintenance of agricultural ecosystems that balance maximum positive economic gain with minimal negative environmental effects;
- the ability of the economy to generate enough revenue to pay for the state's needed imports, provide jobs for employable Minnesotans, and sustain Minnesota households at levels above poverty;
- the natural resource base needed to support Minnesota's economic sectors and transportation needs with energy and material inputs, or the economic ability to import these inputs;
- economic, environmental and societal systems matched to the state's dynamic climate system.

[1] The Minnesota 2050 Project's partnership with the SCPP is described later in this Introduction; see also App. vi

Project Progress

Natural Resource Assessment - Trends

The first European settlers to arrive in Minnesota were met with an amazing sight. As they looked west, tall-grass prairie stretched as far as the eye could see, across the southwest half of the state and beyond. Arid blufflands, with their exposed gravelly soil, stood under the scorching summer heat and drying winds, home to species that thrived on those conditions. Depressions on the rolling land below supported pockets of wetland. Bison, American elk, and gray wolves roamed the prairie; species such as Sprague's pipits, chestnut-collared longspurs, bobolinks, and western meadowlarks filled the air which was clear and clean. Fire was a regular visitor to the prairie that burned through the open grasslands.

Looking to the north, the landscape changed and became more rolling, the climate wetter and fires less frequent, allowing trees to establish and dominate the landscape. Dense forests of oak, elm, and sugar maple stretched through central Minnesota, populated by white-tailed deer, raccoons, gray and fox squirrels, wood ducks, wild turkeys, red-shouldered hawks, Cerulean warblers, Blanding's turtles, and Cope's gray tree frogs. Scrub oak woodlands marked the transition between prairie to the southwest and the mixed conifer-hardwood forests and brushlands of north central Minnesota, and the conifer forests, bogs, and swamps of northeast Minnesota. There were many unique species in these forests, including wolverine and woodland caribou, moose, Canada lynx, great gray owl, spruce grouse, northern goshawk, fisher, pine marten, forest salamanders and wood turtles.

And then there was the water. Large to small streams flowed clear and sparkling under the prairie sun, and shade-dappled through the forests, writhing with abundant brook trout. Wetlands, groundwater, and warm to cold water lakes created a patchwork of diverse water forms across the landscape. The largest cold water body, Lake Superior, and its tributary rivers held over 70 native fish species.

As European settlement expanded, things changed. The landscape and the species it supported were disrupted by logging, agriculture, settlement, development, and mining activities. Ninety-nine percent of Minnesota's tall grass prairies disappeared beneath the plow. Many fish and other aquatic wildlife declined precipitously due to unregulated fishing and massive changes to aquatic habitats. Several wildlife species also disappeared altogether from Minnesota, including American Bison, wolverine, woodland caribou, and the passenger pigeon, which is now globally extinct. Some species, such as the grey wolf, suffered persecution and near extinction as a result of social intolerance. World War II brought the use of pesticides and other chemicals, which found their way into the water, fish, and birds; and some, such as the bald eagle, nearly went extinct. Air quality declined as economic activity grew.

Recreation was valued by Minnesota's earliest residents. Minnesota's first state park, Itasca, was established in 1891 by the legislature to protect the headwaters of the Mississippi and provide residents with a natural retreat. Starting in the 1960s, awareness of the declining state of our resources began to increase and several laws were enacted to address water and air quality issues, to regulate the taking of fish and to protect endangered species. These actions have had tremendous positive impacts. Water quality has improved, and significantly impaired fish communities recovered. Populations of the bald eagle and gray wolf have rebounded. Air quality has improved, with aggregate emissions of regulated pollutants dropping by 15% from 1985 to 2005.

Even so, today 27% of all mammal species, 31% of all bird species, and 32% of all fish species in Minnesota are recognized as Species of Greatest Conservation Need by the Minnesota Department of Natural Resources (DNR). On the plant side, only 5% of land areas surveyed under the County

Biological Survey remain as remnant native plant communities, and 256 native plant species are listed as special concern, threatened, or endangered. There are fish consumption advisories for most lakes in Minnesota, due to the ubiquitous, air bourne presence of mercury in our waters. And although emissions of regulated air pollutants have fallen, carbon dioxide emissions have increased significantly – going up 53% from 1985 to 2005. The growth of carbon dioxide is not only one of the top challenges for Minnesota air quality – its effect on climate change will be one of the greatest challenges for all of Minnesota's resources into the foreseeable future.

Natural Resource Assessment - Drivers

A number of compelling factors are driving significant changes in Minnesota's natural resources – changes that are occurring now and changes that are projected into the future. As mentioned above, Minnesota's once abundant terrestrial wildlife – birds, mammals, reptiles, amphibians – now has numerous species whose populations are in decline. The most significant driver of this change is the **loss and degradation of critical habitats** necessary to support these species, habitat losses caused by the increasing **fragmentation** of forest and prairie remnants, the **homogenization** of forest species, and **changes in the species mix** found on the landscape. Increasing removal of aquatic vegetation along shorelines and within lakes is also altering essential habitat for game and non-game fish communities.

Minnesota's famous lakes, rivers, and streams are increasingly impaired by **solids and nutrient loading, and contaminants such as mercury, pesticides, endocrine disrupters, and pharmaceuticals.** The Minnesota Pollution Control Agency has identified 2,250 **impaired water** bodies in Minnesota; and this with 90% of the State's surface waters *yet to be tested*. These impairments are degrading aquatic habitat by changing aquatic vegetation, water clarity, habitat physical structure, and dissolved oxygen levels; all of these are negatively impacting fish. And all of the fish in Minnesota lakes and rivers have some amount of mercury in them, which has resulted in a fish advisory for most lakes across the state.

Another major driver impacting fish populations is **invasive aquatic species.** Minnesota waters now contain sixteen invasive aquatic plants, invertebrates, and vertebrates – including Eurasian watermilfoil, zebra mussels, and sea lamprey – which threaten native fish through competition, predation, and habitat alteration. Through these same interactions, **invasive terrestrial plant and animal species** are also drivers of change in wildlife and native plant communities.

Changing land use is clearly the "driver behind the driver" in many of these cases. **Widespread development** of natural, agricultural, shoreline and forestry lands for residential, commercial, industrial, and transportation uses is having major impacts on the land and water resources in terms of changes in vegetative land cover. These changes are the primary

Figure 2: Boating and swimming should be avoided and a fish consumption advisory is in effect because of contaminated sediments in this West Duluth water.
Credit: CR Planning, Inc.

cause of habitat loss and degradation discussed above. In addition, the type of management practices used on agricultural and forestry lands is also altering land cover; in particular, as acres of annual row crops increase, the amount of perennial land cover decreases. This change is negatively impacting the land resource through **soil erosion, loss of soil structure, nutrient loading, and contaminants**.

Changing land use is also a prime driver of **hydrologic modifications** such as **drainage tiles and ditching** on agricultural lands, and **increases in impervious surfaces** associated with developed lands. These hydrologic modifications, in combination with the changes in vegetative land cover, are resulting in the water impairments described above.

Finally, changing land use is driving changes in **access to outdoor recreation resources.** Shoreland development and changing ownership and management of forest lands in particular are creating barriers for non-owners to use lakes and forests for recreational purposes. In addition, **demographics and lifestyle preferences** are changing the demand for, and use of, different types of recreational resources. Most Minnesotans participate in outdoor activities that are dependent on our natural resources: hiking, boating, fishing, bird watching, hunting. Over 82% believe outdoor recreation is important to their lives. Conserving, protecting and improving our natural resources is critical to our lives and our environment

Climate Change - The Wild Card

Looming behind all of the changes described above is the wild card of climate change, whose effects may in the end outweigh all of the other drivers. Climate change will also exacerbate negative effects of other drivers on natural resources. The burning of fossil fuels for electricity generation, heating and cooling, and transportation are increasing in Minnesota and the entire world, leading to ever increasing concentrations of carbon dioxide and other greenhouse gases in the well-mixed global atmosphere. There is no doubt that greenhouse

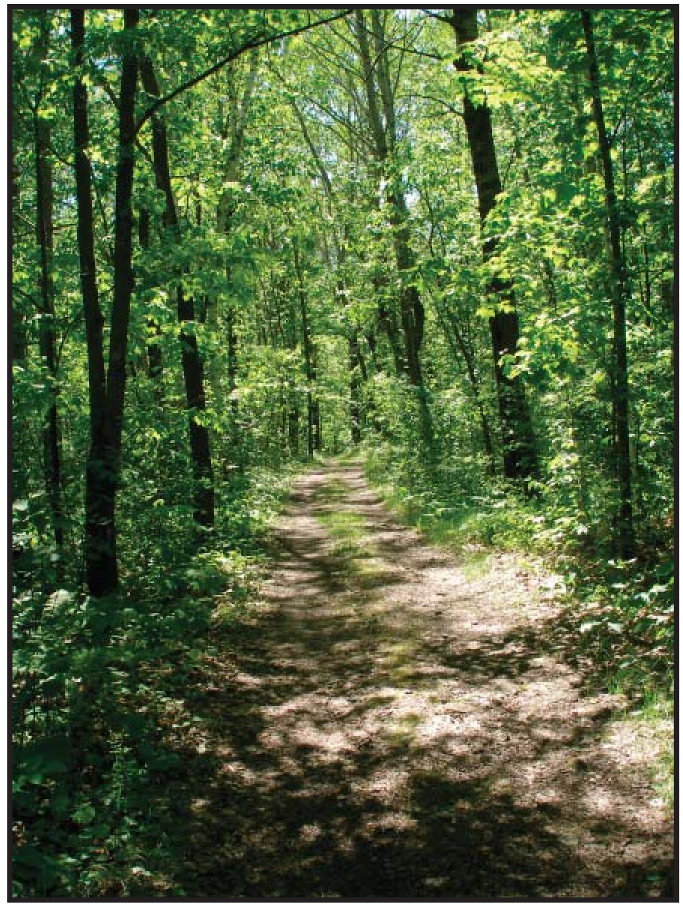

Figure 3: Hiking trail in Banning State Park.
Credit: Michael Kelberer, University of Minnesota

gas concentrations will remain elevated and in fact continue to rise for at least another 50 or 100 years or more. This will happen even if humanity greatly reduces future greenhouse gas emissions in order to avoid even greater climate change. There is an unprecedented consensus among international scientific groups regarding the effects of these greenhouse gases on future climate. The Intergovernmental Panel on Climate Change indicates that it is virtually certain that climate over land will warm in the future, with best estimates being that global temperatures will increase by 1.8 to 4.0 °C (3.2 to 7.2 °F) by the year 2090-2099 (relative to 1980-1999 levels). Warming is expected to be greater at high latitudes, and in Minnesota warming is anticipated to be approximately twice as great as the global mean rise.

The best scientific estimates are for Minnesota to have summers 7 to 16 °F warmer by 2095 (compared to 2000) and winters 6 to 10 °F warmer by 2095. Those represent enormous climate shifts in a relatively short time period. Moreover, the average temperatures are not the only ways in which climate will change. It is believed to be very likely that rainfall and storms will get more intense (i.e., a greater fraction of precipitation will fall in fewer events) and that droughts will occur more often and cover more area than at present.

While the specific regional impacts of climate change are still being studied, it is extremely likely that climate change will interact with and amplify all of the other drivers described above to intensify their impact on all of the state's resources. For example, climate change is expected to affect the frequency and intensity of wildfires and wind-storms, and the spread of agricultural and forest diseases and insect pests (both native and exotic). Minnesota's geographic location at the interface of the three great North American biomes—tallgrass prairie, eastern deciduous forests, and northern boreal forests—also makes it much more sensitive to potential climate change than a region embedded in the center of a large biome.

Climate change will have direct effects on Minnesota's resources as well. Global warming will directly impact agricultural crops, forests, wetlands and other vegetation communities. Historically rapid climate change in this century has resulted in existing Minnesota vegetation being mis-matched with their finely tuned temperature adaptations – in other words, they will live in habitats to which they are no longer as well suited climatically. Exactly how badly mis-matched vegetation will be is not yet known.

The issue is more challenging for long-lived perennial vegetation that dominates forests, grasslands, and wetlands. Climate change could negatively impact the state's natural vegetation if higher temperatures and associated temperature and moisture extremes cause physiological stress, and if species are unable to migrate north and/or east fast enough to keep up with the rate of climate change. It is likely that in the northern forests, spruce, fir, and birch will diminish and be steadily replaced by oaks and maples if the climate is relatively moist, or by scrub oak if it becomes drier. Cold-adapted fish and wildlife species, such as lake herring and moose, are also likely to decline or disappear, and adverse impacts on many northern species are possible, and in fact, likely. Minnesota may lose its cold water fish, its winter sports, and a good portion of its tourism economy. The very natural resources we manage for, and the ways in which we manage them, may need to change radically in the next 50 to 100 years, and we need to begin now the careful deliberations necessary to do so intelligently, effectively and in an informed matter.

Climate change should be considered as a fact from a policy standpoint. To effectively manage in the face of climate change will require understanding of the potential bounds of that change, the implications of such change, and the alternative strategies we could employ to optimally sustain our natural and economic resources into the distant future.

Public Engagement and Outreach

The major public engagement effort will come in phase II of the project – when the public and environmental stakeholder organizations will have the benefit of the well-organized scientific information of the Preliminary Plan to base their input on. During the project's second phase it will:

- Hold focused conversations with a broad range of stakeholder groups about Preliminary Plan information and the development of final plan recommendations; and
- Link the Preliminary Plan information to the development of statewide environmental scenarios by the Minnesota 2050 project.

Meanwhile, the SCPP project team has undertaken a number of efforts to lay the groundwork for connecting with interested citizens and stakeholder groups across Minnesota regarding the development of the SCPP.

First, a project website has been established (www.mnconservationplan.net). The site contains information about the project (purpose, structure, contact information) and invites visitors to get involved during the planning process. The site will provide public access to plan materials as they become available, and will provide an easy way for stakeholders to provide feedback on these materials.

A project brochure has been designed and printed, and is being distributed at stakeholder meetings (e.g. The Minnesota Sustainable Tourism Conference and the State Fair).

A database of stakeholder organizations has been created. These organizations have agreed to relay information about the SCPP project (news releases) to their memberships. The first news release went out in May, and focused on the launch of the web site as a platform for stakeholder input and a way for stakeholders to monitor the project's progress.

To leverage its outreach budget to the greatest extent possible, the preliminary plan phase partnered with public outreach efforts by the Minnesota 2050 project and the Campaign for Conservation. Each effort involved a series of workshops inviting members of the public to articulate their visions for the future of Minnesota's natural heritage. See Appendix VI for more on these outreach efforts.

Preliminary Funding Priorities

As part of the Preliminary Plan process, the project team was asked to provide an initial set of recommendations to inform the LCCMR's 2007 request for proposals. Each resource team reviewed the data that had been collected, identifying current trends in the condition of the resource, key issues (drivers of change) related to that resource, and issues that affected more than one resource. Based on this review and the collective expertise of the participants, the project team recommended that the LCCMR focus funding priorities on these key areas:

- Identify, protect and manage land areas that provide benefits to multiple natural resources.
- Establish statewide habitat corridors using consistent methodology and criteria.
- Acquire important data on a regular basis (e.g., LIDAR, parcel and land cover).
- Manage development to decrease effects on natural resources.
- Increase understanding of potential effects of climate change on natural resources.
- Increase understanding of effects of contaminants on natural resources.

Please see Appendix III for more detail on these preliminary recommendations.

> ***"[In 2050] we did walk through the area's state park to see the last Norway pine. The unique thing about the tree it now has leaves and not needles."***
>
> ***—Minnesota 2050 Project participant***

Air

Land

Wildlife

Water

Fish

Outdoor Recreation

Natural Resource Profiles

Statewide Conservation and Preservation Plan
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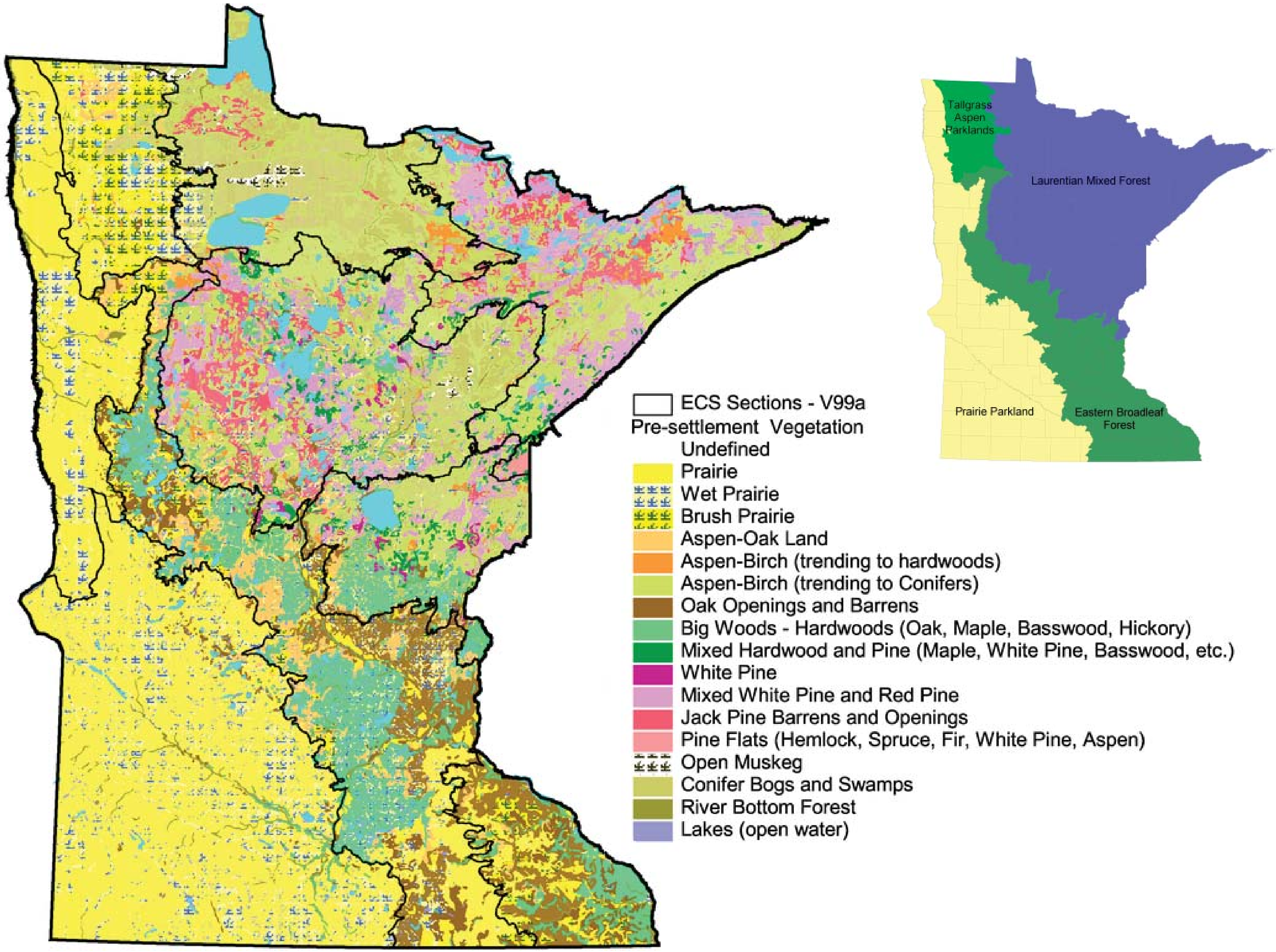


Figure 1: Map of Pre-settlement Land Cover based on Marschner's Map. Credit: Terry Brown, University of Minnesota.

Natural Resource Profiles Overview

During the first phase of the Statewide Conservation and Preservation Plan process, project team members compiled profiles for Minnesota's natural resource areas: air, land, wildlife, water, fish, and outdoor recreation. These groups of experts reviewed existing documents and data to:

- Establish a "baseline" condition for the resource (most often, the pre-settlement condition – see Figure 1, facing page);
- Assess the current condition of that resource, and the trends that got it there; and
- Determine the "drivers of change" propelling those trends.

Understanding these drivers of change is a critical prerequisite to making science-based projections of the likely future state of the resources, and descriptions of these drivers of change are therefore a large component of the natural resource profiles that follow. As described in this section, drivers of change can be both "proximate" (i.e. close to the actual impact on the resource, such as loss of land habitat, or the loading of solids into water systems), and "higher order" (such as land development choices and climate change). Within each profile, the analysis begins with the proximate drivers of change, which are discussed starting with drivers that have the greatest overall impact on the resource followed by drivers that have successively less influence. Connections from these drivers to higher order drivers are then made.

Certain drivers such as habitat degradation show up within several resource profiles. Cross-cutting drivers are an attractive target for policy and investment actions since the benefits of these actions will flow to multiple resources. The identification of these cross-cutting drivers was a major step in forming the project's recommendations on possible issues for investigation in the second phase of the project.

As these profiles were being created, the project team was receiving input from the public via the Minnesota 2050 project and the Campaign for Conservation survey (see the Introduction). Not surprisingly, Minnesotans appear to be well-connected to their natural environment and quite conversant with the conservation issues confronting the state, as illustrated by the quotes from participants found at the end of each profile.

The general structure of each natural resource profile is:

- A short description of the history of the resource in Minnesota
- Discussion of drivers of change:
  - » Definition of the proximate driver
  - » Connection to higher order drivers
  - » Influence of the proximate driver on the resource in Minnesota
  - » Identification of gaps in knowledge and opportunities for research

"Our schools will teach and practice the needs for sustainability beginning in kindergarten"

—Minnesota 2050 participant

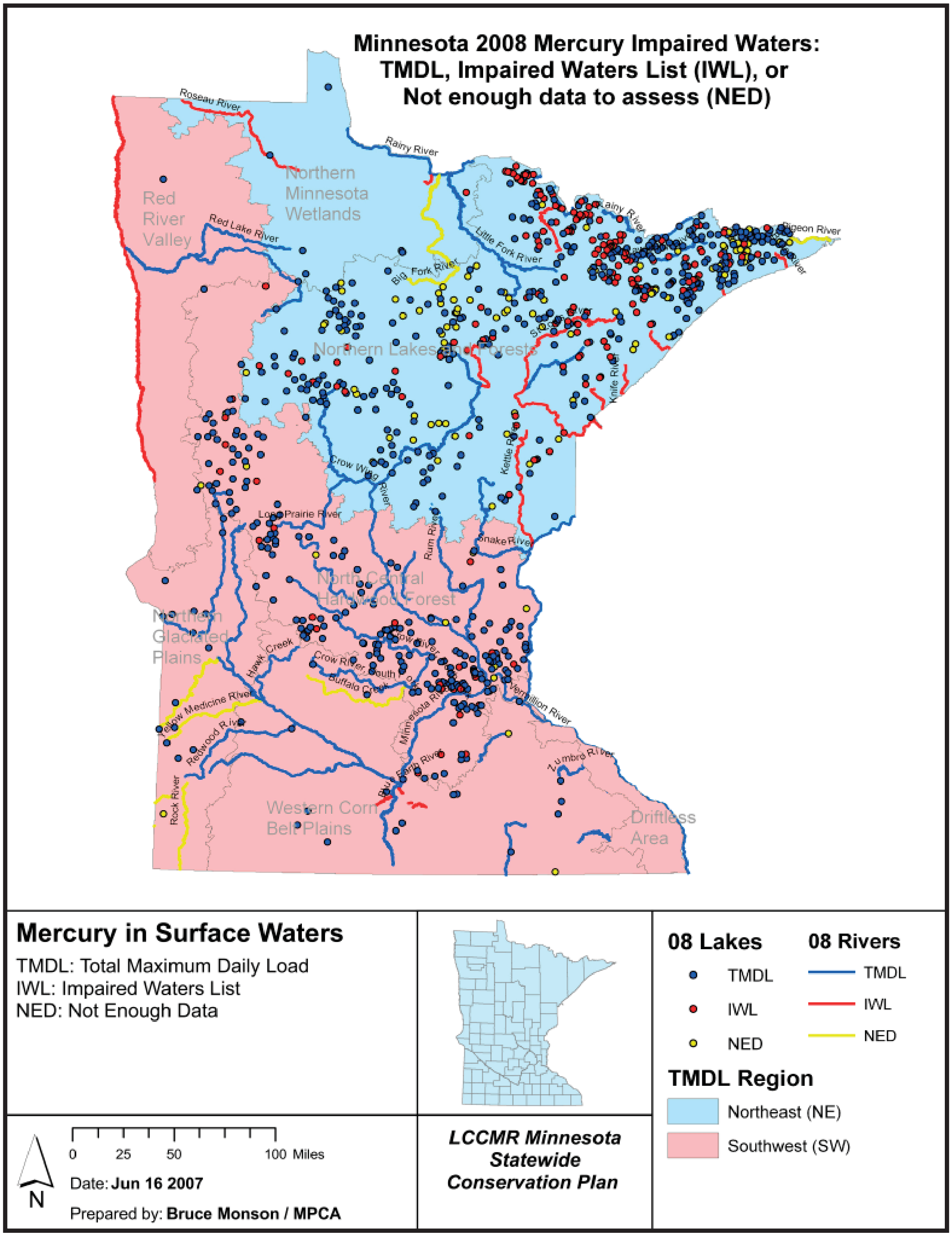


Figure 1: Mercury Impaired Waters in Minnesota. Poor air quality not only has direct effects on the health of Minnesota residents, but air-borne pollutants also impair other natural resources. Mercury emissions, for example, have had a widespread and severe negative impact on Minnesota's waters. Credit: Bruce Monson, MPCA.

"Air pollution is the inevitable consequence of neglect. It can be controlled when that neglect is no longer tolerated. It will be controlled when the people of America, through their elected representatives, demand the right to air that they and their children can breathe without fear."

—Lyndon Baines Johnson

History

The air resource is in its best state when it's unnoticed in the day-to-day lives of Minnesotans. Pollution in the form of smog, smell, and noise all contaminate the air resource and can diminish its benefit to people's lives. Choices made at the state level, in particular energy and transportation choices, impact air quality to the point where it does become noticed, with impacts on the lives of Minnesotans ranging from nuisance to health-risk.

Air is a free-flowing resource that knows no political boundaries. The energy and transportation choices of other states affect our air quality in Minnesota, while our policy choices can can have an impact on air quality elsewhere. This lack of problem containment can be a challenge to policymakers attempting to improve air quality in Minnesota. However, there are direct policies that, when adopted, can protect and increase the quality of air for all Minnesotans.

Air is an important resource whose quality has far-ranging impacts in Minnesota. The respiratory health of Minnesotans, particularly children, is affected by air particulates, ozone levels, and other air pollutants. According to the Minnesota Pollution Control Agency (MPCA), air pollution can contribute to cancer, heart attacks and other serious illnesses. A 2003 study by the federal Office of Management and Budget noted that the estimated value of the health benefits of cleaner air is often several times the cost of making air pollution reductions.

Air pollution has wide-ranging impacts on land and water resources in Minnesota, as well. Mercury, an air pollutant from burning fossil fuel sources like coal, is deposited in lakes and rivers through precipitation (see Figure 1, facing page). It then contaminates aquatic ecosystems, fish, and humans who consume them.

The health of portions of Minnesota's economy depends on the air quality of the region. The contamination of fish by mercury from coal-fired power plant emissions hurts fishing-based tourism. Scenic landscapes blurred by smog negatively affect tourism. In the agricultural sector, air pollution can cause lower crop yields. Forests that are impacted by air pollution may be less resistant to invading pests and disease.

Baseline Air Quality Conditions in Minnesota

Air is comprised mainly of the elements nitrogen (78%) and oxygen (21%), with very small amounts of argon, carbon dioxide and other trace gases. It is reasonable to assume that air quality at the time of European settlement was excellent, with the exception of the impacts of occasional fires caused both by lightning and prairie fires deliberately set by humans.

Air Quality Trends (1985-present)

Air pollutants can be categorized by their source, or by the regulatory structure of the federal Clean Air Act. The Clean Air Act regulates "criteria" pollutants (lead, nitrogen oxides NOx, and sulfur oxides SOx) particulate matter (PM_{10} and $PM_{2.5}$, particulates

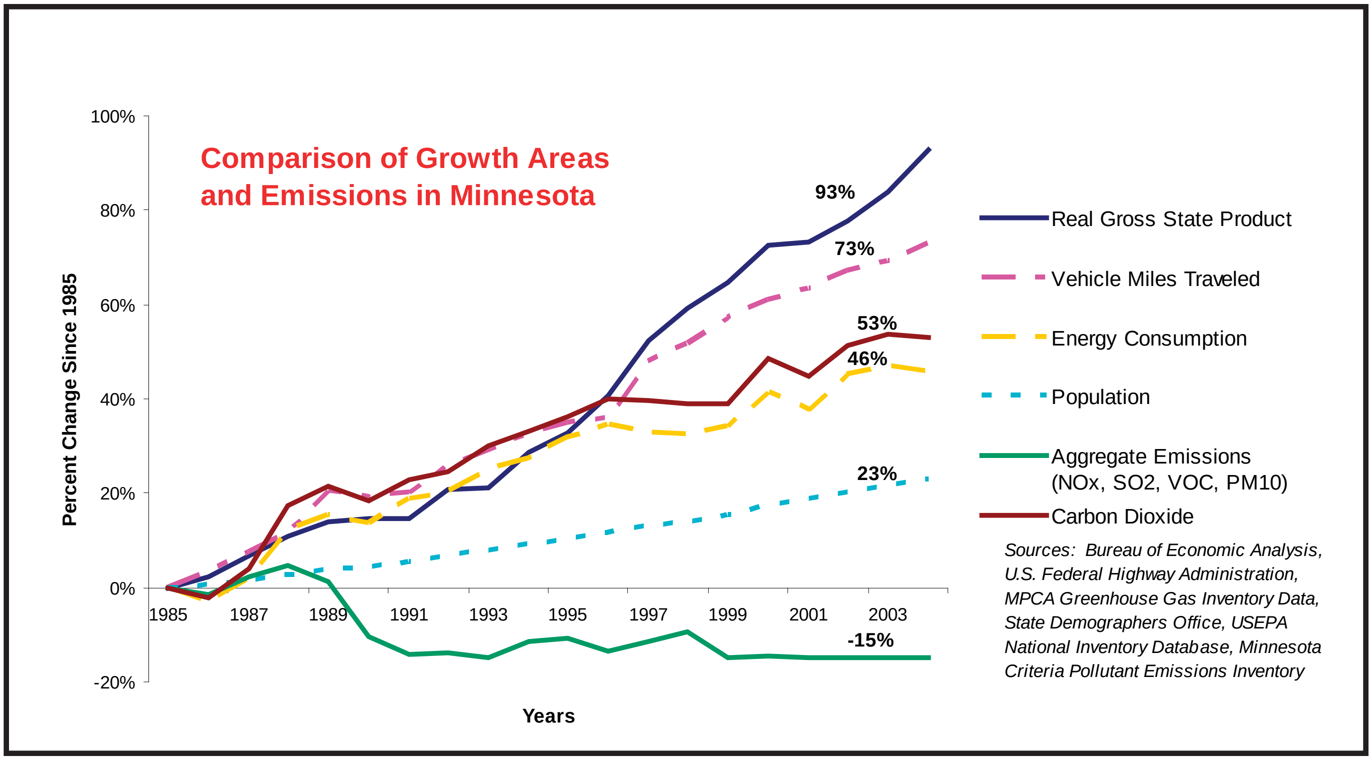


Figure 2: Comparison of economic and emission growth factors in Minnesota from 1985 to 2005. Credit: MPCA

less than 10 μm and 2.5 μm respectively), carbon monoxide (CO), and ozone (O_3). These compounds have National Ambient Air Quality Standards (NAAQS) that specify the maximum concentration that is allowed in ambient air for protecting public health and materials. In addition, the Clean Air Act regulates an additional 188 hazardous air pollutants, often called "air toxics". These compounds are regulated based on allowable emissions, rather than resulting air concentrations. Carbon dioxide (CO_2), the primary greenhouse gas responsible for global warming, is not currently regulated by the Clean Air Act.

The main driver of air quality change is the consumption of energy, and in Minnesota, the top two drivers of energy consumption are electrical power generation and transportation (see Drivers of Change, below). While Minnesota's energy consumption for electricity and transportation has increased, progress has been made on air quality with regards to specific pollutants over the past twenty years (see Figure 2). Minnesota's real gross state product grew 93% between 1985 and 2005, with corresponding growth in the number of vehicle miles traveled, energy consumption, and population. On the plus side, due to pollution control measures, the aggregate emissions of pollutants such as NOx, SOx, volatile organic compounds, and particulate matter – all of which are covered in the state's implementation plan under the federal Clean Air Act – have actually decreased 15% during that time period.

During that same time period, however, CO_2 emissions have increased 53%. While the state has successfully reduced aggregate emissions of "criteria" pollutants, the growth of carbon dioxide emissions and the resulting exacerbation of climate change is one of the top air quality challenges for the state.

Current Air Quality in Minnesota

The Air Quality Index (AQI) is a tool developed by the United States Environmental Protection Agency (USEPA) to provide a standard method for reporting daily air quality conditions around the country. The AQI number is reached by hourly measurement of four pollutants: ground-level O_3, SO_2, CO and $PM_{2.5}$. The pollutant with the highest value determines the AQI for that hour.

According the MPCA, air quality in Minnesota is usually ranked as Good, Moderate or Unhealthy for Sensitive Groups with an occasional Unhealthy For All ranking. Air Pollution Health Alerts are issued for one (or more) of the four pollutants based on monitoring or forecasting from weather patterns. More alerts for Unhealthy for Sensitive Groups and Unhealthy days are expected in the future as a result of the tightening of the daily O_3 and $PM_{2.5}$ standards by the USEPA. Minnesota currently meets all National Air Quality Standards set by the USEPA.

In the Twin Cities area, three air quality alerts for Sensitive Groups were issued in 2006. Rochester experienced two days of Unhealthy for Sensitive Groups. No other alerts were issued in 2006.

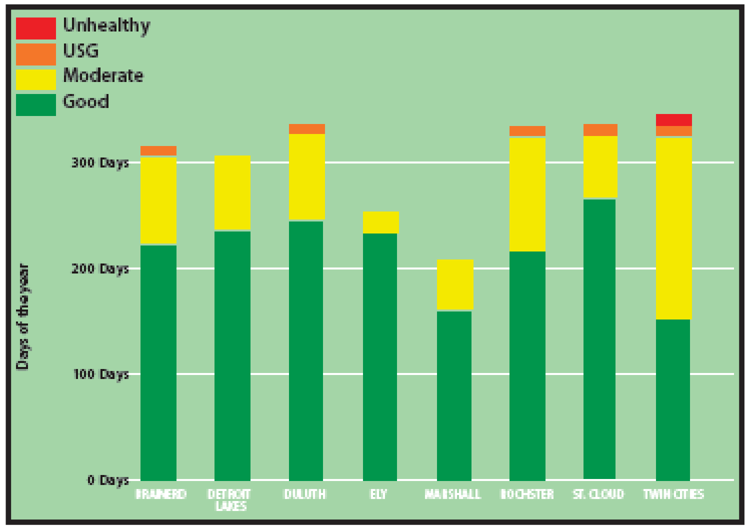


Figure 3: The Air Quality Index (AQI) is measured at locations around Minnesota. Some regions do not show 365 days of readings due to monitoring problems or the phase in timing for new region. Credit: MPCA

In 2005, the cleanest air was in Ely with nearly all Good air days and only 19 Moderate days. The worst air quality was in the Twin Cities with more Moderate days than Good, five Unhealthy for Sensitive Group days and three days that were considered Unhealthy for All (see Figure 3).

Minnesota has been a leader in monitoring concentrations of air toxics, and controls their point source emissions as much as possible through the state's air permit system. A number of studies have been conducted by the MPCA to assess air toxics across the state and in the Metro area. Their most recent study (2005) analyzed the results of monitoring 73 toxic air pollutants, and found that benzene, formaldehyde, and carbon tetrachloride were the only toxics that were found above the health benchmark concentrations during the period of 1995-2001. (For more information, see http://www.pca.state.mn.us/air/toxics/at-monitoringstudy-9601.html). Since then, the concentrations of benzene and carbon tetrachloride have decreased below the health benchmarks. The major source of formaldehyde is from direct and indirect emissions of gasoline powered vehicles.

Drivers of Change

The main drivers of change for outdoor air quality in Minnesota (and nationally) are

- electrical power generation;
- and transportation.

These drivers of change affect our climate, human health, ecological health, and other valued features of our society.

Electrical Power Generation

As Minnesota's economy and population have grown, so too has the state's energy consumption, which in turn has led to sharp increases in electrical power demand. This increase in demand has been largely met by coal-fired power plants. In 2004, 65% of electricity generated in Minnesota was derived from coal (see Figure 4, next page). The next largest sources of electricity generation were nuclear power (25%) and natural gas (3%).

Carbon dioxide (CO_2) is a greenhouse gas that forms from combustion reactions such as burning coal for electricity or powering a gasoline engine vehicle. When released into the atmosphere, CO_2 acts as a greenhouse gas and is the most significant human contribution to global warming. Carbon dioxide

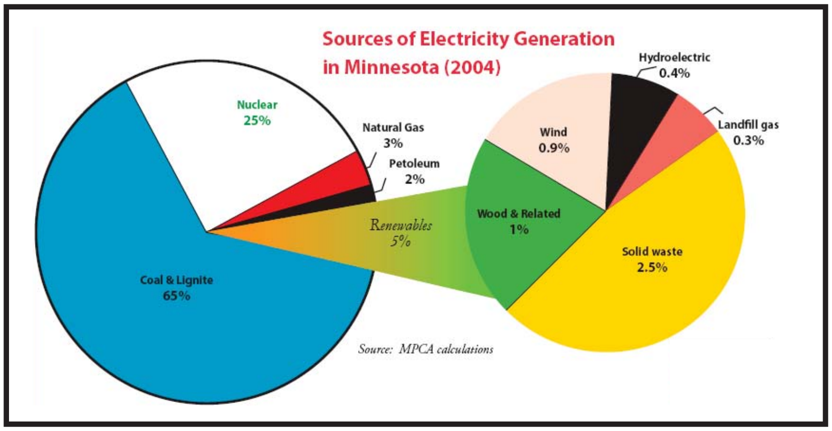


Figure 4: Sources of Electricity Generation in Minnesota for 2004. Credit: MPCA

accounts for three-fourths of all greenhouse gas emissions, both in Minnesota and the nation as a whole.

Most scientists agree that the full impact of climate change will be felt in the future (see the Intergovernmental Panel on Climate Change, 2007 Working Group 1 report). However, over the last 100 years, mean annual temperature in Minnesota has increased about one degree Fahrenheit. This temperature increase is not evenly distributed throughout the four seasons – change has been most pronounced in the winter and spring seasons. On average, the winter season is about four degrees Fahrenheit warmer than in the late 1800's.

Electricity generation accounts for approximately one-third of all CO_2 produced in Minnesota. The vast majority of this CO_2 is from coal-fired power plants. An increased reliance on coal-fired power plants, plus emissions from other sectors of the economy, has increased carbon dioxide emissions in Minnesota (see Figure 5).

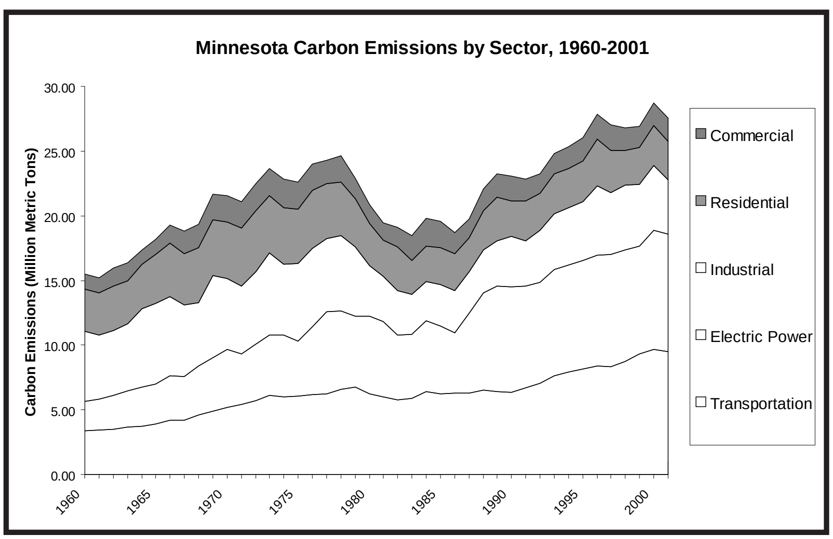


Figure 5: Carbon emissions by sector. Credit: Max Handler, University of Minnesota

Mercury Pollution

Another air pollution problem resulting from electrical generation sources is the emission of the air toxic, mercury. Although mercury pollution effects are manifested through fish contamination (see Water Natural Resource Profile), the problem originates as an air contaminant. When mercury is emitted to the atmosphere by coal-fired power plants, it is eventually deposited into waterways through precipitation. It reaches the sediments where microbes transform it to methylmercury. Methylmercury bioaccumulates in fish, and in humans and wildlife when they consume methylmercury-contaminated fish.

Methylmercury has been linked to birth defects in infants whose mothers had consumed contaminated fish. Impacts on cognitive thinking, memory, attention, language, fine motor, and visual spatial skills have been observed in children exposed to methylmercury as fetuses. A study by the Center for Disease Control shows that most people have blood mercury levels below a level associated with possible health effects. However, pregnant women and women who plan to become pregnant are advised by the EPA and FDA to limit consumption of certain fish.

Nearly two-thirds of Minnesota's impaired waterways, as defined by the federal Clean Water Act, are impaired because of mercury levels (see Figure 1, page 18). As a result, most of the state's lakes have fish consumption advisories.

The MPCA estimates that total mercury emissions from sources in Minnesota were about 3,340 pounds of mercury in 2005. Energy-related sources (mostly coal-fired power plants) made up 58% of these emissions.

To address the state's largest emissions sources, the state legislature passed the Mercury Reduction Act of 2006. The act requires three large electric power plants in the state to reduce emissions by 90 percent by 2014. This will result in a decrease in emissions of about 1200 pounds of mercury from current levels, a reduction of about 70%. About one-third of the mercury being added to Minnesota's environment by the power industry will be eliminated.The plants affected are: Xcel Energy's Sherco Plant in Becker; Xcel Energy's Allen S. King plant in Oak Park Heights' and Minnesota Power's Clay Boswell plant in Cohasset.

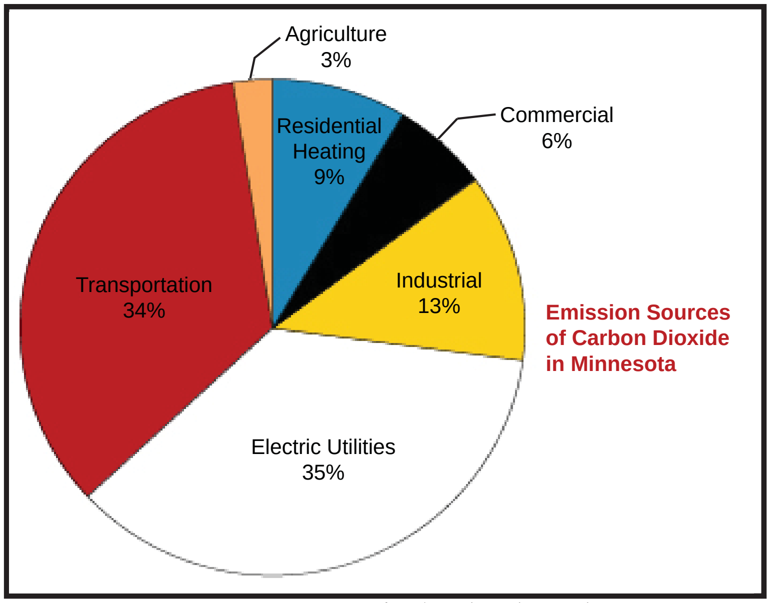


Figure 6: Emission sources of carbon dioxide. Credit: MPCA

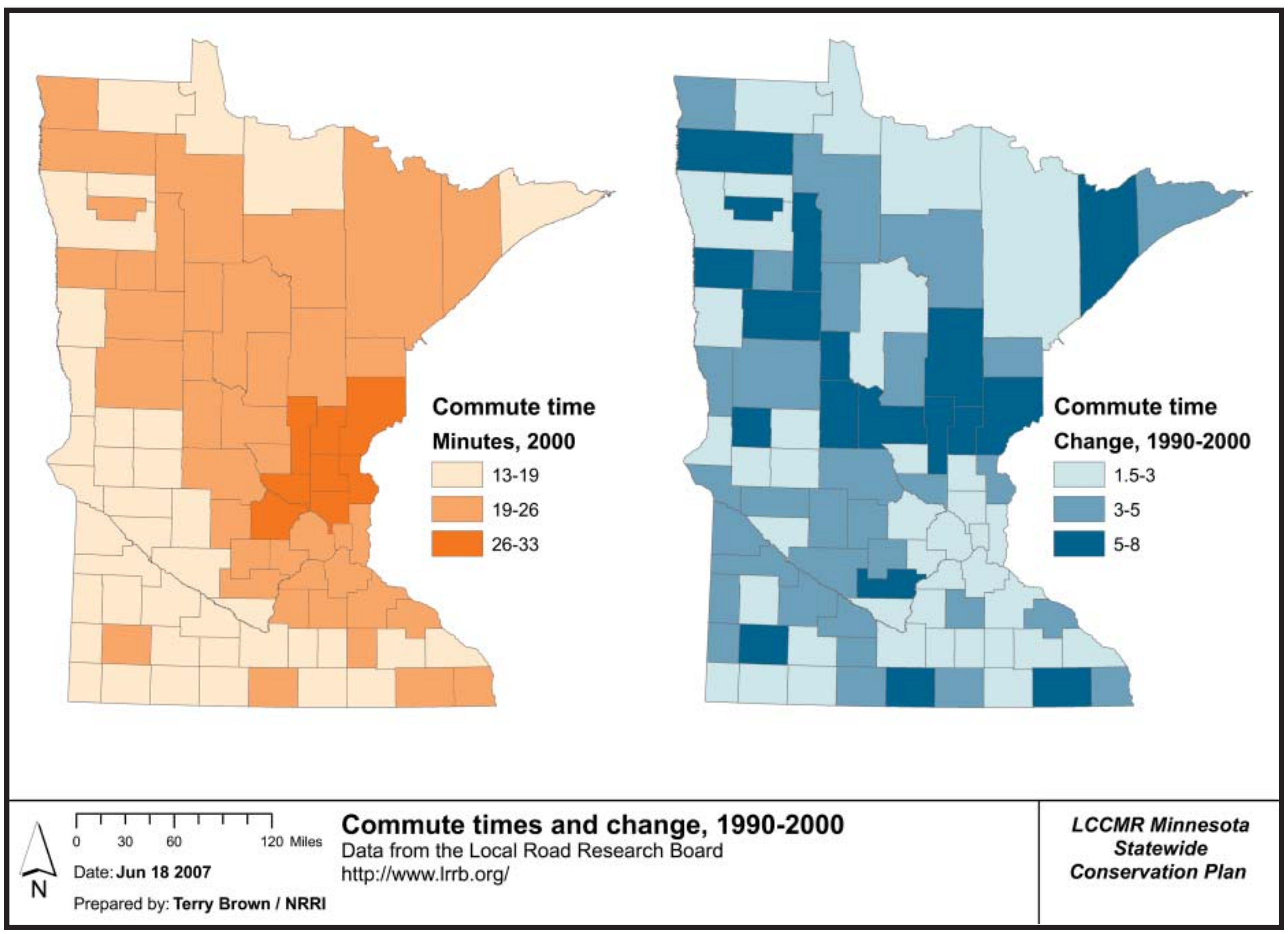


Figure 7: Change in Commute Times (1990-2000); Average Commute Time by County (2000). Credit: Terry Brown, University of Minnesota

Transportation

From 1985 to 2005, the numbers of miles driven by vehicles in Minnesota increased 73%. The carbon dioxide emitted from these vehicles also has contributed to climate change in Minnesota. Vehicles also emit CO, PM, NOx, and contribute significantly to tropospheric O_3 formation. About one-third of greenhouse gases emitted in Minnesota are a result of transportation (see Figure 6).

In addition to the increase in miles driven, traffic congestion and longer vehicle idling times contribute significantly to carbon dioxide emissions.

The map of commute times (see Figure 7) indicates that the counties north of Minneapolis/St. Paul, east of St. Cloud and South of Duluth had the longest average commute times in 2000.

Emissions from vehicles contribute to many health problems including: aggravated asthma; chronic bronchitis; reduced lung function; irregular heartbeat; heart attacks; and premature death in people with existing heart and lung conditions. Reducing emissions can lead to lower health care costs and fewer days that Minnesotans with these health conditions miss work or school.

Hybrid and flex-fuel vehicles that use less petroleum gasoline and/or use alternative fuels like ethanol and biodiesel emit less carbon dioxide than traditional gasoline vehicles.

Indoor Air Quality Issues

Concentrations of many contaminants are often greater indoors than in ambient air. People also tend to spend a majority of their lives indoors. Indoor air contaminants such as volatile organic compounds and radon impact human health. Surprisingly, there are fewer data sets available on indoor air quality compared to outdoor air quality. Information on indoor air quality and human exposures is a relevant data gap that the team recommends for further research.

"In 2050, electricity will be produced in more efficient and environmentally sound ways."

—Minnesota 2050 participant

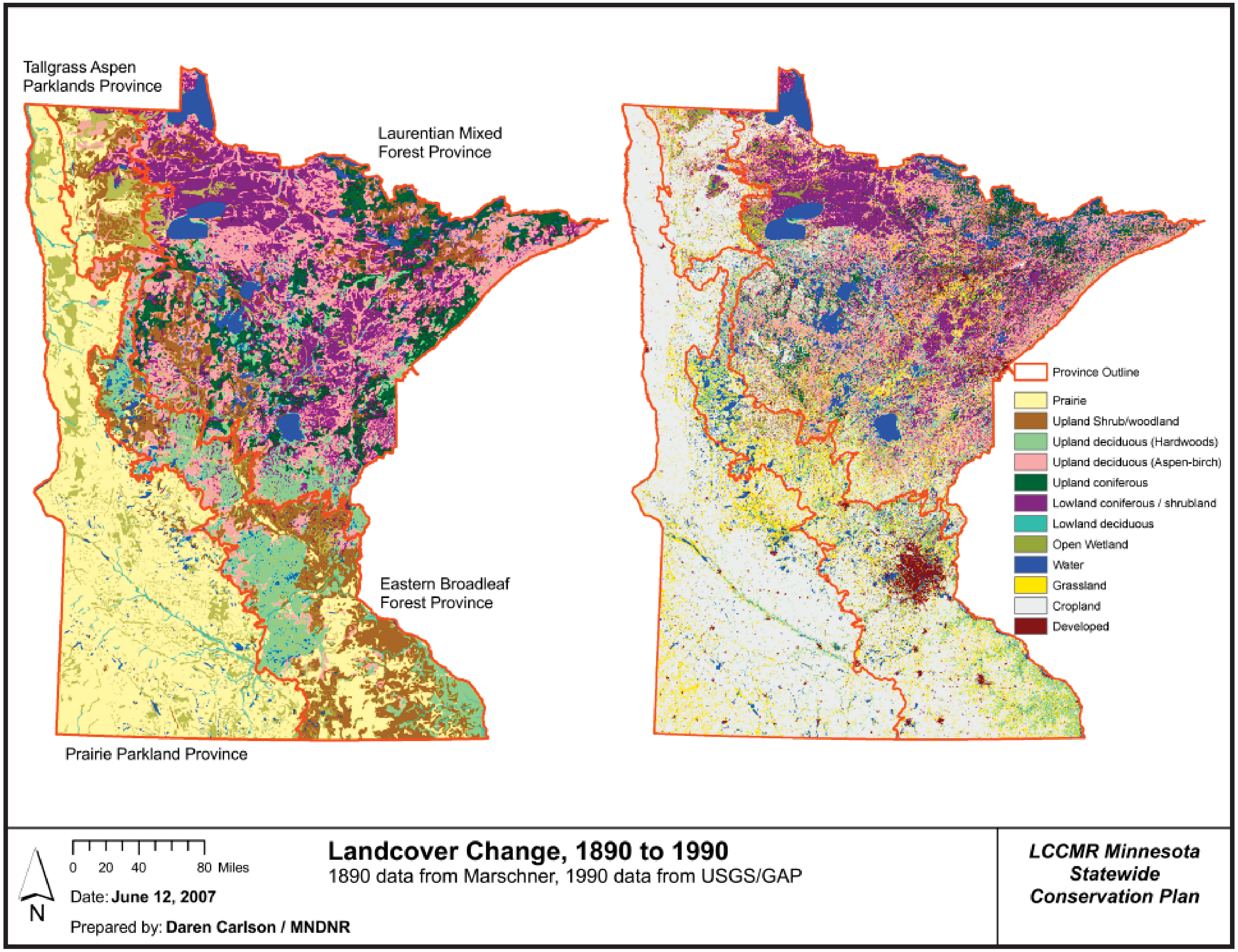


Figure 1: Marschner's Map of vegetation around the time of European settlement and contemporary landcover based on 1990 GAP data.
Credit: Daren Carlson, Minnesota DNR

"Examine each question in terms of what is ethically and esthetically right, as well as what is economically expedient. A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends to do otherwise."

—Aldo Leopold, *Sand County Almanac*

History

For purposes of this report, the land resource is defined as soils, land cover, with a particular emphasis on the four dominant vegetation associations as well as developed land uses, and the underlying geology across the entire state of Minnesota. Land also shows evidence of change induced by 'drivers' including both natural and constructed or engineered processes. The land resource:

- Provides food, fiber, shelter and energy.
- Is the source of diverse biological and physical key resources for human use and appreciation, including outdoor recreation.
- Is the source of biological and physical resources for other animals.
- Provides industrial raw materials, including timber and mineral resources which are the basis for major industries.
- Is a key component of the state's hydrology and water resources, including water storage (on the land with surficial lakes, or within the soils and geologic resource as groundwater, and bedrock aquifers) and transport (rivers and streams).

The land provides habitat for diverse plants and animals valued by humans for their use, beauty and increasingly the ecosystem processes and environmental services (e.g., clean water, productive soils, biodiversity, etc.) we have come to depend upon. The primary focus here is on the conservation of habitat values, productivity, processes and services of the Land resource.

Broadly speaking, there are five major categories of land cover/land use types in Minnesota:

- Agricultural
- Forest
- Grassland and Prairie
- Mining
- Developed - Residential/commercial/industrial/ roadways

At the time the first European settlers arrived, Minnesota offered a rich and diverse landscape. Early settlers in southern Minnesota found the tall-grass prairie stretching across the southwest half of the state. Arid bluffs supported species adapted to the scorching summer heat, drying winds, and thin gravelly soil, while depressions on the rolling land below supported pockets of wetland. Fire was a regular visitor to the prairie, maintaining the open grasslands.

Further north, the landscape was more rolling, the climate more moist, and fires less frequent. Because of reduced fire frequency, trees dominated the landscape. Oak woodlands marked the transition between prairie to the southwest and the oak, elm, and sugar maple forests of central Minnesota. Mixed conifer-hardwood forests dominatws in north-central and northeastern Minnesota.

The state was a mosaic of prairie, mesic hardwood forest, and mixed conifer-hardwood forest stretching in bands trending roughly from the southeast to the northwest across the state. The particular plant community present at a given location was the result of a complex interaction of many factors, including soils, topography, slope, aspect (the direction a site faces), local weather patterns and regional climate, hydrology, and the history of major and minor disturbance —including fire, windthrow, and the presence or absence of large grazers such as elk and bison. The vegetation at the time of European settlement is shown in Figure 1, page 26.

Cover Type	Acres (1890)	Acres (1990)
Cropland	0	23,981,079
Grassland	0	5,109,924
Developed	0	599,675
Open Wetland	4,163,031	2,074,773
Lowland Conifer/shrubland	6,639,649	5,350,747
Prairie	15,677,426	27,632
Upland Shrub/Woodland	6,383,580	1,031,659
Upland Deciduous (Aspen-birch)	8,362,227	7,053,315
Upland Deciduous (Hardwoods)	4,388,564	2,179,753
Total Acres*	**48,774,203**	**49,073,973**

Table 1: Change in cover type between the dates of the General Land Office Survey (circa 1848-1907, depending on the region of the state) and 1990 GAP landcover. Source: Daren Carlson, Minnesota DNR. Note: Total Acreage amounts differ primarily to increased mapping accuracy and/or change in the amount of open water area; open water acreages are not included in the cover type data.

With the advent of European settlement, existing plant communities and patterns of interaction on the landscape (both human and natural) were disrupted, and the patterns of disturbance permanently altered. The land resource became the foundation of the Minnesota economy. Logging, land clearing, settlement, agriculture, mining and urban development became part of our history and changed the landscape forever. It should be noted that the pre-European settlement was not devoid of human impact, notably by Native Americans. Today we continue to seek a broader understanding of these historic landscapes and the factors that shaped them.

At the time of settlement, the entire state was, with the exception of Native American villages, a matrix of native plant communities. Today, satellite land-cover analysis has identified approximately 19 million acres of native and semi-native habitat remaining in the state, less than half of the original landcover. Of this acreage, only a small percent (e.g., 5% of the area surveyed to date) meet the high standards necessary to be included in the Minnesota County Biological Survey maps of native plant communities. The remaining sites in the survey areas are of lower quality, or represent non-native plant communities that have developed since European settlement in response to new and altered disturbance regimes.

There are slightly over 2,000 plant species documented as occurring in the state; almost 20% are introduced, either from other countries or from outside the Midwest. Of the native species, 256 are state listed as Special Concern, Threatened, or Endangered. Two, the Minnesota dwarf trout lily (see "Trout Lily", facing page) and Frenchman's bluff moonwort, are known to occur only in select locations in Minnesota and nowhere else on earth. These endemic species are especially vulnerable to extinction.

The land resource today provides recreational and economic opportunities for many. However, the land resource is impacted to a very broad degree by many of the drivers of change to the state's other natural resources. Moreover, it is perhaps one of the slowest to recover from various stressors. This is because the time needed to restore all aspects of a complex ecological system such as a prairie is far greater than the time needed to regenerate a specific resource such as a tree. Still other resources are not renewable on a practical timescale; this includes mineral resources and some soil resources.

The key factors that are driving change in the land resources are discussed in the following sections. Recommendations to address long-term conservation of the resources are provided in a separate section of this report and at the end of each section.

Drivers of Change

- Habitat Degradation
  - Fragmentation
  - Altered Natural Disturbance Regimes
  - Invasive Species
- Soil Erosion
- Consumptive Use
- Contaminants
- Changes in Soil Structure
- Soil Nutrient Loading
- Increased Carbon Dioxide

Habitat Degradation

The land uses noted previously imply different types, frequencies, and degrees of disturbance, both natural and human in origin. For example, disturbance on reserved forest is primarily natural in origin and infrequent. For example, forests managed for economic purposes have regular, designed disturbances and shorter periods between disturbance compared to the natural frequency. Disturbance in protected forest is primarily natural in origin and typically occurs less frequently than in managed systems.

The subject of habitat degradation is treated broadly here, and includes a variety of factors that contribute to the deterioration of habitat quality. Permanent loss of habitat due to an irreversible land cover conversion is also discussed under Consumptive Use.

Degradation of habitat, defined here as a decline in its quality, can occur when any specific land cover type is altered. Cause of habitat degradation may include: invasion by noxious exotic or native species, extreme climate events, and temporary or permanent changes of use. Sometimes the change may be temporary and by degree, e.g., forest thinning, with regrowth following. In this example, the area remains forest, but habitat values shift to those of a less dense or younger forest. In other cases, the change may be permanent. Note that alterations of ecosystems, such as restoration, can improve habitat quality—thus modification is not by default negative. Additionally, habitat quality is context dependent- the "appropriate" habitat in any given area depends on societal priorities.

Below are additional factors that are sometimes associated with Habitat Degradation.

Trout Lily
Like all native species, the Minnesota dwarf trout lily has its own specific niche in the ecosystem and relationships to other plants and animals with which it lives. As such, it is a part of the whole, a part whose unknown utility is best expressed in the words of Wisconsin conservationist Aldo Leopold: "The first rule of intelligent tinkering is to save all the parts. The unique genetic information in each species is potentially valuable to all of us. Alkaloids from many wild plants are active ingredients in medicines and other useful products. Loss of the dwarf trout lily would eliminate forever the potential for such benefits. [The dwarf trout lily possesses a genetic and chemical makeup unlike that of any other plant. The dwarf trout lily is found in 3 counties in south central Minnesota and nowhere else in the world.] —from US Fish and Wildlife Service Website. Credit: Welby Smith, Minnesota DNR

Habitat Degradation - Fragmentation

"Fragmentation" describes the degree to which natural land cover types are broken into smaller patches interspersed with non-natural land cover types. Sources of fragmentation can be natural or human-induced; a few examples include the breakup of landscapes by natural disturbance (e.g., windstorm, fire), and human induced processes such as road building and development.

Research has shown that forest areas bordering non-forest vegetation are often warmer and drier, more likely to be affected by wind, and more likely to be invaded by non-native species. This is termed the "edge effect." Similarly, as the amount of fragmentation increases, habitat is created for species adapted to edge conditions, while plant and animal species that require the cooler, more moist conditions in the forest interior experience habitat reductions.

As fragmentation increases and the non-native areas between forest areas increase, these non-native areas can become barriers to animal movement, and can also serve to isolate native plant populations. These isolated populations can be more vulnerable to local extinction, and may suffer from genetic isolation if populations are too far apart to facilitate movement or cross pollination. This can be of significant concern on prairie remnants in Minnesota, which are often very isolated from each other. Corridor plans, such as the one undertaken in the Blue Earth Watershed, are an attempt to overcome some of the effects of fragmentation by identifying areas most suited to habitat restoration (see Figure 2).

Agriculture has historically been the leading source of fragmentation in Minnesota, especially in the agricultural southwest, but also in the forested northeast. Roads development has overtaken agriculture as the leading cause of forest fragmentation in the state. Forest parcelization is also increasing, and may lead to fragmentation. From 1989 to 2003 there was an 18% decrease in the size of forested parcels sold with more than half of the

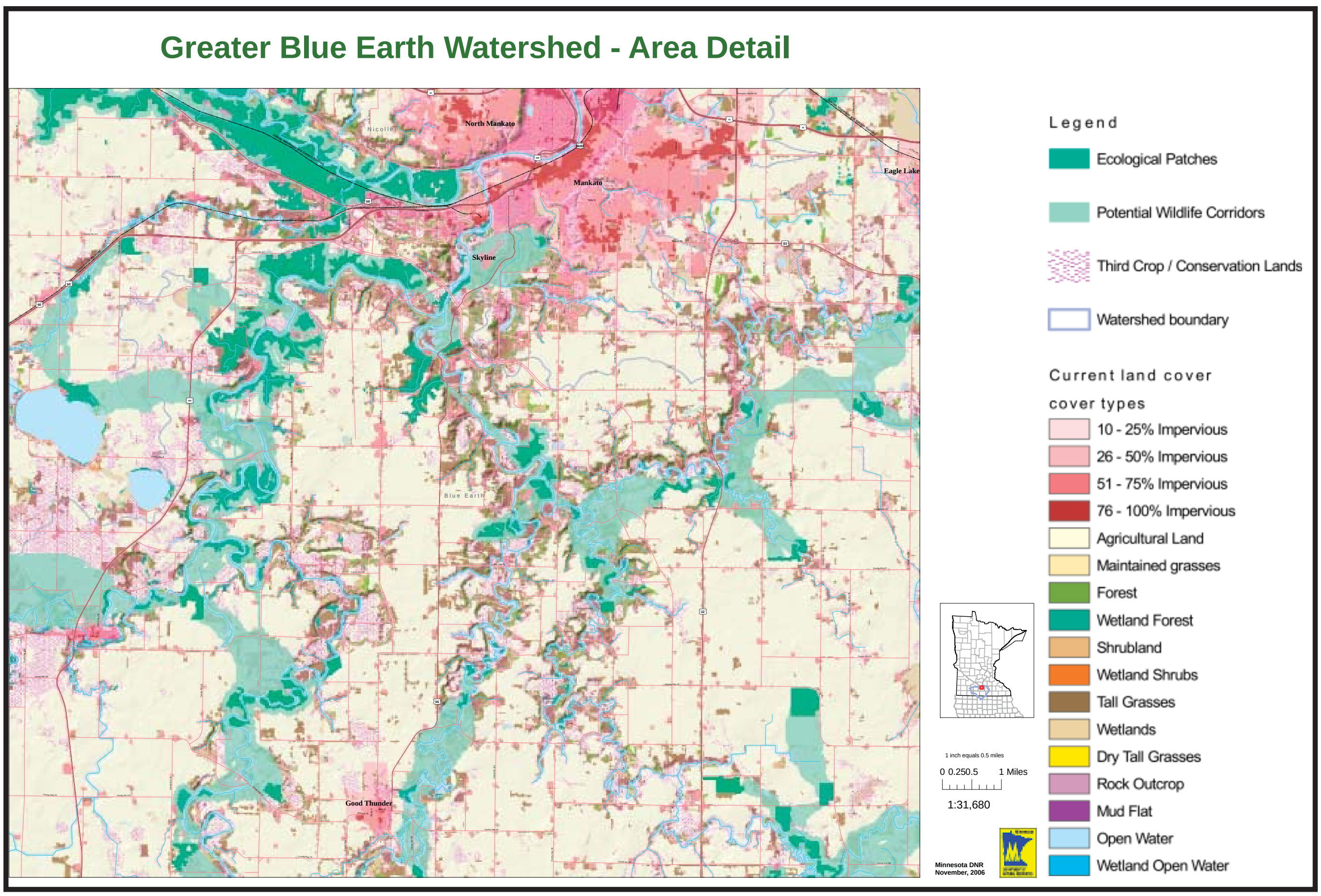


Figure 2: Existing natural areas and open space in the Mankato area. GIS modeling was used to identify potential connections between habitat areas and to reduce fragmentation. Credit: Terry Brown, University of Minnesota

parcels sold being smaller than 40 acres. During that same time period, "individuals accounted for 94% of all acreage purchased and 89% of all acreage sold, indicating a slight but gradual shift in forestland ownership out of [corporations] and to individuals" (Kilgore and MacKay). Forest parcelization does not, however, invariably lead to fragmentation; parcelization and associated fragmentation studies are currently underway.

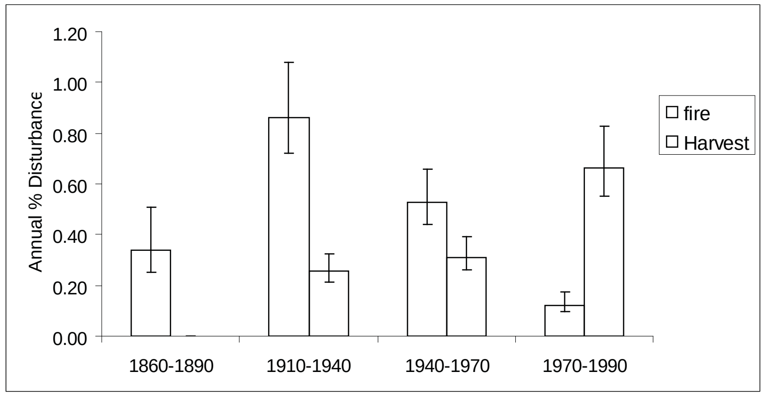


Figure 3: Fire versus logging as disturbance factor in northern Minnesota forests. Credit: Mark A. White and George E. Host University of Minnesota

Some but not all of the concern for forest fragmentation is captured in the dynamics of forest area described in Table 1, page 28. It is also important to understand the forest cover type areas and age class structures for further understanding.

Habitat Degradation - Altered Natural Disturbance Regimes

As used here, natural disturbance regime refers to natural or aboriginal activities common to the land prior to Euro-American settlement. Examples of natural disturbances that have been altered since settlement include natural fires and the influence of grazers such as bison and locusts. However, some natural disturbances such as windthrow damage still influence forested landscapes, sometimes over large areas. Still other disturbances, such as logging, are occurring on a larger scale and more frequently than natural disturbances, and can produce significant changes in landscape composition and structure. For instance, during the early to mid-20th century timber harvest replaced fire as the dominant disturbance factor in managed northern Minnesota forests (see Figure 3). This resulted in more uniform disturbance intervals within these forests and created a more homogeneous and aspen-dominated pattern of forest vegetation in the landscape (see Figure 4).

Eliminating natural disturbances that historically sustained natural systems can and has resulted in a loss of plant and animal biodiversity at species, community and ecosystem levels. For instance,

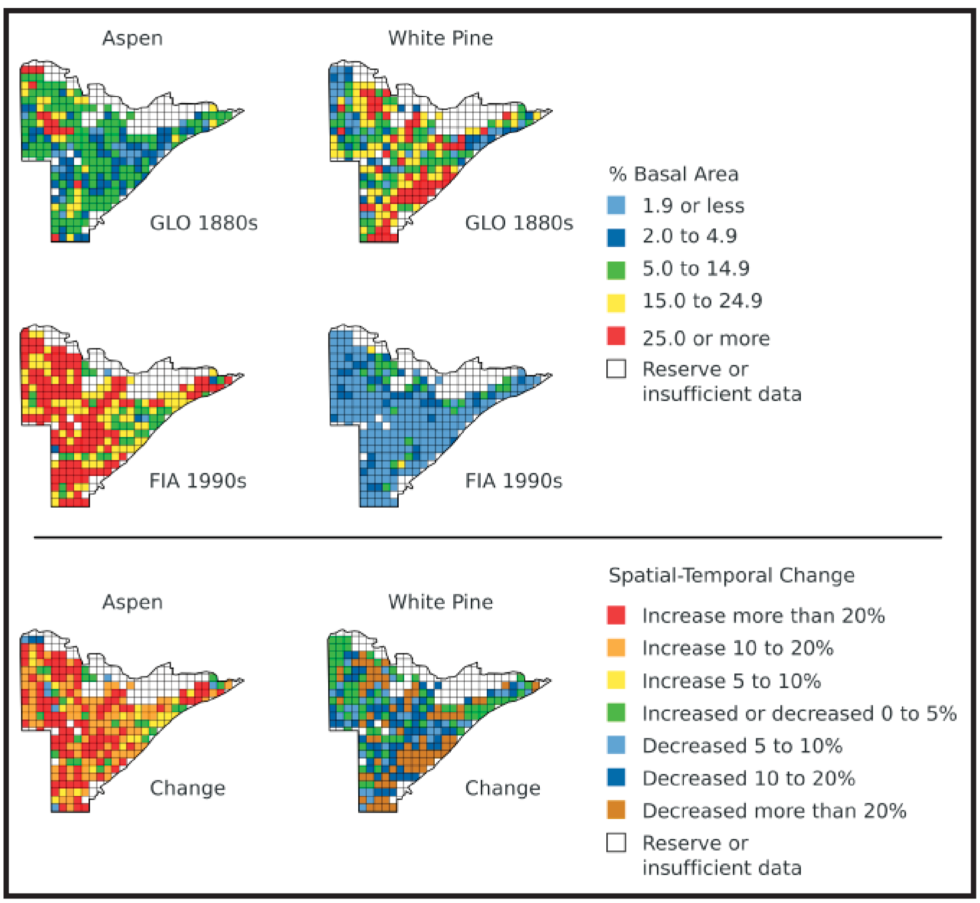


Figure 4: Changes in Aspen and White Pine distribution from pre-settlement to 1990. Credit: S. K. Friedman and P.B. Reich, University of Minnesota

lack of wildfire has contributed, along with timber harvest, to the enormous reduction in natural pine stands throughout northern Minnesota (see Figure 4). Habitat degradation and loss and altered natural disturbance regimes can also amplify each another and have a profound impact on natural areas. As an example, lack of wildfire, along with agricultural land conversion, has led to the near extirpation of oak savanna.

Primary drivers such as climate change and proximal drivers such as nutrient loading may also serve to increase the negative influence of altered natural disturbance regimes. For instance, climate warming is likely to make it even more difficult to retain cold-climate requiring boreal species in our northern forests. Altered natural disturbance patterns influence nearly all the ecosystems found in Minnesota, from prairie to hardwoods, to the mixed coniferous-deciduous forest.

Habitat Degradation - -Invasive Species

Invasive species primarily refers to plant and animal species not native to Minnesota that have escaped cultivation or have been inadvertently transported into new habitats. Species that are native to the region, but overpopulate communities where they would not normally occur are also considered invasive species. Invasive plants have a demonstrated ability to readily colonize in natural areas. They usually displace native species of plants, and in some instances, contribute to declines in native wildlife species. Invasive animal species can also degrade native ecosystems. European earthworms, for example, are non-native species that have a significant effect on species diversity in certain forest types. The Minnesota DNR currently lists 36 terrestrial plant species as invasive (see Table 2).

Amur Maple	*Amur Silver grass*
Birdsfoot trefoil	*Black Locust*
Butter and Eggs	*Canada Thistle*
Common Tansy	*Cow vetch and hairy vetch*
Creeping Charlie	*Crown Vetch/Axseed*
European and Glossy Buckthorns	*Bull Thistle*
Perennial Sow Thistle	*Japanese Knotweed*
Purple Loosestrife	*Hoary Alyssum*
Queen Ann's Lace	*Musk or nodding thistle*
Reed Canary Grass	*Japanese Barberry*
Russian Olive	*Leafy Spurge*
Siberian peashrub	*Norway Maple*
Siberian Elm	*Grecian foxglove*
Smooth brome grass	*Flowering Rush*
Spotted knapweed	*Oxeye daisy*
While and yellow sweet clover	*Exotic honeysuckles*
Wild Parsnip	*Orange Hawkweed*
Yellow iris	*Garlic mustard*

Table 2: Terrestrial plants listed as invasive by the Minnesota DNR

Introduction and expansion of invasive species is in turn driven by a number of other drivers, including population, land use, policy choices and the transportation network. State and Federal agencies and institutions have begun tracking the occurrence and expansion of invasive plants and animals in the upper Midwest more closely in the last decade. Recent efforts in Minnesota and at the Federal level seek to increase research into methods for control of invasive, nonnative species. However, current information lags behind the number and geographic extent of invasive species in Minnesota.

Habitat Degradation - Conclusion

Habitat degradation and loss is affected by nearly all of the primary drivers. Clearly, demographic and land use trends lead to habitat loss, fragmentation and degradation across the state, and contribute to the conversion of native lands to agriculture as well as the conversion of agricultural lands to housing or other development.

Expanding transportation corridors increases fragmentation and improves access to formerly isolated areas, facilitating development and the introduction of exotic species.

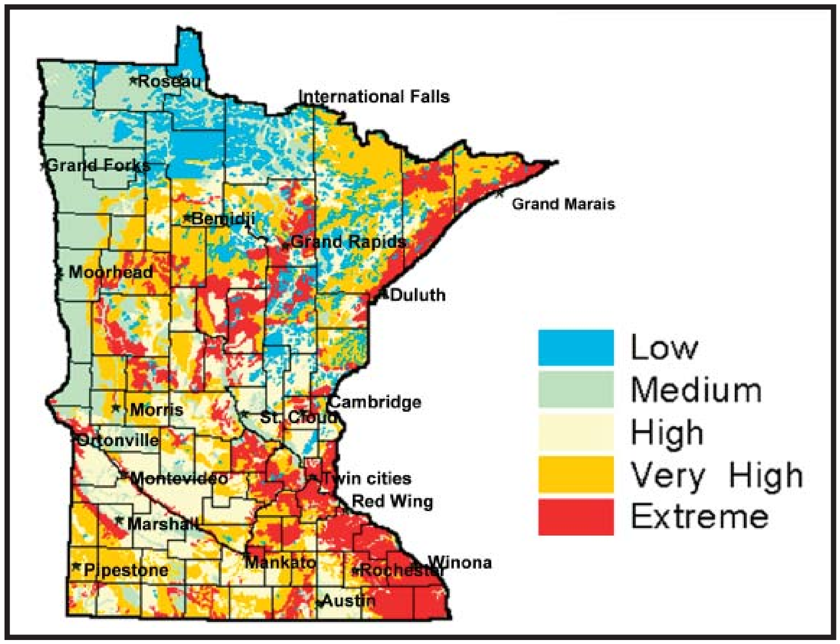


Figure 5: Maps showing erosion potential for three regions in Minnesota. Credit: David Mulla, University of Minnesota

Farm and land use policies influence crop choices. Developing trends in energy policy, especially the interest in corn-based ethanol, may potentially have negative effects on the land resource if areas currently in perennial plant cover are plowed and converted to corn. Natural resource based industries have a strong effect on the land resource because these activities shift the composition of forest stands (in the case of logging) or eliminate the resource completely (as in extractive mining practices). Finally, these all interact with changing climate patterns, which could have major ecosystem effects, particularly at the transitional regions between prairie, broadleaf, and coniferous-deciduous forests.

Particularly important are concerns about the effects of drivers in terms of degradation of the habitat values of the land resource through:

- Changes in landscape structure that lead to loss of plant species diversity
- Increased opportunities for invasive species to move into native plant communities
- Loss of large, natural patches necessary for reproduction of area-sensitive species, such as forest interior and prairie bird species
- Genetic erosion/loss of genetic diversity for native species
- Deterioration in water quality through loss or degradation of buffers for aquatic systems

The full potential and importance of some of these effects is understood for only a few species and situations; impacts are anticipated to vary widely according to species and land cover/land use type.

For effective planning to occur, county biological inventories should be completed for all counties in MN, including those areas in southern Minnesota that have been previously omitted. It will also be important to survey the "average" ecosystem, not just the highest quality ones; thus the county biological inventories should be expanded to simultaneously represent a unbiased census of the state as well as an inventory or our richest remaining communities. GIS analysis of land cover on a statewide basis is needed to identify high priority sites, natural resource corridors, and at-risk ecosystems for protection and focused conservation efforts.

Finally, an effort to create a statewide ecotype project to develop a seed bank and increase native seed stocks representing the genetic diversity of Minnesota plant species is essential for ensuring that species and genotypes persist. These steps are key for preserving both the diversity within the state, and for developing an "ecological infrastructure" that will maximize the ability of the land resource to adapt to new, as yet unknown, conditions resulting from global climate change.

Soil Erosion

Soil erosion refers to the detachment and transport of soil particles by water and wind. Soil erosion by water is a major concern in some areas of Minnesota, including the southeast, the Prairie Coteau, and wherever there are bluffs or other steep slopes. Wind erosion is significant in western Minnesota, especially the Red River Valley. Soil erosion is of moderate concern in other parts of the state with flatter topography and lower wind speeds (see Figure 5).

Erosion is accelerated by soil disturbance such as tillage, grading and construction, removal of protective vegetation and plant residue, reduction in soil organic matter with attendant loss in soil cohesion, and loss of soil structure resulting in reduced water infiltration and increased surface water flow. Changes in land cover also affect erosion. Reduction in perennial plant cover leads to increased surface water runoff and drainage tile flows due to less evapotranspiration from annual crops. Increases in impervious surface area increase concentrated flows and with it, gully and streambank erosion. In addition, the climate in Minnesota has become increasingly wet; this is increasing the amount of runoff and related erosion from rain events.

Erosion results from the interactions between changes in land cover and changing weather patterns has a significant effect on both land and water quality. Streambank erosion, which is a major source of sediment in streams and lakes, is accelerated by these factors. In the Blue Earth River basin 40-50% of the sediment delivered to the mouth of the watershed arises from streambank erosion.

Erosion has a variety of impacts. Soil erosion results in a loss of productive topsoil, frequently leaving surface soil with higher clay and lower organic matter content, lower water infiltration capacity, and poor physical properties for seedling emergence and root growth. In some cases the concentration of sand and rock at the surface is increased due to differential transport of fine materials. Gulley erosion leads to loss and dissection of land. This impacts agriculture, recreation, development opportunities and other uses, as well as loss of native plant cover. The sediment from erosion fills drainage ditches and degrades aquatic habitat.

Changing land use, especially as relates to agriculture, as well as policy choices and industry (both natural resource based and non-natural resource based) directly and indirectly affect erosion.

The number of acres planted to annual row crops have increased dramatically over the last 100 years (see Figure 6) and continues to increase, while the acres in perennial systems such as pasture have decreased. The annual row crop system leads to increased erosion because it creates vast stretches of unprotected bare soil in the spring before before crop canopy closure. Unfortunately, rainfall is highest in the spring when annual row crop soils are most vulnerable to erosion. Rain drops strike the bare ground, dislodging lose particles of soil. Then,

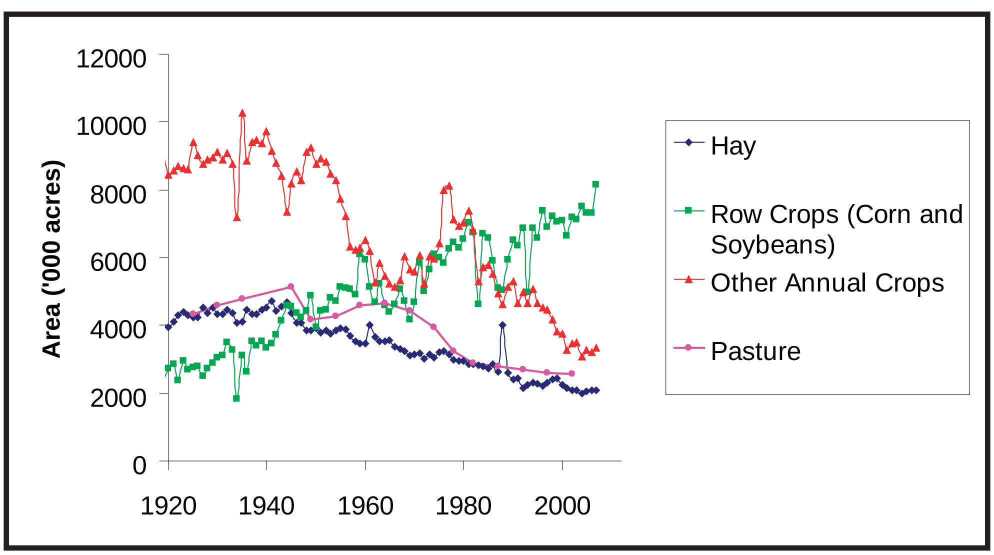


Figure 6: Acreages planted to hay, row crops, pasture and other annual crops. Credit: Laura Schmitt, University of Minnesota..

because there are no established plants to slow down or soak up the rainwater, the raindrops becomes run-off carrying sediment along with them. This run-off quickly enters streams, contributing to streambank erosion. Perenniel systems tend to protect soil from erosion better than annual systems because they provide soil cover all year long.

Policy choices have a strong influence on agricultural practices affecting erosion, especially the:

- relative size of production incentives versus conservation incentives;
- choice of crops for which production incentives are provided; and
- absence of conservation compliance standards on most cropland.

Policy choices also affect the allocation of land among various uses, all of which affect rates of soil erosion. This includes natural resource based industries such as agriculture and forestry, as well as non-natural resource based industry –specifically, construction and construction practices.

There are significant data gaps in determining rates and causes of soil erosion. It is not easily measured by remote sensing, so must be estimated by models for which some data is often not current or available.

- Accurate slope information for erosion estimation is not available in the absence of statewide high resolution elevation data. LiDAR-acquired high resolution elevation data is available for only ten counties at this time. This data is urgently needed to identify critical landscape areas, for modeling to determine sediment delivery and effects of alternative management practices and for estimation of streambank erosion rates.
- Crop and soil cover on agricultural land changes over time and over seasons. Annual surveys of crop residue cover after planting are necessary since remote sensing has not yet evolved sufficiently for its accurate measurement.
- Paired watershed studies on effectiveness of BMPs are needed to estimate how much area needs to be treated to obtain different levels of reduction in erosion.

Consumptive Use

Consumptive use is the non-renewable use of resources such as development of open space via a variety of means, including conversion of native communities to agricultural use, housing developments, unsustainable logging practices, mineral extraction/mining, and similar activities. It is related to the conversion of land use from a sustainable (see definition, text box below) practice to a non-sustainable practice, or the permanent removal of the resource. Examples include:

- Conversion of diverse native plant communities to agriculture.
- Soil loss and degradation from agricultural practices.
- Non-renewable consumption of resources, such as non-sustainable logging practices, non-sustainable cropping practices, and mineral extraction/mining.
- Conversion of land through land development and associated infrastructure.

> The 1987 Brundtland Commission definition: “sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

Consumptive use in previously natural areas results in the permanent loss of habitat. The loss of native plant cover is significantly higher in the southern areas of the state than in the north. Throughout Minnesota areas of native habitat have been converted to other cover types (see Figure 7, next page), including agriculture, mining, development, and other uses. Also, in the north, logging and land clearing in the period 1865-1930 dramatically altered the tree species composition and age class structure of the northern forests.

While restoration and re-creation efforts for some habitat types have increased, the rate of loss exceeds the rate of reconstructon and restoration. The final cost of restoring or reconstructing a lost habitat is often quite high, and despite significant expenditures even the best habitat reconstruction efforts cannot achieve the high levels of diversity and ecological function found in even a low or moderate quality remnant natural community. Important research questions are the full extent of potential changes and whether it is feasible to restore some habitat types in the face of climate change, cost and other priorities.

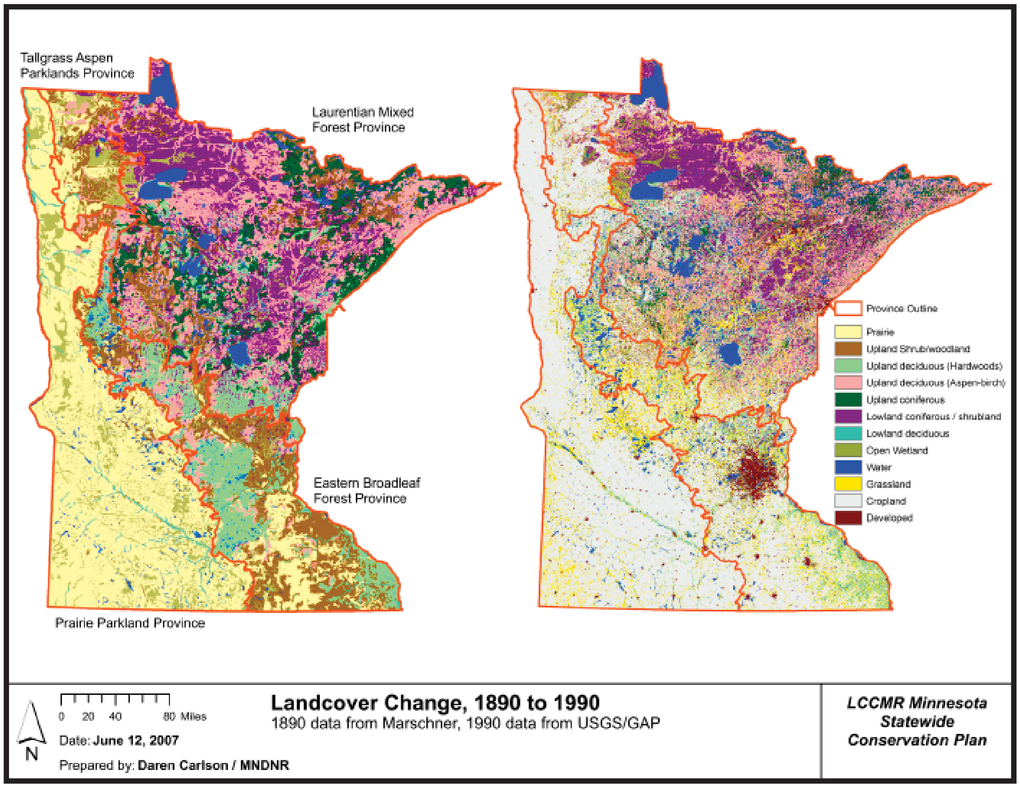


Figure 7: Changes in native land cover in the different ecoregions of Minnesota between 1890 and 1990. Credit: Daren Carlson, Minnesota DNR

Mining inevitably causes changes in the landscape, and directly impacts the land cover as well as the mineral resource itself through consumptive use. As a practical matter, mines have a life cycle that might range from 10 years or less for a small gravel deposit, to more than a hundred years for a large iron-ore deposit. At some point, the cost of mining at a particular location exceeds the cost of obtaining the same commodity elsewhere and the mine closes. There may still be mineral content, and it may, if conditions change, become economically feasible to extract it at a later time. Recycling of mineral-derived products (glass, steel, aluminum, copper, and aggregate) can extend the life of an extracted mineral.

More philosophically, the benefits of mining can be sustainable, even as the supply of the mineral resource is finite. If comprehensive planning recognizes that mining will not go on indefinitely, and the community uses the economic benefits of mining to prepare for or develop an alternative industry or other land use in the wake of mine closure, the community can be sustainable. Mining is, or can be, a temporary use of land. However, the degree to which the land is changed varies greatly depending on the size and depth of the mining operation. Some mineland can be easily converted to other uses (gravel pits to shopping centers or parks and lakes, for example, as in the large commercial area in the city of Maple Grove or Cascade Lake in Rochester). Other mineland is changed greatly and probably for all time (iron mines hundreds of feet deep filling with water).

Some 2004 Minnesota mining industry facts:

- Valued at $1.89 billion; 7th of the 50 states in non-fuel mineral production value
- Number 1 ranked state in iron ore production
- Iron ore is the highest value mineral in Minnesota followed by construction sand and gravel (5th of 50 states), industrial sand and gravel, dimension stone, and lime.

Other impacts of consumptive use include significant impacts on the soil resource, including the loss of soil through erosion, change in soil structure, and altered soil fertility. These are discussed in greater detail in sections on soil erosion, changes in soil structure, and soil nutrient loading.

Consumptive use is driven by nearly all of the primary order drivers. Higher order drivers that are especially significant include:

- Economy
- Policy choice
- Land use
- Transportation
- Climate change
- Natural resource based industry

Contaminants

Agricultural contaminants affecting the land resource include chemical compounds that accumulate in soils of agricultural lands and emissions of these compounds to terrestrial ecosystems. Nitrogen(N) emissions are among the most significant sources of contamination to the land resource; these result from volatilization of reduced forms of N (NHx) from intensive animal agriculture and from fertilization of intensive annual crop production systems. Agricultural contaminants are a significant concern in some areas of Minnesota, including regions where intensive animal agriculture and intensive annual crop production occupy a large portion of the landscape. Pesticide emissions via spray drift and emissions from soil accumulations of pesticides are also a concern in relatively localized areas where conditions cause significant spray drift or where significant soil accumulations of pesticides exist. For example, atrazine leaching risks are shown in Figure 8.

Agricultural contamination affects the resource by:

- Nitrogen(N) deposition causes eutrophication in terrestrial ecosystems and changes in plant communities, frequently increasing the abundance of invasive species and reducing native biodiversity.
- N deposition also causes acidification of soils, as well as changes in soil nutrient and carbon cycling.
- Accumulation of N in agricultural soils makes conversion of land to less-intensive forms of agriculture more difficult by promoting the growth of weeds and invasive plant species.
- Deposition of pesticides by spray drift and other mechanisms affects adjacent land use and ecological communities. Field-margin areas, which are often contaminated by pesticides in this way, are of great significance for biodiversity conservation, water quality protection and other aspects of environmental quality protection in agriculture-dominated landscapes.

Agricultural contamination is driven by several primary order drivers. Higher order drivers that are especially significant include:

- Land use, especially in allocation to intensive animal production systems.
- Policy choices, such as regulatory standards affecting emissions from intensive animal production systems, and other policy measures that encourage intensive animal and annual

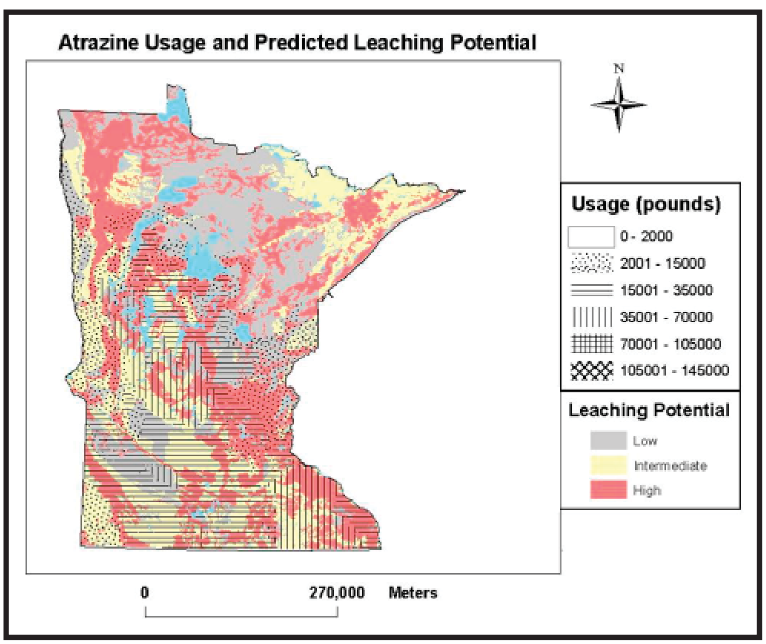


Figure 8: Atrazine usage and predicted leaching potential. Credit: David Mulla, University of Minnesota.

crop production, such as subsidies to major commodity crops used for animal feed.

Urban and industrial uses are also contamination sources for the land resource. "Brownfields" is a term used to describe land resources that have been degraded or destroyed through the contamination of land cover ecosystems, soil, or hydrogeological systems. Brownfields include abandoned, idled, or underused industrial and commercial properties where expansion or redevelopment is complicated by actual or suspected environmental contamination. Brownfields also include historic land-based disposal sites such as landfills and industrial dumps, railroad corridors and related uses such as grain elevators, smaller contaminated sites such as gasoline stations or drycleaners, and abandoned mines and airports.

There are also some significant long-term contaminant issues of national scale, such as superfund sites in Silver Bay & Striker Bay associated with mining. The St. Louis River estuary is the only EPA-designated Area of Concern (AOC) in the State of Minnesota (shared with Wisconsin) of the 28 AOCs in the Great Lakes basin. Most of the drainage to the St. Louis AOC originates in Minnesota.

Information on the location of brownfield sites and the types of contamination is collected by the MPCA and available at http://www.pca.state.mn.us/backyard/neighborhood.html

Changes in Soil Structure

Soil structure refers to the arrangement and degree of aggregation of sands, silts and clays that make up natural soils. Soil structure is diminished as aggregate size and strength decrease, and as the spaces and continuity of spaces between aggregates decrease. Soils with poor structure may be relatively impermeable, have increased runoff, and poor aeration. Poor soil structure may arise from: heavy machinery traffic at times when the soil is relatively wet; by repeated tillage operations that bury crop residue and lead to oxidation of soil organic matter; by management practices that rely on inorganic fertilizer rather than animal or green manures; by management practices that decrease soil biological activity (especially earthworms); or by cropping systems that have shallow rooting plants. Decreased soil structure leads to poor soil aeration that can reduce biomass accumulation and crop productivity. Decreased soil structure can also lead to increased runoff and erosion which decreases topsoil depth and causes sediment deposition at lower slope positions. Decreased soil structure also leads to reduced water storage in soil and reduced soil biological activity. Changes in soil structure in forested ecosystems can result in decreased forest productivity and increases in weedy or invasive species. The predominant driver for increased soil compaction in forests is heavy logging equipment in inappropriate seasons or under the wrong soil moisture conditions.

Soil Nutrient Loading

Nutrient loading refers to an unnaturally high and typically excessive increase in nutrients to natural systems. Nutrient loading to the Land Resource in Minnesota occurs from a variety of conditions.

The largest source of nutrient loading in Minnesota is excessive application of fertilizer and manure to agricultural fields. Other notable examples include excessive application of fertilizers (particularly Phosphorus(P)-containing fertilizers) to residential lawns and atmospheric redeposition throughout the state of primarily fall-applied ammonia fertilizer to crop ground. Nutrient loading occurs largely as a result of human activity through land use decisions, often at the local and property owner level.

For groundwater and Gulf of Mexico effects, nitrogen(N) is the primary nutrient pollutant. For lakes and streams, phosphorus is the primary nutrient pollutant. Phosphorus(P) is a bigger concern in Minnesota than nitrogen. Phosphorus is building up in Minnesota soils as a result of agricultural or horticultural applications of fertilizer and manure in excess of crop removal rates. Atmospheric redeposition of nitrogen on natural plant systems, and sediment transport of phosphorus into lakes can also have significant effects.

Nutrient loading influences a number of other proximal drivers on the Land Resource, particularly invasive species, habitat degradation and loss, altered natural disturbance regime.

There are significant data gaps in determining rates of nutrient loss across the landscape. These rates are controlled by climate, landscape features, and management practices. Further study is needed to:

- Evaluate the impact of changing climate on nutrient losses in runoff, erosion, and drainage.
- Evaluate the impact of alternative cropping and animal production systems on the nutrient losses.
- Develop tools to identify critical landscape areas where the largest losses of nutrients are occurring.
- Conduct paired watershed studies to evaluate the effectiveness of BMPs for nutrient reductions.

Increased Carbon Dioxide

Emissions of carbon dioxide (CO_2), one of several greenhouse gasses, have increased by about 80% between 1970 and 2004. CO_2 is the largest contributor to greenhouse gasses, constituting 77% of total greenhouse gasses emitted in 2004 (IPCC 4th assessment report). In order of magnitude, electricity generation, transportation and industry are the major contributors to increased CO_2. They account for 80% of CO_2 emissions. The increase in atmospheric CO_2 is occurring at a global scale, and this increase does not show strong geographic variation across Minnesota: most ecosystems are exposed to similar CO_2 environments. The ecological and economic implications of increased CO_2, however, vary between the agricultural regions to the south and the forested regions of the north.

It is also important to note that increased CO_2 has both direct effects, including changes in plant productivity and response to insects and diseases, and indirect effects due to climatic change resulting from increased CO_2 and other greenhouse gasses. A 50-year assessment needs to include both these direct effects and the potentially more important response of forest and agricultural landscapes to changes in temperature and precipitation patterns (see Figure 9). It is also important to note that the effects of elevated CO_2 do not occur in isolation, other greenhouse gasses, such as ozone, are also showing steady increases. The response of ecosystems to a changing trace gas environment is complex and not entirely predictable.

CO_2 has both direct and indirect effects on the land resource, with the indirect effects being stronger drivers of change.

Direct effects include:

- Short term (and perhaps persistent) increases in plant productivity due to the CO_2 fertilization effect. However, these increases are smaller in infertile than fertile conditions

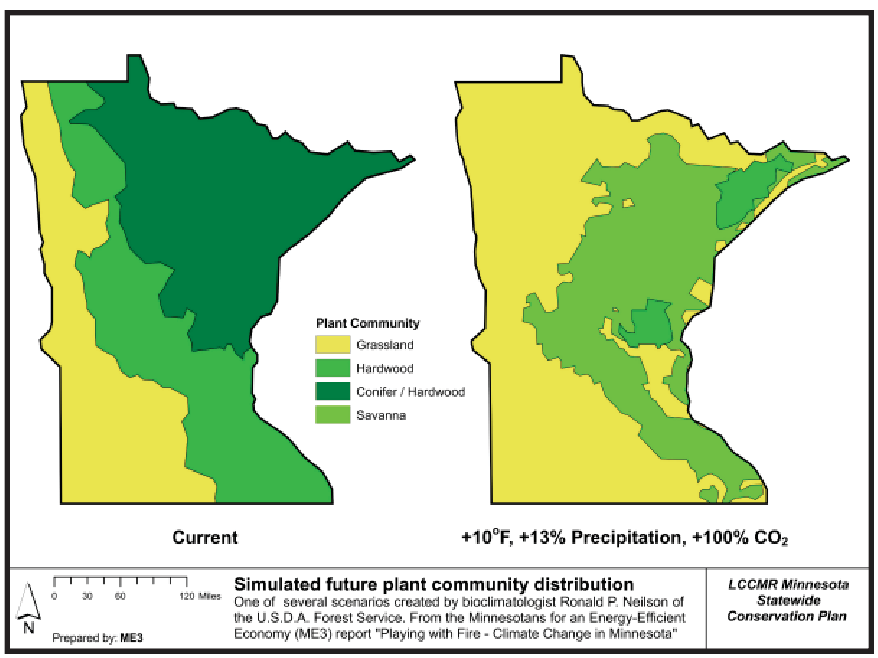


Figure 9: Projection of future plant community distribution based on one climate change scenario. Credit: Minnesotans for an Energy Efficient Economy (now Fresh Energy).

- Potential adverse effects on nutrient availability-a kind of "reverse" eutrophication due to excess carbon
- Decreased nutritional value of crop plants due to reduced levels of nitrogen (N) in seeds
- Changes in plant defense mechanisms resulting from changes in leaf chemistry

Indirect effects include:

- Changes to species composition of native communities in response to changes in the mean and variation in seasonal and annual temperature and precipitation regimes. These include both direct climate effects and indirect effects of climate change on invasive species, native insects and diseases, and on major climate and disturbance events such as droughts, windstorms, and fires.

Collectively, such changes are likely to be enormous by the end of the century and should represent a major area for long-range policy consideration.

CO_2 increases result from several primary order drivers; among the most significant drivers are:

- Energy, particularly generation of energy from fossil fuels
- Transportation, use of hydrocarbon fuels
- Industry via energy consumption and emissions

There is considerable data on documenting the increase on CO_2 and other greenhouse gasses, and the fact that, under current mitigation policies, these emissions will continue to grow over the next few decades (Intergovernmental Panel on Climate Change). There are also numerous studies documenting the immediate response of agricultural crops and forest species to altered trace gas composition. The primary gaps in knowledge are understanding the long-term effects of multiple interacting stresses on ecosystems. Specifically, research should address how changes in trace gasses, temperature and precipitation will influence pest/pathogen relationships, food webs, the spread of invasive species, ecosystem nutrient dynamics, and other ecosystem-scale processes.

Figure 10: William O'Brien State Park.
Credit: Michael Kelberer, University of Minnesota

"We need a no-net-loss-of-public-lands ethic."

—Minnesota 2050 Project participant

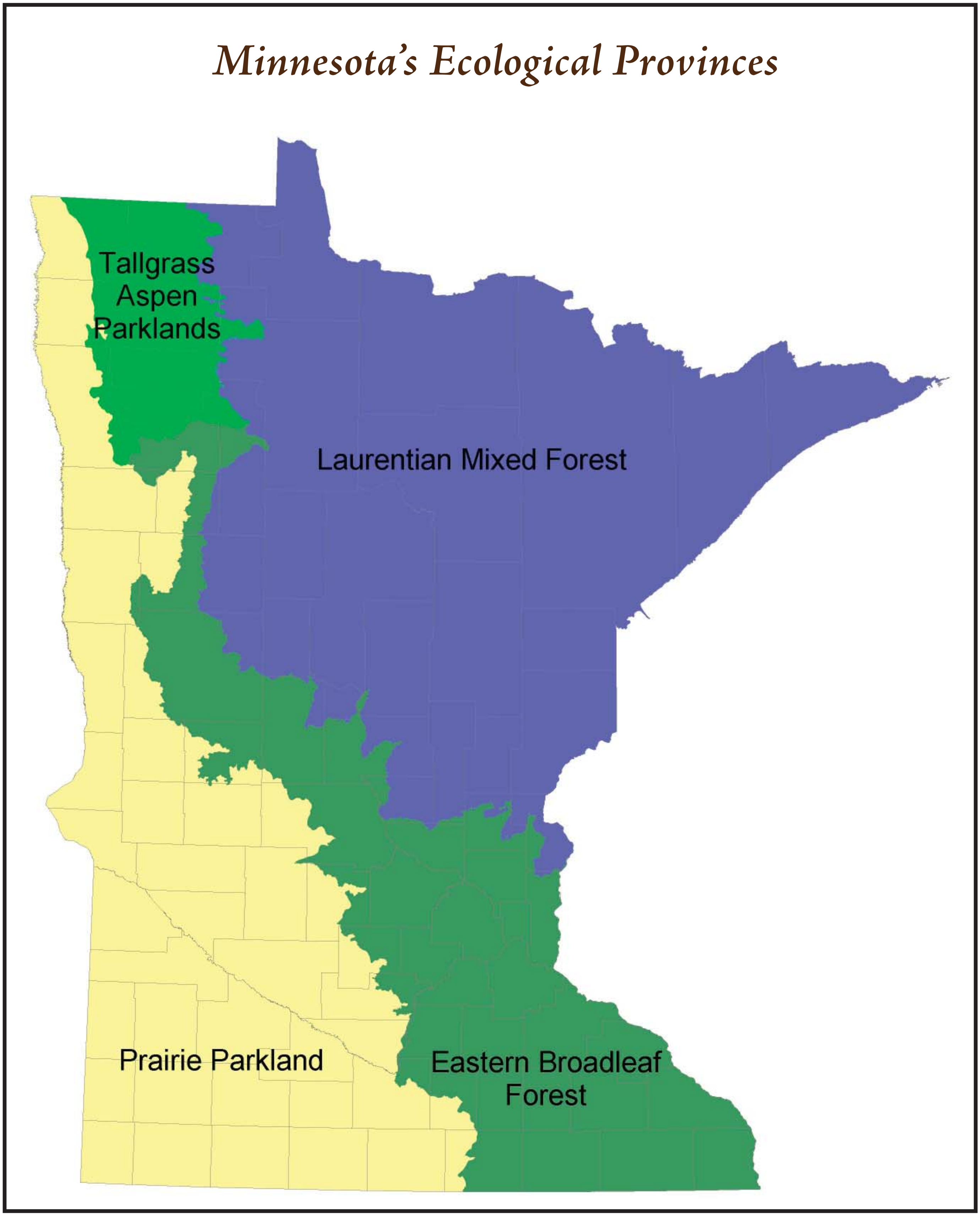


Figure 1: Minnesota is fortunate to contain parts of four major ecological provinces, with a resulting greater diversity of wildlife species than many similarly-sized neighboring states. Credit: Terry Brown, University of Minnesota.

WILDLIFE

Natural Resource Profiles

"For if one link in nature's chain might be lost, another might be lost, until the whole of things will vanish by piecemeal."

—Thomas Jefferson

History

Wildlife is a vague term. Traditionally it referred to free-living terrestrial vertebrates (e.g., birds, mammals, reptiles, and amphibians), but is more often used now to refer to all non-domesticated plants, animals, and other organisms (i.e., biodiversity). We adopt an intermediate approach here, defining wildlife to include all free-living terrestrial vertebrates and invertebrates (i.e., animals), although our primary focus is on vertebrates because they comprise the best studied and most appreciated groups of Minnesota wildlife.

Minnesota is home to approximately 312 species of birds, 83 species of mammals, 29 species of reptiles, and 22 species of amphibians, plus untold thousands of invertebrate species. Of this total, the primary legally recognized game species include 45 species of birds and 21 species of mammals. The vast majority of Minnesota's wildlife species are classed as nongame wildlife. Several wildlife species are no longer present in Minnesota, including the American bison, wolverine, woodland caribou, whooping crane, swallow-tailed kite, and long-billed curlew. At least one species, the passenger pigeon, is globally extinct. Still others are very rare today compared with pre-settlement periods, including American elk, mule deer, and greater prairie chicken. Nevertheless, some adaptable wildlife species have increased to what are undoubtedly all-time highs, such as the white-tailed deer, Canada goose, wild turkey, raccoon, and American crow.

The Minnesota Department of Natural Resources (MN DNR) recognizes 22 mammal species (27% of all mammal species in Minnesota), 97 bird species (31%), 6 amphibian species (27%), and 17 reptile species (59%) as "Species of Greatest Conservation Need". Many of these species are also listed on state and/or federal endangered and threatened species lists. They include the eastern spotted skunk, trumpeter swan, peregrine falcon, piping plover, king rail, northern cricket frog, massauga, and Blanding's turtle. Many invertebrate species have also been identified as Species of Greatest Conservation Need including a number of jumping spiders, tiger beetles, skippers, and butterflies.

Baseline Conditions

Minnesota is located at the crossroads of four major ecological provinces (see Figure 1, facing page): the Prairie Parklands, the Tallgrass Aspen Parklands, the Eastern Broadleaf Forest, and the Laurentian Mixed Forest. This results in Minnesota having a greater diversity of wildlife species than similar-sized neighboring states.

Prairie Parklands

The Prairie Parklands province covers 30% of the state, including a large portion of the southwestern corner of the state plus the Red River Valley corridor to the west. Historically this region experienced periodic wildfires, which prevented encroachment by woody vegetation from the Eastern Broadleaf Forest and Tallgrass Aspen Parklands. Before European settlement it was dominated by tallgrass prairies and wetlands (see Figure 2, next page). The area was home to a diverse suite of grassland wildlife. Prairie songbirds such as Sprague's pipits, chestnut-collared longspurs, bobolinks, western meadowlarks, and western kingbirds were abundant. Wetlands were populated by numerous species of breeding waterfowl including trumpeter swans,

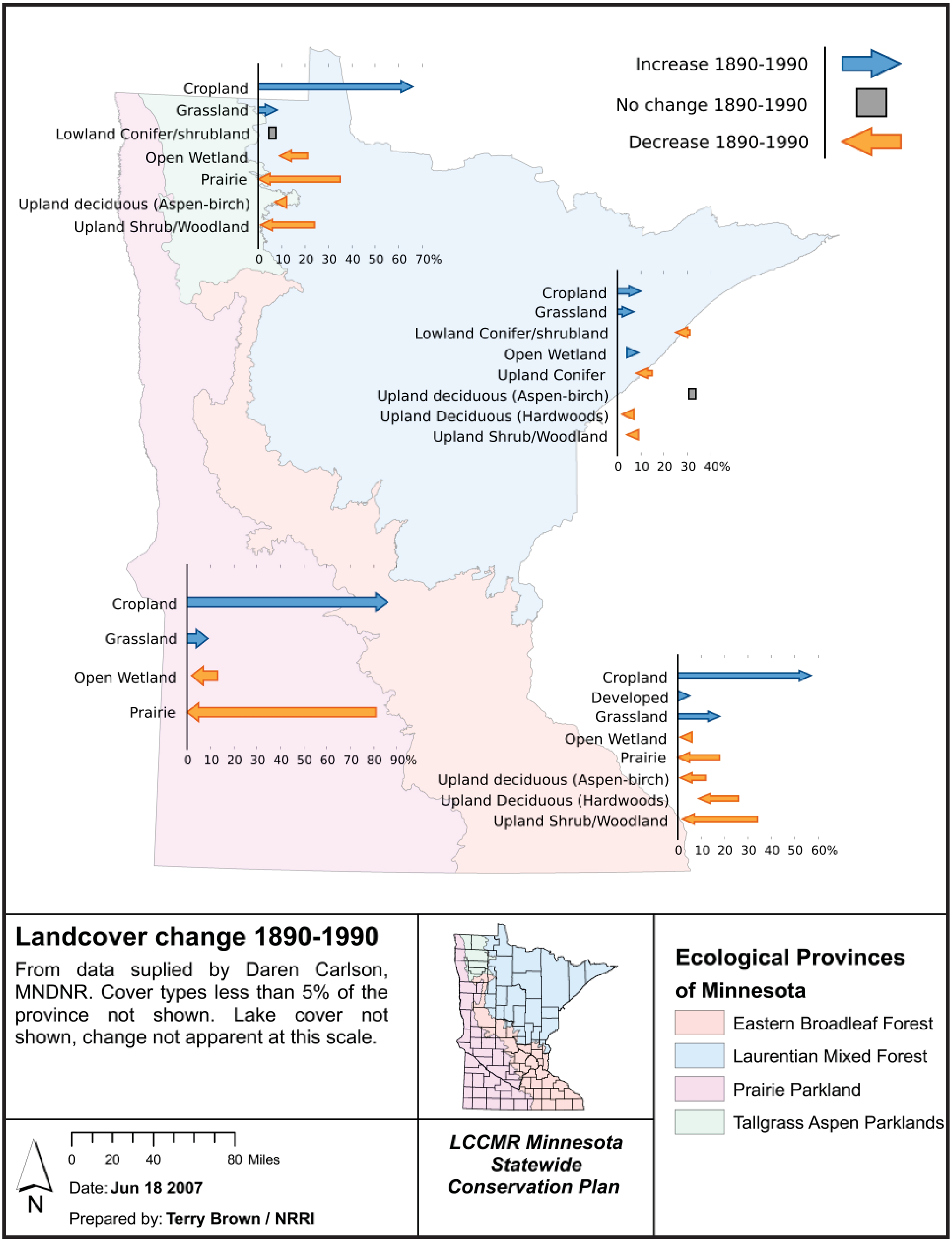


Figure 2: Landcover change 1890 - 1990. Credit: Terry Brown, University of Minnesota.

Canada geese, wood ducks, mallards, and blue-winged teal, with numerous other species migrating through in spectacular abundance during spring and fall. Waterbirds such as American white pelicans, American bitterns, black terns, marbled godwits, and western grebes were common, as were gallinaceous birds like the sharp-tailed grouse and greater prairie chicken. Bison and American elk were the dominant herbivores. Gray wolves and badgers were important predators. Unique herpetofauna included Great Plains toads and western hognose snakes.

Tallgrass Aspen Parklands

The Aspen Parklands covers only a small part of the Minnesota landscape (6%), but represents an expansive ecological province, stretching from northwestern Minnesota all the way into middle Alberta. Historically (see Figure 2, facing page) the area was a mixture of tallgrass prairies and fire-dependent deciduous woodlands dominated by aspens and bur oak. Frequent fires kept prairie in drier areas of the region. In wetter areas, wetlands, peatlands, and woodlands persisted. The region was home to numerous birds including sharp-tailed grouse, ring-necked ducks, upland sandpipers, and sandhill cranes. White-tailed deer, American elk, and moose were the dominant herbivores.

Eastern Broadleaf Forest

The Eastern Broadleaf Forest formed a diagonal belt across Minnesota (see Figure 2) and functioned as a transition zone between prairies to the southwest and mixed coniferous forests to the northeast. The area varies from level plains to the steep blufflands that border the Mississippi River. Broadleaf forests covered about 22% of Minnesota and were dominated by maples, oaks, elms, and basswood. Important wildlife species included white-tailed deer, black bear, raccoon, gray and fox squirrel, wood duck, red-shouldered hawk, Cerulean warbler, Louisiana waterthrush, Blanding's turtle, and Cope's gray treefrog. Many unique reptiles and amphibians, such as smooth softshell, milk snake, common water snake, massasauga, and pickerel frog occurred in the southeastern blufflands.

Figure 3: Black-throated Blue Warbler. Credit: David Cahlander

Laurentian Mixed Forest

The Laurentian Mixed Forest is the largest province in the state, covering the north-eastern 43% of the state (see Figure 2). The region is characterized by conifer forests, lakes, mixed hardwood and conifer forests, conifer bogs, wetlands, and extensive brushlands, especially in the transition zones with the Prairie Parklands and the Eastern Broadleaf Forests. The region had vast old-growth forests of white and red pine as well as extensive old-growth forests along the north shore of Lake Superior. Fire was a dominant, natural regenerating force in both forests and brushlands. There were many unique species formerly found in this province including wolverine and woodland caribou. Common forest species of the region included the ruffed grouse, gray wolf, moose, black bear, white-tailed deer, forest salamanders, and wood turtles. A plethora of Neotropical migrant birds visited in the summer, including the as broad-winged hawk, black-throated blue warbler (see Figure 3), bay-breasted warbler, and ovenbird. A few bird species, such as the spruce grouse, northern goshawk, gray jay, and boreal chickadee, lived in the northern forests all year round. Common in aquatic areas were bald eagles, osprey, common loon, beaver, and otter. In the brushlands and fens of the ecoprovince sharp-tailed grouse, short-eared owl (see Figure 4), yellow rail, sandhill crane, and northern harrier were abundant. In sandy beach areas near Lake Superior and the large lakes of the region piping plovers, spotted sandpipers, and common tern were common.

Drivers of Change

- Habitat Loss and Degradation
- Habitat Loss in Prairie and Tallgrass Aspen Parklands
- Habitat Loss in Eastern Broadleaf Forests
- Habitat Loss in Laurentian Mixed Forest
- Climate Change
- Exotic and Invasive Species
- Diseases
- Pollution
- Hydrologic Modifications and Man-Made Structures
- Exploitation/Social Tolerance/Persecution

Habitat Loss and Degradation

The major historical driver of change for wildlife throughout Minnesota has been habitat loss. We defined habitat loss very broadly to include habitat destruction, habitat degradation, and habitat fragmentation. These habitat changes are expected to affect wildlife into the future. Habitat loss occurs from many drivers of change including a**griculture, urbanization and development, forest harvest and management, shoreland development and recreation, and fire suppression.** These drivers affect each of the provinces to a different degree. For example, change in the prairie provinces has been driven largely by agriculture. Habitat loss in the Eastern Broadleaf Forest province are driven by agriculture and urbanization, while changes in the Laurentian Mixed Forest province are largely driven by agriculture, forest harvest and management, exurban development, urbanization, shoreland development, and fire suppression.

Figure 4: Short-eared Owl. Credit: Scott Meyer

Quality habitat is essential to the survival of wildlife because it provides the necessary substrate for breeding, feeding, and shelter. There is a direct relationship between the population size of wildlife species and the amount of habitat. As habitat area decreases so does the size of the wildlife population. Population size is a critical element in the health and vulnerability of a species and its ability to survive. As the population size decreases, its chance of survival also decreases.

Habitat loss occurs in a variety of forms and degrees. Habitat destruction is the complete eradication of a parcel of habitat. For instance, conversion of native wetlands, prairies, forests, or brushlands to agricultural, to residential or to industrial uses are generally permanent changes and represent permanent loss of habitat for wildlife.

Habitat degradation occurs when the habitat is still present, but its value to wildlife has been impaired or changed significantly. For instance, urban and exurban development may retain some characteristics of the habitats, but wildlife species have varying responses to these changes. Native species such as American robins, raccoons, and white-tailed deer have adapted well to these habitat changes, while

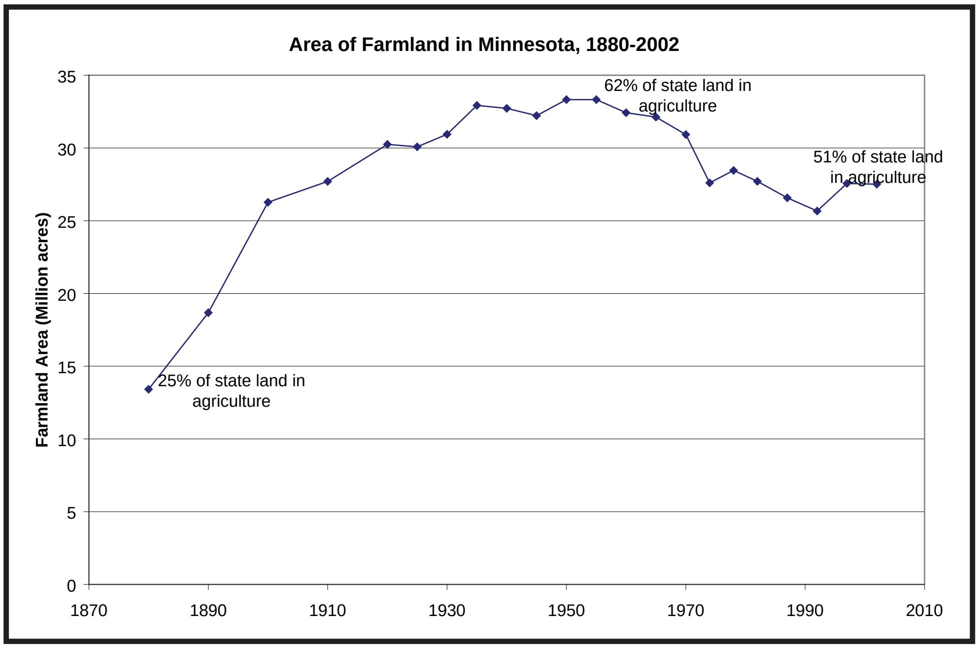


Figure 5: Area classified as farmland in Minnesota. Credit: Laura Schmitt, University of Minnesota

others like Neotropical migrant forest birds or prairie species have been disrupted. Forest harvest and management may be considered a temporary habitat change, but the long term effects in Minnesota have been degradation of the forest environment by homogenization and creation of excessive edge. Homogenization is the process of simplification of the forest tree species composition and habitat structure. The reduction in tree species diversity by the loss of coniferous tree species such as pine and spruce in the Laurentian Mixed Forest Province is an example of homogenization. Similarly, a silt-laden wetland is habitat degradation because it no longer provides suitable habitat for ducks. Finally, fire suppression in prairies or brushlands can result in habitat degradation due to the over-maturation of the habitat by succession to shrubs or trees. The habitat is still present, but not in a form necessary for native prairie or brushland species to utilize.

Habitat fragmentation is the break-up of large contiguous areas of habitat into smaller and smaller parcels or "fragments." The habitat fragments are no longer close enough or sufficiently connected to allow wildlife to move freely among habitats. Habitat destruction such as road construction contribute to fragmentation, whether it be prairie, wetland, brushland, or forest. This process results in smaller and smaller populations of wildlife species in the remaining fragments. As the process continues, populations become smaller, more isolated and less healthy. Basic wildlife population-level processes become disrupted and may render these populations susceptible to local and regional extinction. These processes include species habitat selection, the size of the gene pool, gene flow, dispersal, inbreeding depression, and predator-prey dynamics.

Habitat Loss in Prairie and Tallgrass Aspen Parklands

The prairies have experienced the greatest amount of habitat loss of any region in the state; indeed it is widely known now as the agricultural region rather than the prairie region. Most of this habitat loss occurred more than 100 years ago when the prairies were initially settled by European immigrants. Losses continued throughout the 20th century and continue today (see Figure 5). Diversity in grassland acres increased with the Conservation Reserve Program, but not native prairie was not restored. Estimates of cumulative habitat loss exceed 99% for tallgrass prairie and 90% for prairie pothole wetlands. Remnant habitats are highly fragmented, often consisting of narrow strips of prairie habitat along roadsides or drainage ditches.

Once the land was converted to agricultural use, the types of agricultural production practices have also changed over time. Acres of perennial-based pasture systems and diversified cropping systems have shifted to monocultures of annual row crops. This trend has intensified to the present. In general, historical farming practices had less impact on wildlife populations than the large-scale operations currently in use.

Species	Mean Number	Annual Trend	Probability
Western Kingbird	0.81	-8.49	0.03
Grasshopper Sparrow	2.07	-7.61	0.02
Western Meadowlark	18.9	-7.22	< 0.0001
Dickcissel	2.97	-5.98	0.0003
Eastern Meadowlark	1.33	-2.84	0.15
Vesper Sparrow	13.11	-2.73	< 0.0001
Savannah Sparrow	13.11	-0.69	0.13
Horned Lark	11.63	-0.55	0.65
Clay-colored Sparrow	5.68	-0.49	0.41
Bobolink	14.5	-0.31	0.73
LeConte's Sparrow	0.68	1.50	0.54
Sedge Wren	5.55	1.96	0.03

Table 1: Route-regression analysis of grassland songbirds in Minnesota, 1966-2005, as based on annual Breeding Birds Surveys.

Nesting success of waterfowl, pheasants, and songbirds utilizing small fragments of remnant habitat is usually too low to maintain viable populations. Grassland songbirds have declined more than any other group of North American birds, and data from Breeding Bird Surveys conducted in Minnesota corroborate these national trends (see Table 1). In the last 40 years, 10 of the 12 most typical grassland songbirds have declined, 5 of them at statistically significant levels. It is difficult to determine the causes of population declines for most species of grassland birds, but general reasons include loss of local and regional breeding habitats (see Figure 6).

Agriculture – Conversion of land to agricultural use has resulted in habitat loss. The shift toward cultivation of annual row crops, fire suppression, and draining of wetlands also degrade habitat.

Agricultural Policy–The Conservation Reserve Program (CRP) has provided tremendous benefits to prairie species of ducks, pheasants, and songbirds since 1985. Many of these acres are likely going to be coming out of CRP contracts over the coming years.

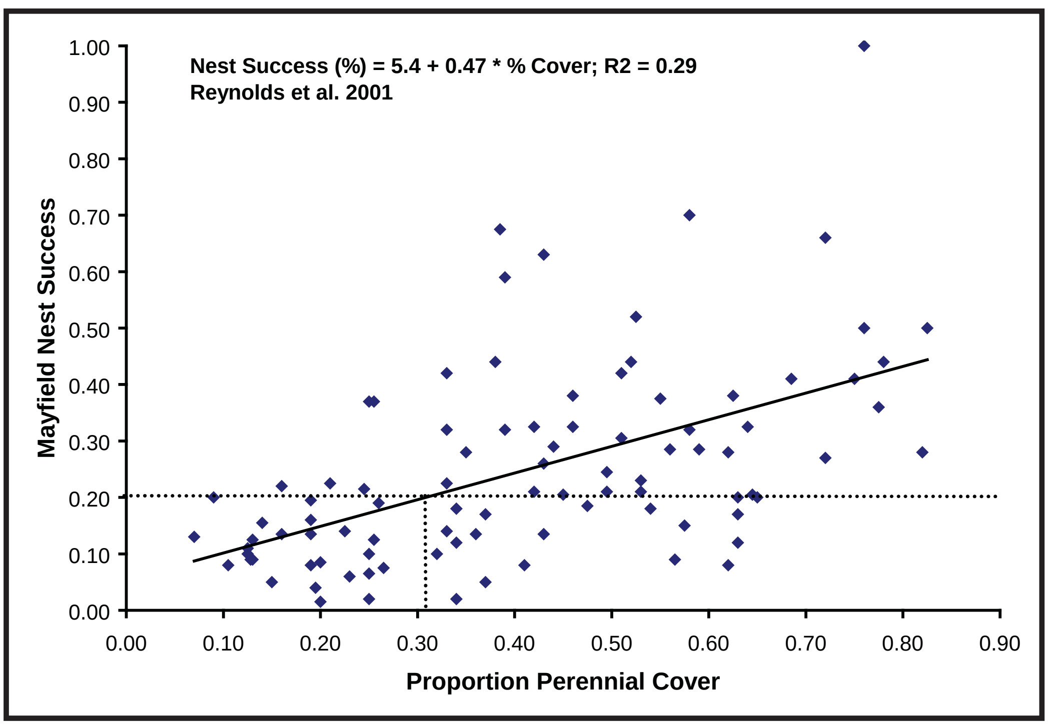


Figure 6: Nesting success of dabbling ducks as a function of % perennial cover in the surrounding 2 x 2 mile landscape in ND, SD, and MT. Credit: Reynolds et al. 2001

How these lands are managed will have enormous impact on wildlife. Future agriculture programs focusing on diversification, set asides, or biofuel production have enormous potential to help reverse habitat losses in the Prairie Region.

Data gaps include:

- Better understanding of the effects of habitat fragmentation and area-sensitivity on abundance, but especially on productivity of prairie wildlife.
- Design of working agricultural landscapes that are sustainable, profitable for producers, and also provide ecological benefits in terms of water quality, carbon sequestration, and wildlife habitat. Biofuels have potential to be a win-win situation (e.g., cellulose, perennial crops), but they also have the potential to cause tremendous harm (e.g., increased corn acreage). Diversification of prairie agriculture makes sense even if biofuels are not developed.

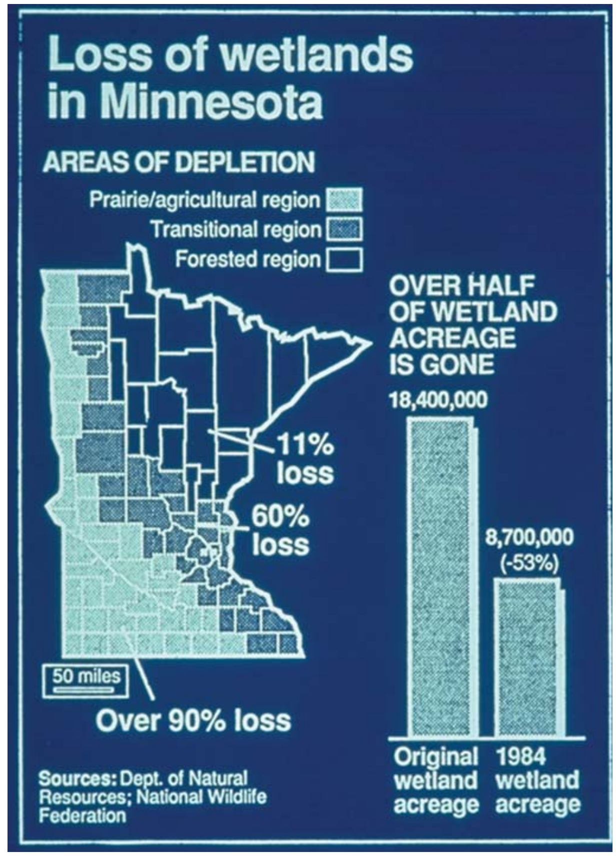


Figure 7: Wetland losses in Minnesota since Euro-American settlement times. Note that prairie losses are 90%. Credit: Minnesota DNR and National Wildlife Federation

Habitat Loss in Eastern Broadleaf Forests

In the Eastern Broadleaf Forest region, substantial areas of upland shrub woodland, upland hardwoods, prairie, and wetlands have been lost. Oak savannah is an ecosystem type that has been particularly affected within this province, with losses estimated at greater than 99%. Wetlands have been less affected, with losses averaging 60% of pre-settlement conditions as opposed to 90% in the prairies (see Figure 7). In most cases more wetland habitat has been altered than lost. Road construction in the region has also resulted in fragmentation of habitats.

Wildlife still utilize habitats across most of the wildland-to-urbanized gradient within this region, but the composition of the wildlife community has changed. This phenomenon has been best studied in birds, which actually occurs in greatest diversity in partially altered landscapes. Changes in composition occur because new species, especially those tolerant of human-dominated landscapes like American robins, common grackles, house sparrows move into and permanently occupy landscapes following habitat change. Birds that require larger tracts of forest like pileated woodpeckers, wood thrushes typically decline when their habitas decline. Species such as the Cerulean warbler are of concern because of the loss and fragmentation of mature floodplain forests found in this province.

When species are especially successful at exploiting human-altered habitats, some of the most serious wildlife problems occur in suburbanized and more populated landscapes. Under these conditions, overabundance rather than rarity becomes the focus of management. White-tailed deer are one of the best studied example.

Fragmentation of habitats through habitat loss and road construction are important issues for some wildlife. Some reptile and amphibian species experience high mortality when crossing roads to seek breeding habitat in the spring. In some locations, this mortaility is an important population limitation.

Urbanization and Development – Eastern broadleaf forests have been less affected by agriculture than the prairie region, but impacts from agriculture are still substantial. This area has also been heavily impacted by urbanization and development. Twenty-two of Minnesota's 25 largest cities are located in this province, most are in the 7-county Metro area.

Suppression of natural disturbance regime – Fire suppression has also caused great change in this region, especially through reduction of oak savannah habitats.

There is a significant gap in understanding the effects of habitat fragmentation and area-sensitivity on wildlife populations and especially on productivity. The greatest future threat in this region is due to increases in urbanization and exurbanization. Management approaches that can effectively make these urban and exurban areas more wildlife friendly are needed. Data and a better understanding of the critical habitats necessary to maintain an already large and growing list of species of special concern are also critical.

Figure 8: Piping Plover.

Habitat Loss in Laurentian Mixed Forest

Habitat loss in the Laurentian Mixed Forest has primarily been due to agricultural activity, especially in the southern and western portions of this province. Urban and exurban residential development as well as shoreline development have been extensive within the province. These have all resulted in habitat destruction, habitat degradation, and fragmentation of forested areas. Forest harvesting and management have also been extensive and have resulted in the homogenization of forested areas with replacement of coniferous forests with deciduous species such as aspen. Brushland areas in the western regions of the province have been affected by both habitat replacement with agriculture and by habitat degradation due to fire suppression with its resulting over-maturation. In general, many of the wetland ecosystems have been maintained. Most losses of wetlands have occurred in association with agricultural activity in the southern and western portions of the area or in dredging and filling operations in the St. Louis River Estuary.

Fragmentation of forests, brushlands, and wetlands in this province has been most pronounced in the southern and western regions as well as near the large cities and towns of the region.

Habitat loss concerns for Minnesota's wildlife in the Laurentian Mixed Forest include concerns in all the major habitats of the province. Bird species occupying brushland habitats that have been impacted by habitat loss include the sharp-tailed grouse, upland sandpiper, sandhill crane, northern harrier, American woodcock, loggerhead shrike, and golden-winged warbler. Mammals such as the American badger, and spotted skunk, and an important species of reptile, the eastern hognose snake, have been affected by habitat loss. Habitat destruction, habitat degradation via over-maturation, and habitat fragmentation have affected these brushlands. The drastic decline in sharp-tailed grouse over the past 50 years has likely been due to a loss of open brushland habitat from agriculture and over-maturation of the remaining brushlands. Sharp-tailed grouse need large, contiguous open brushlands for their breeding leks in order to observe predators.

The northern forested regions of the state represent some of the most diverse wildlife communities in Minnesota. Forest-associated wildlife include northern goshawk, boreal owl, red-shouldered hawk, ruffed grouse, spruce grouse, and many forest songbirds like the olive-sided flycatcher, boreal chickadee, black-throated blue warbler, bay-breasted warbler, and Connecticut warbler. Several species of mammals in this region are also well-known and of concern such as the gray wolf, Canada lynx, and moose. Reptiles and amphibians are less common in the northern regions, but the wood turtle, several species of salamanders, and frogs are of increasing concern both in Minnesota and worldwide. There are many reasons for changes in these wildlife populations, including habitat loss and complications due to climate change, an example is species moving northward. Most of the concerns for habitat loss in these forests are species-specific or unknown. The reduction in coniferous tree species has certainly affected many species that require conifers for survival such as spruce grouse, boreal chickadee, and bay-breasted warbler.

Many wetland species continue to thrive such as beaver, mink, otter and muskrat, however, many wetland species such as the yellow rail, black tern, Nelson's sharp-tailed sparrow, rusty blackbird are listed as special concern as are many species of waterfowl like the American Black Duck. There are many species-specific reasons for the special concern status for these species, however, habitat loss (destruction, degradation, and fragmentation) is certainly a major contributing threat to their long-term survival in Minnesota. For instance, opening of the forested regions has allowed the mallard to become more common and interbreed with the American Black Duck.

Community type	GLO (%)	FIA (%)
White pine	29.6	0
Black spruce	13	9.9
Larch	11.4	1.6
Red pine	8.3	0.8
Northern white cedar	3.5	6.7
Balsam fir	2.6	4.7
Jack pine	7.9	0.8
Conifers	**76.3**	**24.5**
Paper birch	17	7.9
Aspen	6.3	63.3
Maple	NS	1.9
Ash	NS	2
Deciduous	**23.3**	**75.1**

Table 2: Laurentian Mixed Forest tree species distribution. GLO = general land office bearing tree data circa 1880's. FIA = forest inventory and analysis plots 1990. Source: Friedman and Reich, 2005

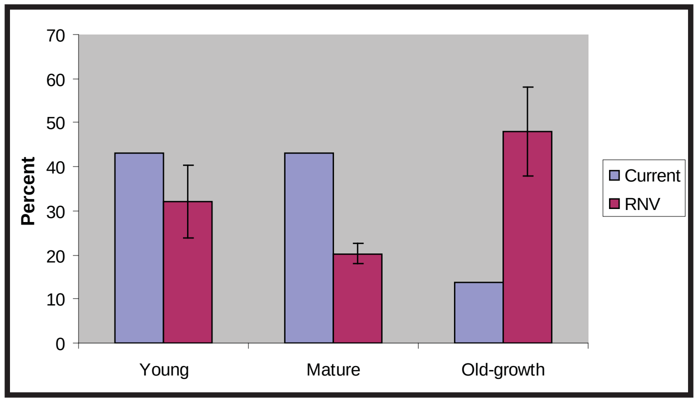


Figure 9: Percentage of forest by age class, current vs. range of natural variation (RNV). Credit: Minnesota DNR.

Among the most severely threatened species in this region are the piping plover (see Figure 8, facing page) and common tern. Both species require open shoreline nesting areas on the mainland or islands adjacent to large water bodies, examples are St. Louis River Estuary, Leech Lake, and Lake of the Woods. Habitat loss due to shoreline development, recreational use of these areas, competition for nesting sites with gulls, and high predation rates all have contributed to reduced populations of these species.

Many species of invertebrates are also of concern within this region. Most are less well-known by the public and many species are still not described by the scientific community. Several species of tiger beetles like hairy-necked tiger beetle, butterflies, snaketails, and skippers are of concern.

Even though the Laurentian Mixed Forest province remains largely forested (66% currently vs. 76% historically) it has substantially changed in terms of age, composition, and structure. Species such as the black-throated blue warbler, the red-shouldered hawk, and the northern goshawk rely on older forest species, which historically comprised approximately 48% of the section versus less than 15% today (see Figure 9). Aspen dominates today's forest, while conifers and other hardwoods have dramatically declined (see Table 2). Many species in greatest conservation need rely on coniferous forest, including several specialists such as the spruce grouse and smokey shrew. Structures created by downed logs, standing snags, a closed canopy, or shrub cover are needed by many forest species. For example, the four-toed salamander relies on rotting logs and dense moss layer (see Figure 10). However, todays' forest managemnt practices often eliminate or reduce these structures.

Figure 10: Four-toed salamander. Credit: Carol Hall, Minnesota DNR

Agriculture – Conversion of forests, wetlands, and brushland habitats to agricultural land has resulted in habitat loss. Agriculture can be linked to changes in water levels, habitat quality, sedimentation, and fragmentation of wetland habitats, all of which are likely contributing factors to declines in wetland-associated species.

Residential and Shoreline Development – Forest, wetland, and brushland habitats throughout Minnesota have been subjected to conversion to residential uses. Extensive shoreline residential and recreational development has created problems for riparian and wetland-associated species such as changes in water levels, habitat quality, sedimentation, and fragmentation of wetland habitats. Two of the most threatened species of the province, the federally endangered piping plover and the common tern, have had extensive loss and disturbance of their sandy, shoreline beach habitat. More recently, the increase in ring-billed gull populations and their associated use of these habitats has exacerbated the problem.

Altered natural disturbance regimes – Fire suppression has also resulted in habitat change due to advanced succession of brushlands with subsequent high densities of shrubs and even tree development. Forest fires were the predominant form of regeneration of most forests of northern and central Minnesota. Except for the Boundary Waters Canoe Area Wilderness, fire has been replaced with forest harvesting and management as the dominant regenerating force. Forest fires and logging do not have the same effects on forest habitat or landscapes; responses of wildlife to each of these disturbances have some similarities and many differences. The long-term effects of these changes on wildlife are speculative.

We need an improved understanding of the effects of habitat loss, especially degradation and fragmentation are needed in this province. The brushlands and forested landscapes have become more heterogeneous with extensive edge reduced habitat patch areas and lower tree species diversity. The long term effects of these changes need better understanding.

Little is known about the status or impacts on many lesser known wildlife species such as amphibians and invertebrates.

Climate Change

Climate change is predicted to have major impacts on the distribution and abundance of all habitats and disturbance regimes (fire, wind, flooding, and drought) in Minnesota (see Figure 11, facing page). The predicted changes in temperature and precipitation patterns in Minnesota will affect all wildlife species, some in predictable ways and for others it is unclear. Most of these changes will be expressed through changes in habitat, diseases, parasites, and species interactions such as predator-prey, while others may be responses to physiological restraints such as temperature.

Wildlife distribution models and recent data for breeding birds show northward shifts in distributions of Minnesota wildlife. Species such as moose, Canada lynx, rock vole, and many bird species with boreal affinities like the bay-breasted warbler, Connecticut warbler, Cape May warbler, rusty blackbird, and spruce grouse will likely be reduced in abundance or disappear from the state. Species currently more common in southern Minnesota or south of Minnesota such as the wild turkey, Northern mockingbird, scissor-tailed flycatcher, tufted titmouse, and great-tailed grackle are likely to increase northward in Minnesota or become more common in the future. There are many indicators of changes in wildlife populations in Minnesota as the opossum, raccoon, coyote, red-bellied woodpecker, and Northern cardinal which have become increasingly more common in northern portions of the state; however, some of these changes are also complicated by increased urbanization, exurbanization, and tolerance by humans.

Increased temperatures and changes in precipitation patterns are also projected to negatively impact prairie wetlands, especially already stressed waterfowl populations in the western and northwestern portions of Minnesota.

Minnesota has a reasonably good network for monitoring selected wildlife species such as game species, selected bird species (federal breeding bird roadside counts), national forest monitoring, and an emerging amphibian roadside survey. Because climate will primarily affect distribution of organisms, these monitoring programs will be critical for detecting future changes in the distribution and abundance of wildlife populations. Many species are not adequately inventoried or monitored such as reptiles, invertebrates, and many of the species of special concern. Without this information, it will be difficult to assess impacts on wildlife species in the future.

Climate change models and subsequent habitat change models will be developed in the future. There is a need to link these models with wildlife distribution and abundance to predict future changes.

Exotic and Invasive Species

Exotic species are defined as those species that occur outside their natural range because of human activity. Exotic species can be considered "invasive species" if they establish themselves and increase by crowding out native species. There have been hundreds of introductions of exotic wildlife species in Minnesota, but fortunately most of them have not become invasive. In comparison with aquatic ecosystems and plant communities, the establishment of invasive, exotic species have been substantially less. The most common invasive wildlife species that have established themselves in Minnesota include the European starling, house

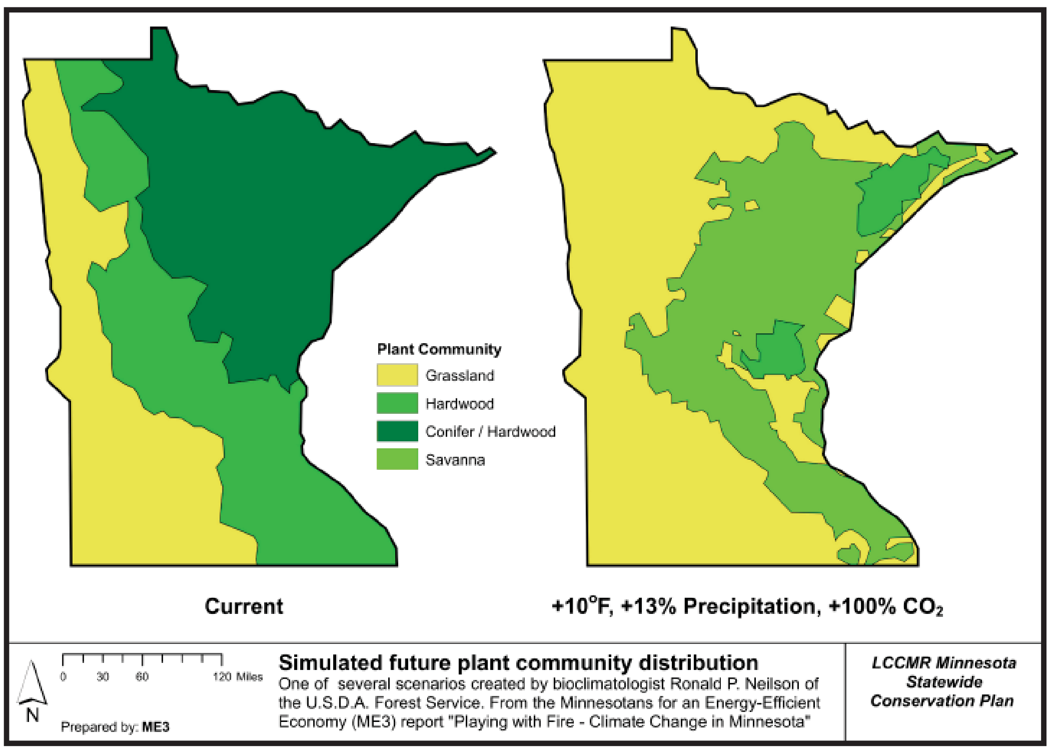


Figure 11: This map projects what Minnesota vegetation cover might look like if average temperatures in the state rise 10 degrees Farenheit and precipitation increases 13% at double historical CO2 levels. This is one of several scenarios created by bioclimatologist Ronald P Neilson of the U.S.D.A. Forest Service. Credit: Terry Brown, University of Minnesota

sparrow, house finch, Norway rat, house mouse, and several species of earthworms of European origin.

Many of the established invasive species have been confined to human-dominated habitats, others have become established in native Minnesota habitats and are detrimental to native wildlife species. European starlings have successfully competed with native cavity-nesting bird species such as the Eastern bluebird. The house finch has displaced the native purple finch in many instances. There are no native earthworms in Minnesota. The presence of non-native earthworms is a growing concern, especially in forests where their activity has affected understory plant species, tree seedlings, and soil structure with potentially cascading effects on small mammals, amphibians, and bird populations. Earthworm impacts, especially in hardwood forest, have also been associated with exacerbation of negative effects of white-tailed deer and aiding in spread of other exotic species such as slugs and plants like European buckthorn.

Exotic insects and their impacts on plants have also contributed to vast problems in Minnesota with subsequent effects on wildlife. For example, Dutch elm's disease, a fungus thought to originate from Asia, has affected elms throughout Minnesota, particularly in urban areas. More recently, the gypsy moth and the emerging emerald ash borer, both exotic insects, are predicted to become invasive and have major effects on trees in Minnesota if they become established.

There are several diseases that have been introduced (e.g., West Nile virus) into the United States and subsequently to Minnesota. These will be covered below under Diseases.

Basic information on the impacts of exotic species on Minnesota wildlife are critical, especially for those that establish themselves as invasives. Since many of these exotic species have entered into other parts of the US and Canada, early gathering of information is essential. Most of the true impacts of exotic and invasive species on wildlife are unclear.

Diseases

Many diseases are found throughout Minnesota's wildlife. These include botulism in birds such as pelicans, rabies in mammals, and brainworm in moose. A number of exotic diseases such as West Nile virus are also emerging as potential threats to wildlife in Minnesota. As globalization of the economy and inter-continental transportation continues, exotic and invasive diseases will likely become even more prevalent in the future. Moreover, new molecular techniques are allowing better identification and tracking of diseases.

There are many diseases that affect Minnesota wildlife, but the actual impacts on wildlife species are unclear. Botulism is intoxication/food poisoning and is well-documented in many species of waterfowl including pelicans and cormorants. Canine parvovirus is important in attenuating the Minnesota wolf population increase, and heart-worm, a southern disease is appearing here in Minnsota. Rabies is a virus with a reservoir primarily in mammals such as skunks, raccoons, fox, coyote, and bats. Brain worm is a nematode that is found in white-tailed deer and other ungulates. It generally is not lethal to the white-tailed deer, but can be lethal in moose. Moose are susceptible in places where they overlap with the white-tailed deer. It has been documented that over 100 species of birds have died through the relatively recent introduction and increase in West Nile virus. The overall effects of diseases on wildlife populations are subtle and difficult to detect.

More information is needed on the effect diseases have on wildlife species in Minnesota. These data needs should be carefully coordinated with other federal agencies responsible for the assessment on the effects of disease.

Pollution

One of the most dramatic success stories in the recovery of wildlife populations over the past 50 years has been the recovery of the bald eagle, peregrine falcon, osprey, and many water-associated species following the banning of the pesticide, DDT. While it was in use, DDT and its metabolites accumulated in the upper food chains of fish-eating birds. The chemical disrupted calcium metabolism, which is key for forming stong egg shells. The resulting thin shells caused unsuccessful nestings and a drastic decline in population. With the banning of DDT, eagles and other water bids have been able to recover. Furthermore, regulation of new chemicals and point sources of pollution have led to reductions in many contaminants.

Pollutants cause direct mortality to wildlife individuals and subsequently populations or, in the case of nutrients or sediment, they can disrupt habitats, especially wetlands or near-shore aquatic zones. As with disease, the effects of pollutants on wildlife populations can be subtle and difficult to detect. For example, sedimentation in wetlands and near-shore lake and river systems result in physical changes to habitat structure and to food supplies for wildlife. Similarly, nutrient loading results in eutrophication of aquatic habitats and disruption of aquatic food chains.

The ultimate effects of other pollution sources on Minnesota wildlife populations are unclear. Elevated mercury levels have been found in many aquatic habitats throughout Minnesota. Many fish-eating species such as otter, mink, common loon, and common tern have been shown to be affected by high levels of mercury. Atrazine, an agricultural pesticide, has been shown to have effects on reptile and amphibian populations. PBDE's have been found in wildlife populations throughout the world. PAHs, a byproduct of petroleum use, have also been found widely in wildlife populations. They are known to disrupt various physiological processes such as development, but the actual linkages to the viability and survival of wild populations is unknown.

Pollution affects wildlife populations throughout Minnesota. However, it is unclear to what extent these factors limit natural populations in the wild. Information is needed on the extent of the overall effects of pollution in the environment relative to other factors with direct linkages to population effects such as habitat loss. Without question, pollution contributes to problems with Minnesota wildlife and in concert with other limiting factors, serves to further exacerbate population levels for many species. Recent reductions and concerns for amphibian populations may be a priority for data. Amphibian populations appear to be affected by a wide variety of issues, including habitat loss, climate change, diseases, parasites, and pollution.

Hydrologic Modifications and Man-Made Structures

There are a wide variety of additional drivers that have effects on wildlife in the state of Minnesota. These include hydrological modification to aquatic ecosystems such as dams and dredging activities as well as non-natural structures such as roads, communication towers, artificial night lighting, and more recently wind turbines.

All of these modifications and structures contribute to both changes in habitat or direct mortality to wildlife. Vehicles are well-documented to kill millions of amphibians, birds, butterflies, mammals, reptiles, and other insects. In addition, roads, especially the wider ones, contribute to fragmentation of landscapes and reduced dispersal of wildlife populations. Dispersal and subsequent gene flow among wildlife populations is extremely important to maintain their viability. Mortality on migrating birds caused by communication towers, especially very tall towers, has been well documented in many locations, but has been little studied in Minnesota. Wind turbines have been well documented to kill both birds and bats. Strategic placement of wind turbines to avoid migratory bird pathways in coastal regions can help to reduce these impacts. Similarly, modification of night lighting in cities and on towers can reduce the impacts on wildlife.

The overall effect and risk to Minnesota wildlife populations of these structures is unknown and difficult to study. Mortality on roads is widespread, whereas mortality from towers and wind turbines are infrequent, but intensive, hundreds or thousands of birds can be killed in one evening. Basic information on the contributions of these non-natural structures to mortality in Minnesota wildlife are needed.

Figure 12: Bobolink on the prairie. Credit: Anonymous

Exploitation/Social Tolerance/Persecution

The role of direct human-mediated factors as drivers of change in Minnesota wildlife welfare is currently not a major issue nor should it be considered a serious problem in the foreseeable future. This is because state and/or federal wildlife and natural resource laws regulate both exploitation and persecution of wildlife, populations of most species that might be persecuted or overexploited are monitored, and the trend in public and legislative attitudes is toward greater protection. Social tolerance or intolerance is variable but any serious effect on wildlife is still subject to regulation such that, barring the role of a species as an important vector of a serious human disease, wildlife populations will remain viable. The gray wolf was subject to social intolerance and persecution until the late 1960s but the federal Endangered Species Act protected it, allowing it to increase from about 700 to 3,000 today. The population was declared recovered and the species was removed from the endangered species list in 2007. It remains under state protection despite its depredation on livestock. Only highly regulated taking is allowed and the population will be monitored regularly.

"I worry about a decline in grassland birds especially as there is increased emphasis on ethanol production."

—Campaign for Conservation workshop participant

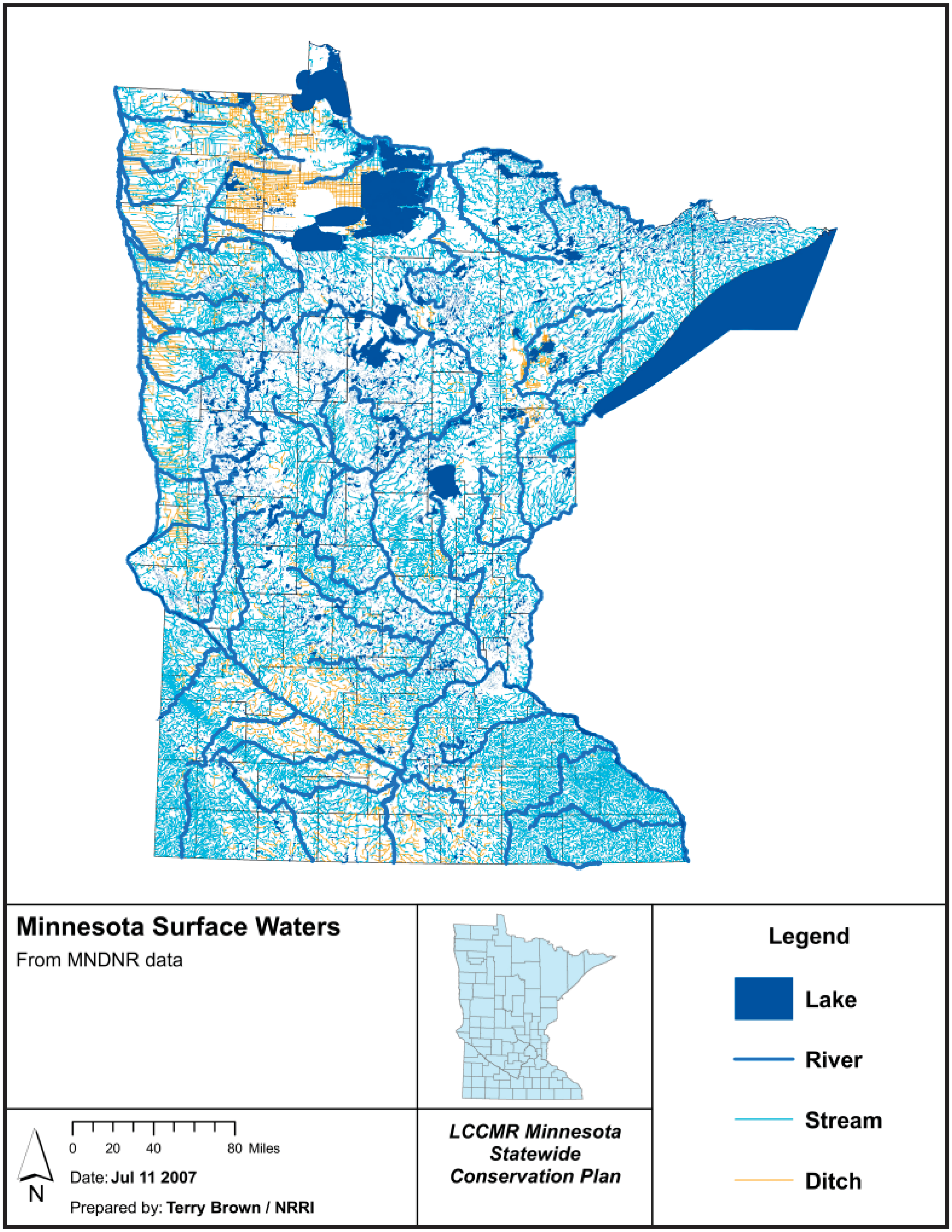


Figure 1: Surface waters in Minnesota. Credit: Terry Brown, University of Minnesota.

"The frog does not drink up the pond in which he lives."

—American Indian Saying

History

Water is one of Minnesota's most important and most visible natural resources. Water underpins much of the state's economy and provides its citizens and visitors with a wide variety of recreational options. Compared to many parts of the United States, Minnesota contains a high diversity of water resource types, ranging from large rivers to small streams, cold water to warm water lakes, many different wetland types, and groundwater. This is due to Minnesota's glacial history and diversity of landforms. This aquatic diversity, across seven aquatic ecoregions supports an impressive range of plant and animal species.

Prior to European settlement and the subsequent population expansion a wide range of natural or baseline water resource conditions could be documented in the state. Water bodies ranged from naturally oligotrophic waters with low nutrients, low productivity and high water clarity to naturally eutrophic waters with high nutrient concentrations, high productivity and low water clarity. Lake Superior is one of the most oligotrophic systems in world. Minnesota's shallow lakes are naturally eutrophic. Not all pre-settlement water conditions were pristine. Many water bodies were not clear due to naturally occurring concentrations of arsenic, salt, methane, radon, radium and dissolved solids. As efforts move forward to conserve and improve the quality and quantity of Minnesota's water resources, it will be important to distinguish these natural variations from those caused by human activities.

The current condition of Minnesota's water resources is quite different from the pre-settlement era. The clearing of the land, conversion of the land to agricultural systems and urban/suburban development have all had a direct impact on water resources. Figure 2 shows the result of these stressors on the north shore region of Lake Superior.

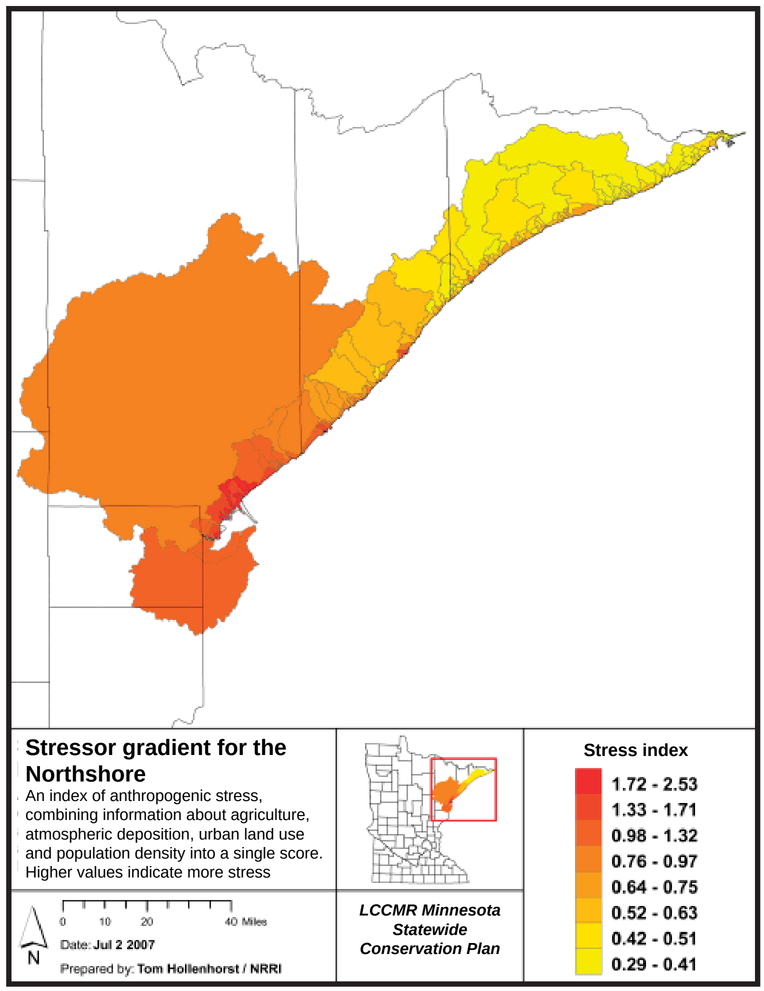


Figure 2: Northshore stressor gradient. The stressor index is a means of integrating a series of environmental stress factors into a single number. The factors include road density, population density, percent agriculture and residential development, and numbers of point sources of pollution (including discharge permits, presence of mines, power plants and dams). This index has been used to identify 'reference areas' (those that represent the best ecosystems, which have high conservation value) as well as 'at-risk' ecosystems.
Credit: Niemi et al., University of Minnesota.

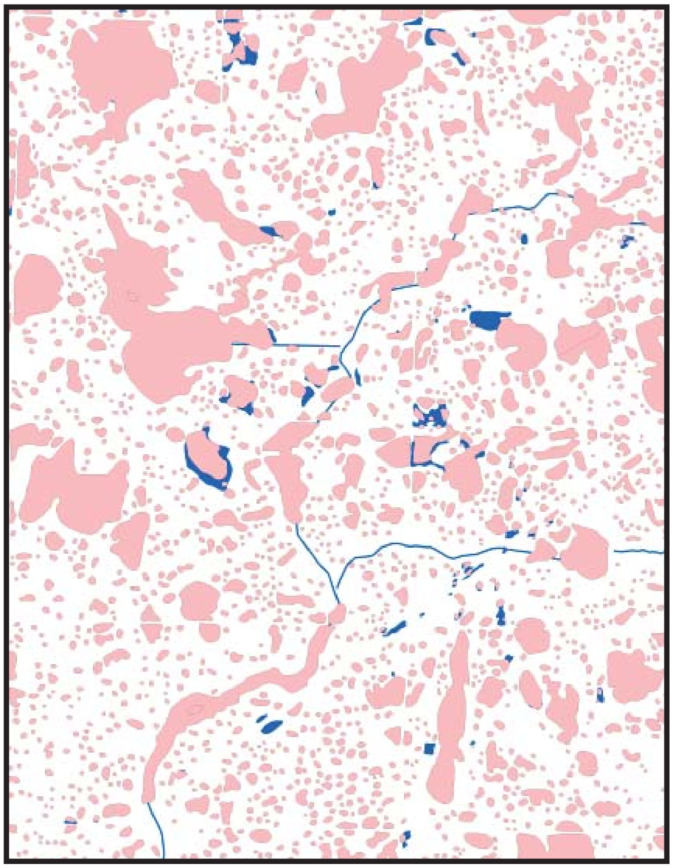


Figure 3: Wetlands of Kandiyohi County. Blue indicates existing wetlands. Salmon indicates drained (and therefore theoretcially restorable) wetlands. Credit: Rex Johnson, US Fish and Wildlife Service.

It is currently estimated by the Minnesota Pollution Control Agency (MPCA) that approximately 40% of Minnesota's rivers, lakes, and streams are considered "impaired" under the Clean Water Act, and do not meet water quality standards.

The hydrologic cycle and the natural balance between surface water and groundwater has been disturbed. It is estimated that nearly 95% of the wetlands in the state have been drained. An example of this is found in Figure 3, which shows the number of former wetlands that could be restored in Kandyohi County.

Surface Water and Ground Water Connectedness

The quantity of both surface water and ground water varies naturally across the state due to variations in climate and geology. These two systems are highly interconnected with significant changes to one reflected in the other. Baseflow in rivers, the flow that occurs after runoff and drainage from rainstorms or snowmelt have ceased, is in reality ground water that drains to surface channels. Current recharge rates for Minnesota's groundwater are depicted in Figure 4, facing page.

Nonsustainable withdrawal of groundwater can have significant impacts on surface waters. Over-pumping of groundwater in the Twin Cities metro area has caused decreased baseflow in trout streams, forcing the relocation of groundwater wells. In many parts of the state, groundwater pumping has threatened calcareous fens. In north central Minnesota water use permits were not renewed after wetlands were impacted by groundwater pumping for irrigation.

Surface water is typically managed on a watershed basis, recognizing that surface water does not cross watershed boundaries. Managing ground water and aquifers will require that we recognize the boundaries of the aquifer, and the land area that contributes water to the aquifer. Those boundaries are determined by the arrangement of water-bearing and water-confining geologic materials (see Figure 5, facing page). Most aquifers and confining units in Minnesota have not been mapped. This deficiency precludes understanding of aquifer capacity, recharge rates, and land areas contributing water to aquifers that is required to manage these resources.

Although these two systems are interconnected, most of the drivers of change to the overall resource act primarily on one or the other and they are discussed separately in this report. Where a driver impacts both systems, it is discussed within the system where it has the larger impact.

Drivers of Change: Surface Water

- Solids Loading
- Nutrient Loading
- Aquatic Habitat Loss
- Contaminants
- Hydrologic Modification

Minnesota has an abundance of surface water (see Figure 1, page 58): 93,000 miles of rivers, streams and ditches; approximately 870,000 wetlands covering 10 million acres; and 3 million acres of lakes larger than 10 acres, about 13,000 in all.

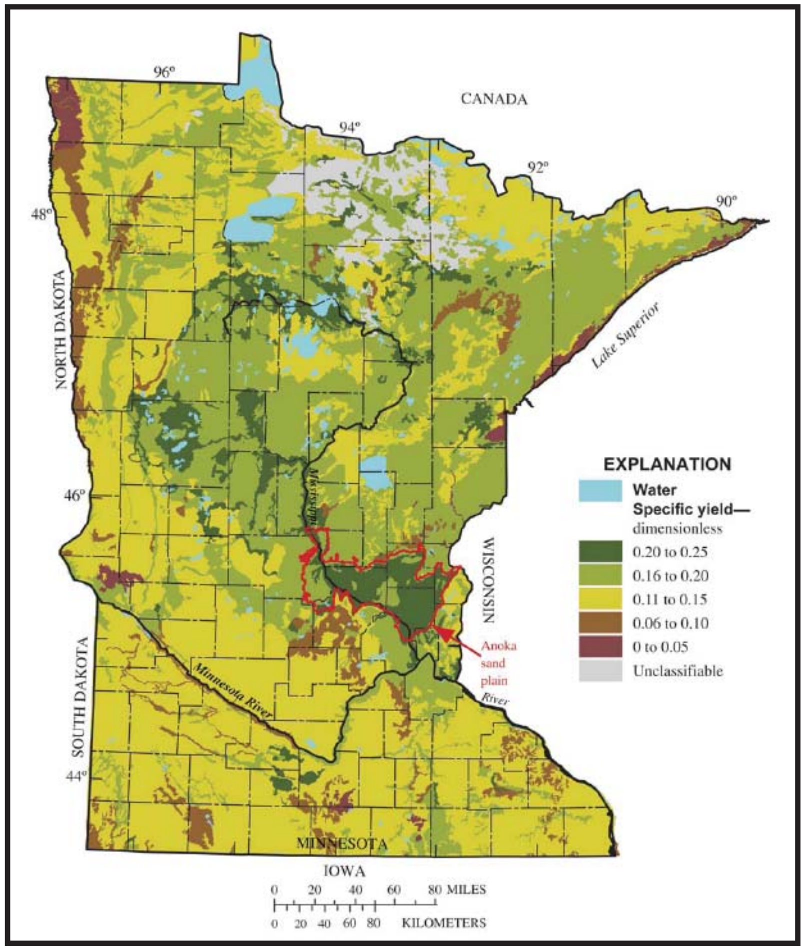


Figure 4: Average annual recharge to surficial materials in Minnesota (1971 - 2000) estimated based on RRR model. Credit: Lorenz and Delin (2007).

Minnesota's rivers, streams and ditches are fed by surface runoff, as well as by springs and baseflow from shallow and deep aquifers. Annual runoff varies from one inch in parts of western Minnesota to 9 inches in southeastern Minnesota and up to 16 inches along portions of Lake Superior. Runoff is highly variable, largely in response to snowmelt, rainfall and evaporation patterns.

Solids Loading

Solids loading results from activities such as agriculture, shoreland development, urbanization, construction activities and stormwater drainage. Erosion of sediment from bluffs and streambanks is also important and can be influenced by runoff variability.

Solids delivered from the watershed can cause cloudy or turbid water which negatively impacts fish and aquatic communities (Note: The impacts of sedimentation on fish and aquatic communities are addressed in the Fish Natural Resource Profile). Turbid waters absorb more solar radiation and become warmer than those water bodies with clear water and can result in associated changes in plant and animal communities. Sediment particles themselves may contain significant amounts of organic matter, nutrients, and toxic pollutants such as heavy metals and pesticides, and thus they become sources of secondary pollutants. Sediments that are not associated with secondary contaminants are known as "clean" sediments.

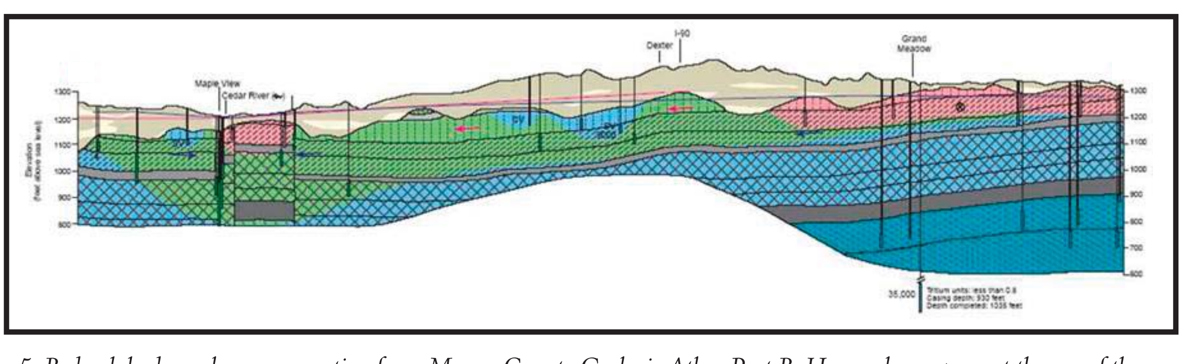


Figure 5: Bedrock hydrogeology cross-section from Mower County Geologic Atlas, Part B. Here, colors represent the age of the ground water. The pink water has entered the ground in the last 50 years, the green water is of intermediate age, and the blue water is as old as 35,000 years. Credit: Minnesota DNR.

Moving water generally has the capability of becoming more turbid than standing water. One prediction of climate change is an increase in the number and intensity of extreme storm events. As climate tempurature increases there is a greater potential for introduction of fine and coarse sediments to all surface water bodies. In conjunction with high flows and lower bank erosion causing further increases in concentrations of fine and coarse sediments.

Better data for sediment loads and sediment sources are needed. Monitoring can be difficult and expensive. Stormwater sediment concentrations and secondary pollutant concentrations and loads are extremely variable in space and time and are event-based. The higher levels of pollutants which occur as a result of rainstorms, high winds on lakes, and during snowmelt runoff are difficult to sample. This is particularly true for smaller, flashier streams, because higher flows and higher loads of sediments occur during unpredictable, short-duration rainstorms and during spring snow-melt runoff which is highly variable from year-to-year. Reliable methods to differentiate ("fingerprint") in-stream versus external sources of sediment to a river would assist in the development of TMDLs for sediment impairment. While the MPCA has had some support for research in this area, the state is encouraged to continue to invest in this needed research.

A better understanding of the critical landscape areas is also needed. These are small areas that contribute disproportionately large amounts of sediment to surface waters. Also needed is a better understanding of streambank and bluff erosion processes, and the influence of them on hydrologic management. Additional data are needed to develop models that link climate to landscape

Water: Shared Resource Implications

Within the State: North Central Lakes Collaborative

The North Central Lakes Collaborative is an affiliation of citizens, organizations, local governments, and state agencies working together to identify and promote strategies for sustainable healthy lakes in central Minnesota. The five county area encompassing Aitkin, Cass, Crow Wing, Hubbard, and Itasca counties is a rapidly growing region of the state with 30-year growth projections expected to exceed 60%, far exceeding statewide average growth projections. The Brainerd Lakes area is among the country's fastest growing "micropolitan" areas, ranking 27th in the nation with a 24.5% increase in population during the previous decade. These population growth statistics do not consider the popularity of central Minnesota for seasonal housing such as lakeshore homes. With this rapid-paced growth comes a number of challenges to the long-term sustainability of the region's water resources, which include over a fifth of the state's lakes and 11% of the state's river miles (42% of the Mississippi River miles within Minnesota). Local planners are faced with a dilemma: how to accommodate growth while still maintaining natural systems that contribute to a high quality of life for all residents, particularly in a tourism-driven economy.

Initially organized in 2003 as one of five pilot project areas under Governor Pawlenty's Clean Water Initiative, the North Central Lakes Collaborative has since made important contributions to sustainable healthy lakes in the region and statewide. Among these accomplishments are the development of Alternative Shoreland Development Standards, a suite of regulatory tools that are available for local governments to adopt into their zoning ordinances; delivery of information and technical assistance to over 30 landowners interested in conservation easements as a means of protecting their land and lakeshore for future generations; implementation of a regional wastewater treatment strategy to promote the regular maintenance and inspection of dispersed on-site sewage treatment systems (septic tanks) common in rural Minnesota; and production of a number of radio spots and newspaper articles under the popular Lake Waves communication series that informs lake users and residents about lake-friendly actions they can take to protect lake water quality and aquatic habitats.

The strength of the North Central Lakes Collaborative lies in the diversity of individuals, organizations, and government contributing time and creativity to seek balanced solutions for the complex challenges facing central Minnesota lakes.

to surface/groundwater runoff to water quality, fish and wildlife, and infrastructure. More data are needed to evaluate the effectiveness and cost-benefit of planning, Best Management Practices (BMPs) strategies and engineering solutions being used to address the issue.

Nutrient Loading

Phosphorus is the nutrient of most concern in surface waters in Minnesota (see Figure 6). It is a naturally-occurring nutrient that is required for plant growth but in excess amounts it promotes a proliferation of algae that results in reduced dissolved oxygen content as algae die and decay. Reduced oxygen concentrations stress fish and other aquatic species. The increased productivity also leads to increased turbidity, and to taste and odor impairments in drinking water (Note: The impact of excess nutrients on fish and aquatic communities is addressed in the Fish Natural Resource Profile).

Excessive phosphorus is usually delivered from non-point sources (such as agriculture, shoreland development and urbanization) to waterbodies via surface runoff. Phosphorus also enters Minnesota surface waters from point sources such as the discharge of treated wastewater and stormwater drainage.

More data on the prevalence and trends of phosphorus loading in the state's surface waters are urgently needed. Currently only 10% of the state's surface waters have been assessed.

Best management practices for phosphorus include preventing surface runoff, manure management, stormwater management and other strategies that reduce surface runoff from urban areas.

Aquatic Habitat Loss

Habitat for aquatic organisms is defined as the physical and chemical environment that provides the resources for daily living, including food, protection, nesting and rearing. The most productive and vulnerable zones of rivers and lakes occur at the margin of the land and water (Note: habitat features of importance to fish communities and other aquatic organisms are also addressed in the Fish Natural Resource Profile).

Habitat quality is most susceptible to degradation resulting from human activities occurring near the shoreline and within the watershed of a river, lake, or wetland. Many of these activities result in decreased watershed and riparian vegetation which can result in runoff with elevated water temperatures and increased sediment and nutrient loads.

Human activities that influence habitat quality in streams, wetlands and lakes include:

- residential, commercial or industrial activities,
- logging,
- agriculture,
- mining,
- shoreline or stream channel modifications,
- groundwater and surface water extraction.

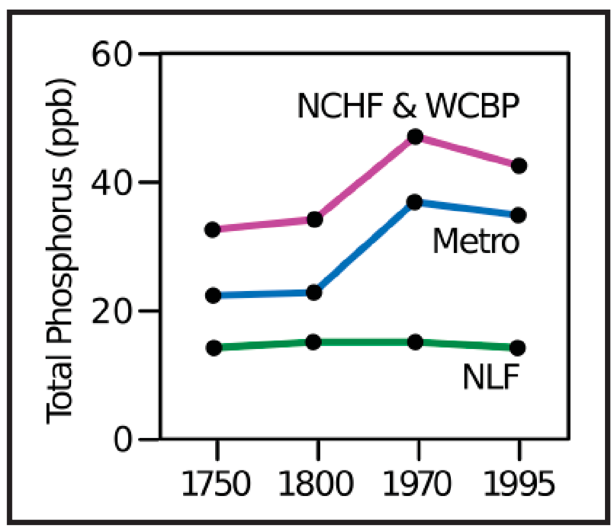


Figure 6: Increases in total phosphorus (TP) over time in 55 representative Minnesota lakes (the dates of the measurements are on the horizontal axis). Phosphorus is a major pollutant, and it has increased significantly in the Metro region lakes and in the center of the state (which is labeled NCHF and WCBP) over the past 200 years. Lakes in forested northeastern Minneosta (labeled 'NLF') have not seen an increase in phosphorus. Maximum and minimum values may range widely around the points shown, which are averages. Credit: Ramstack et al. 2004. Graphic byTerry Brown, University of Minnesota. This work was funded by LCCMR.

Under changing climatic regimes, wetlands, and the areas as the intersection of the land and water will become even more sensitive as water levels fluctuate and plant communities adapt to changing conditions. Under warmer climates, shading from riparian vegetation will be increasingly important to buffer daily temperature swings in cool and cold water streams.

At a gross scale preliminary tools are available to quantify potential stressors influencing in-stream and in-lake habitats and ecosystems. The water/land margin areas as well as aquatic vegetation beds and shallow areas are poorly mapped, and therefore poorly protected. Riparian and shoreland protection rules should be considered to protect these valuable and vulnerable areas. Further research on the potential impacts of changing climate, including increasing temperatures as well as the increasing number of intense storms is needed to identify vulnerable ecosystems and habitats. Such efforts will allow us to prioritize protection and restoration activities.

Contaminants

There are a number of chemical, physical, and microbiological contaminants that can impact water quality. The focus of this section is on specific toxic chemical contaminants that have the greatest impact on the state's water resources. We recognize that there are "legacy" contaminants in our lake and river sediments such as PCBs; "emerging" contaminants that are just now being detected in the environment, such as pharmaceuticals, brominated flame retardants, and perfluorinated compounds; and metals, such as mercury. We will highlight the important contaminant drivers of change below.

Mercury

Mercury is the contaminant of primary concern in surface waters in Minnesota. It is a naturally occurring but toxic metal. It is mobilized into the environment from coal-fired power plants (certain kinds of coal contain mercury), mining, and some manufacturing processes. Mercury is emitted into the atmosphere, but then enters lakes and rivers with precipitation. It is be transformed by bacteria into methylmercury, which bioaccumulates in fish. Current levels of mercury in the environment are considerably greater than preindustrial levels, as recorded in lake sediments (see Figure 7).

Methylmercury is a potent neurotoxin, and poses particular risk to children and fetuses when exposed.

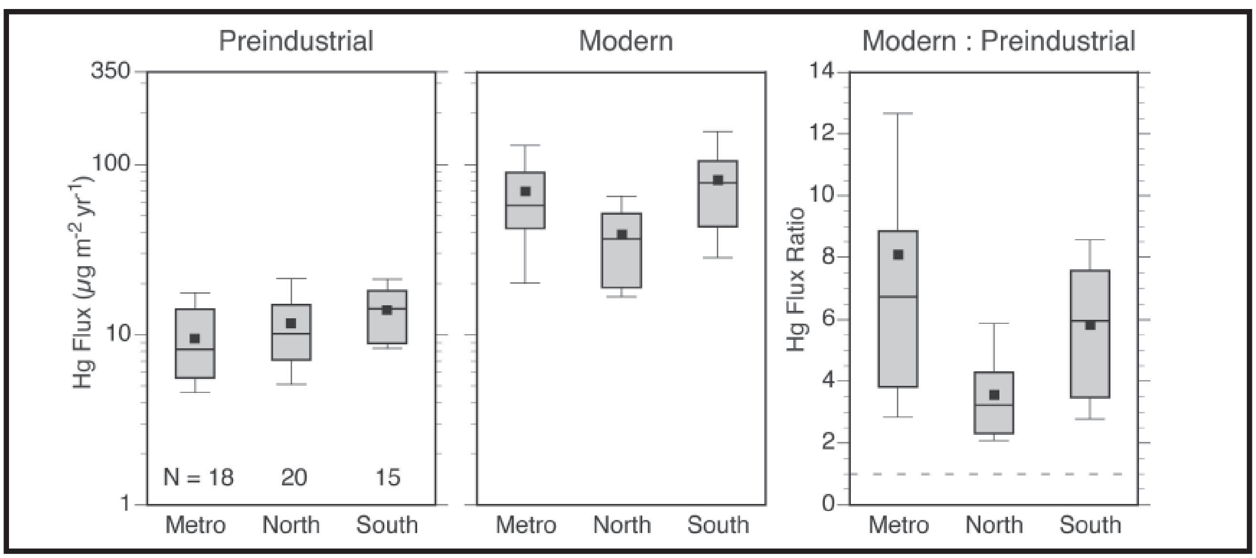


Figure 7: Box plots of sediment - Mercury (Hg) fluxes and flux ratios for the study lakes by region. Preindustrial is the mean Hg accumulation rate prior to 1860 and Modern is the mean rate post-1994. Metro = Minneapolis-St. Paul metropolitan area, North = northeastern Minnesota, South = south central Minnesota (rural). Boxes represent interquartile ranges, bars delineate upper and lower 10%, and the center line is the median; means are shown by closed squares. Credit: Engstrom, Balogh and Swain (2006). This work was funded by LCCMR.

These potential risks from methylmercury exposure has led the Minnesota Department of Health to issue fish consumption advisories for all of our lakes and streams. Because the primary source of this contaminant is the atmosphere, it is discussed more fully in the Air Natural Resource Profile (see page 18).

Pesticides

Pesticides affect both surface and groundwater. Generally, they are of more concern in groundwater than in surface waters (see Groundwater section, page 68). In a limited set of surface water samples collected in agricultural production regions of the state between May and July 2005, 98% exhibited the presence of atrazine and deethylatrazine, and 76% exhibited the presence of metolachlor. In no cases, however, did concentrations of these pesticides exceed federal or state health guidelines or maximum contaminant levels for drinking water.

Pharmaceuticals/Endocrine Disruptors

Many consumer goods and products contain chemicals that can mimic the behavior of hormones and other chemical signals of the endocrine system in animals, known as endocrine disrupting compounds (EDCs). These chemicals include common additives to detergents, food packaging, and plastic containers, as well as naturally excreted estradiol, and the synthetic estrogens in birth control pills and menopausal medications. Consequently, they are very widespread in our environment. They end up in wastewater, but since wastewater plants are not designed to remove these kinds of compounds, they are discharged to natural waters. Agriculture practices are also a source, due to the extensive use of animal hormones, and the use of certain hormonally active pesticides. Landfill leachate is another source. The occurrence of EDCs is directly related to population, and cultural behavior.

Studies of their impacts on wild populations of fish in the Mississippi River, and the results of laboratory studies on fish done by researchers at the USGS, University of Minnesota, and St. Cloud State University, have clearly demonstrated the potential for these estrogens and estrogen-mimicking compounds to affect the reproduction capability of male fish. Their impacts on other wildlife in the state, or on humans, are much less understood.

Pharmaceuticals in the environment are primarily a result of the use of antibiotics and other drugs in

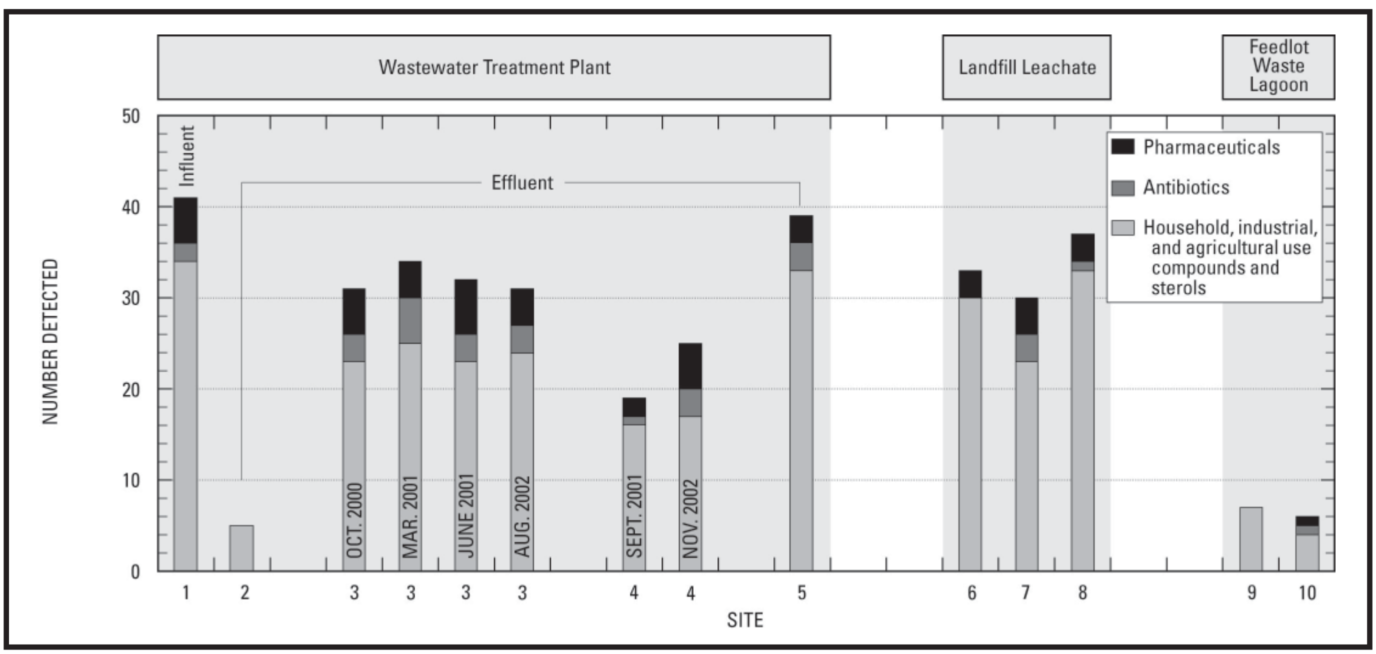


Figure 8: Organic wastewater compounds detected in wastewater treatment plant, landfill leachate, and feedlot waste lagoon samples, Minnesota, 2000-02. (site identification numbers can be found in table 1 and figures 1 and 2 of the report.). Credit: Lee et al. (2004), USGS.

commercial animal operations, and in the disposal of consumer drugs in waste water by the general population. The USGS has documented the widespread occurrence of a wide range of over-the-counter and prescription drugs in our surface and groundwater both nationally and locally.

A state-wide study of organic wastewater compounds in 2000 to 2002 by the USGS demonstrated that 74 of 91 potential compounds were detected at least once. The most commonly detected compounds were metalochlor, cholesterol, caffeine, DEET, bromoform, several plasticizers, a synthetic musk, a plant sterol, and cotinine (see Figure 8, page 65). The fate and impacts of these drugs in our surface waters is largely unknown.

The risks to humans posed by the presence of EDCs and pharmaceuticals in our water is unknown at this time; there are limited data on the impacts to wildlife populations. Critical information that is needed includes:

- Persistence and reactivity of compounds once released to the environment.
- Exposure of compounds to people and animals – concentrations in surface, ground, and drinking water supplies.
- Impact of exposure to individual species.
- Risk assessment for populations (as opposed to individuals).
- Human toxicity data.

Hydrologic Modification

There are three primary types of hydrologic modification in Minnesota. These include:

- Impervious surfaces in urban settings.
- Surface ditching in all 10 major river basins.
- Subsurface tile drainage in the Minnesota River Basin.

Dams are also a type of hydrologic modification, but have been typically less important than the other types of hydrologic modification for impairing water quality. Where they exist they have huge impacts; changing lotic habitats to lentic, preventing fish passage, and, as a result, causing the extinction of other organisims such as freshwater mussels (see Fish Natural Resource Profile).

Hydrologic modification is a stressor to water bodies because it changes the volume, rates, and timing and duration of water runoff from the landscape. Hydrologic modifications impact most stages of the water cycle.

Hydrologic modifications affect surface waters through the following mechanisms:

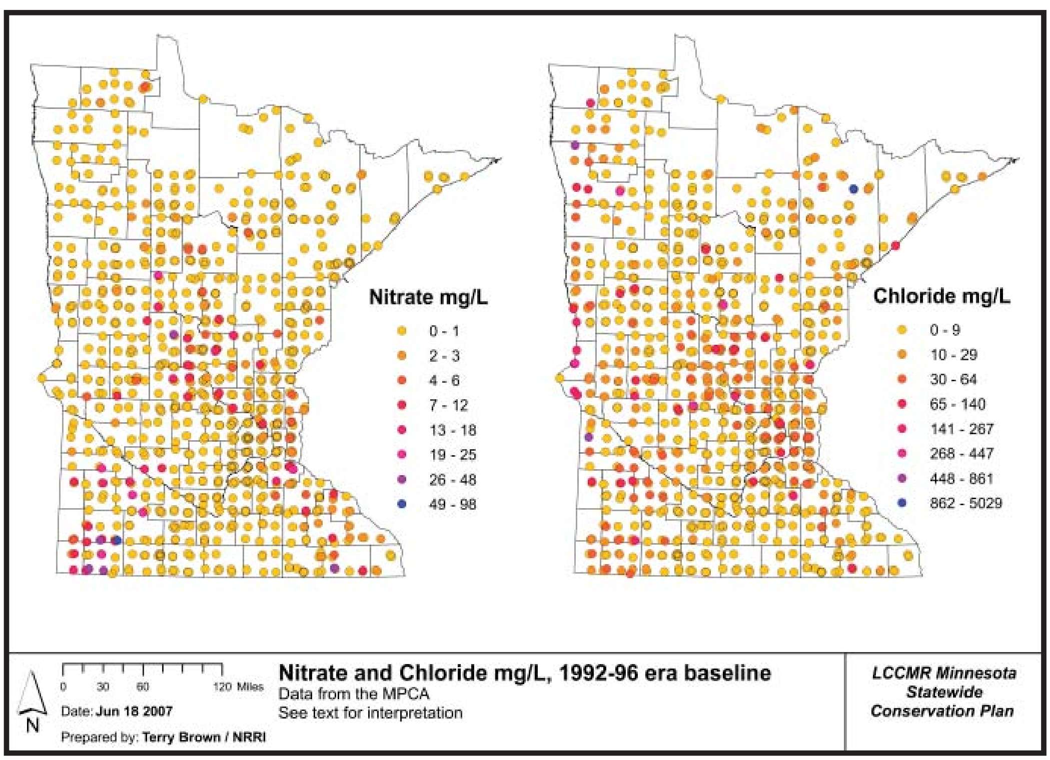


Figure 9: Nitrates and chlorides in Minnesota surface waters. Credit: Terry Brown, University of Minnesota.

- Surface ditching, artificially straightened natural streams, and impervious surfaces increase total runoff of sediment, phosphorus and contaminants to surface waters.
- Subsurface tile drainage increases the delivery of nitrate(N) and pesticides to surface waters (see Figure 9, facing page).
- Impervious surfaces coupled with surface ditching and straightening of natural streams increase peak flows, which results in flooding, channel scouring (erosion) and alteration (see Figure 10).
- Impervious surfaces cause flow velocities and amounts to increase and then decrease more rapidly in response to a given rain event (a "flash flood effect").
- Impervious surfaces cause lower base flows which exacerbate drought impacts, especially temperature and oxygen extremes.
- Surface ditching and subsurface tile drainage lower the shallow water table, and caused the loss of nearly 90% of the natural wetlands in southern Minnesota over the last century. Impervious surfaces produce lower base flows which impacts seasonal wetland persistence.

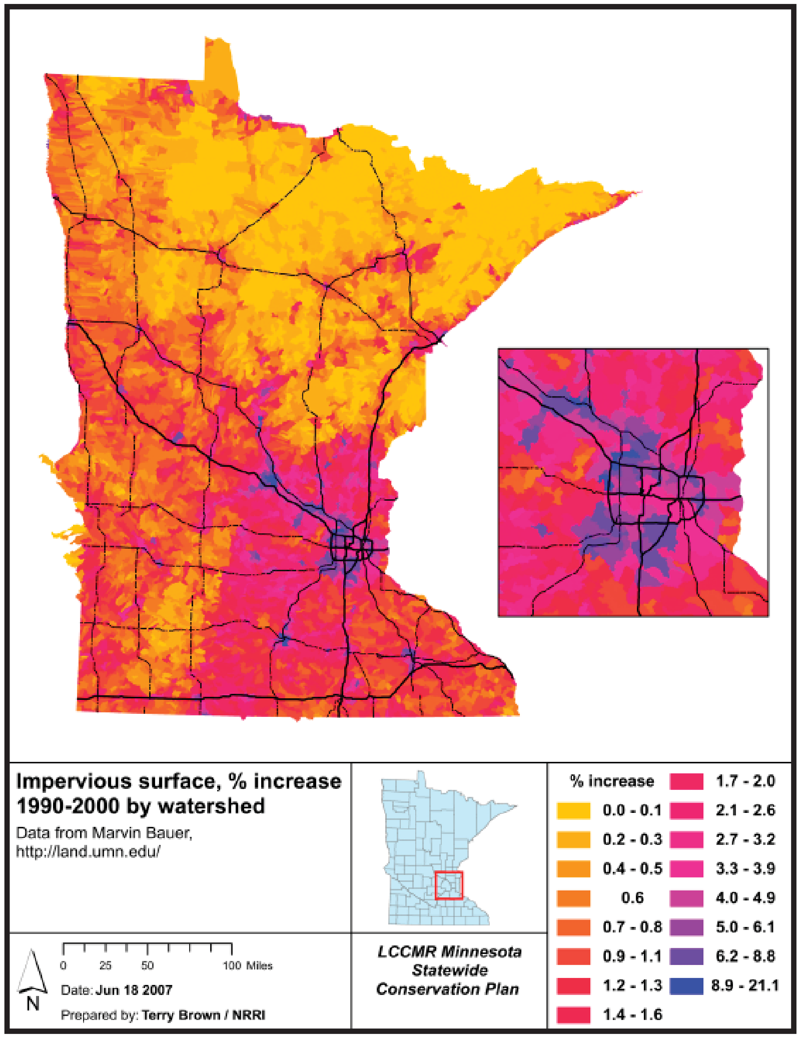


Figure 10: Impervious surface increase by watershed 1990-2000. Credit: Marvin Bauer, University of Minnesota. Funded by LCMR. Figure prepared by Terry Brown, University of Minnesota.

Because of these effects, hydrologic modification is a major consideration in managing stormwater runoff to minimize water pollution.

Changing demographics, in the form of increased population, and land use, in the form of urbanization, have resulted in large increases in urban growth and rapid expansion in the extent of impervious surfaces. Energy (ethanol) and agricultural policies and practices have encouraged a shift toward annual cropping systems, which has brought about increased surface and subsurface drainage. Historical ditches, tile drains, and channelized stream reaches persist and continue to be associated with many water quality problems.

An increasingly wetter climate in the Minnesota River basin caused a large increase in the extent of subsurface tile drainage over the last two decades. Potential changes in climate will further amplify the effects of poor societal land use management decisions. Most dramatically, projected increases in the frequency of severe storms may exponentially increase channel and shoreland erosion, flooding, and soil loss.

There are regional patterns in the impacts of these major drivers of water resource degradation. Minnesota's diverse climate and landforms are associated with regional differences in human activities on the landscape, and therefore, types of stressors.

- In agricultural regions channelization and tile drainage have disrupted flow regimes. Impacts from these activities include sediment, nutrient, and pesticide loading, decreased oxygen, and increased temperature.
- Urban resources are degraded most often by the effects of increased impervious surface area.
- Forested areas are also threatened by impervious surface increases caused second home development along lake shores and streams. Runoff-related changes from increased stream crossings by roads, and the amount of logging have also degraded water in forested areas. Some of the more sensitive forest areas are affected by forest practices such as in wetland areas, riparian zones and where the terrain is steep and has thin or poorly drained soils.
- In the far north, boreal ecosystems are especially vulnerable to changing climatic conditions since hydrologic regimes are forecast to have a greater degree of change than to the south. These areas contain most of the State's cold-water biological communities.

See the Groundwater section below for further discussion on the impacts of hydrologic modification and existing data gaps.

Drivers of Change: Groundwater

- Hydrologic Modification
- Consumptive Use
- Contaminant Loading (pesticides)
- Nutrient Loading

Minnesota hosts a variety of geologic materials in a complex, three-dimensional arrangement. These include glacial drift, glacial outwash and bedrock aquifers. On a regional scale, differences in the water-bearing characteristics of these materials and their arrangement results in extremely uneven distribution of groundwater resources. For example, the western border region has fewer and smaller aquifers than southeastern Minnesota or the Twin Cities area. On a more local scale these differences greatly affect how long it takes precipitation, the origin of groundwater, to travel from the land surface to the aquifers supplying our wells. In many places wells provide water that entered the ground hundreds or thousands of years ago (see Figure 5, page 61). That water was never exposed to human activity and therefore its quality has not been degraded by either natural or human means. In other places, the available aquifers are shallower or are recharged over a much shorter time frame. The water in these aquifers commonly contains contaminants from our industrial, agricultural, or waste management practices.

Not so water rich

"The label of Minnesota as water rich does not fit as well as once believed. The growth corridor stretching through the Twin Cities to St. Cloud already makes significant demands on its renewable water resources, making water supply management a special concern. In the remainder of the state, even today, care also must be taken by local and state officials in planning to meet the demand for and allocation of water."

Use of Minnesota's Renewable Water Resources: Moving toward Sustainability, Environmental Quality Board and Department of Natural Resources, April 2007

Hydrologic Modification

See the discussion of hydrologic modification in the Surface Water section on page 60 for a complete description.

Hydrologic modifications affect groundwater in the following ways:

- When precipitation reaches the land surface, impervious surfaces may prevent their infiltration. These surfaces typically divert the water to stormwater systems that affect both the destination of that water, and the rate at which it travels.

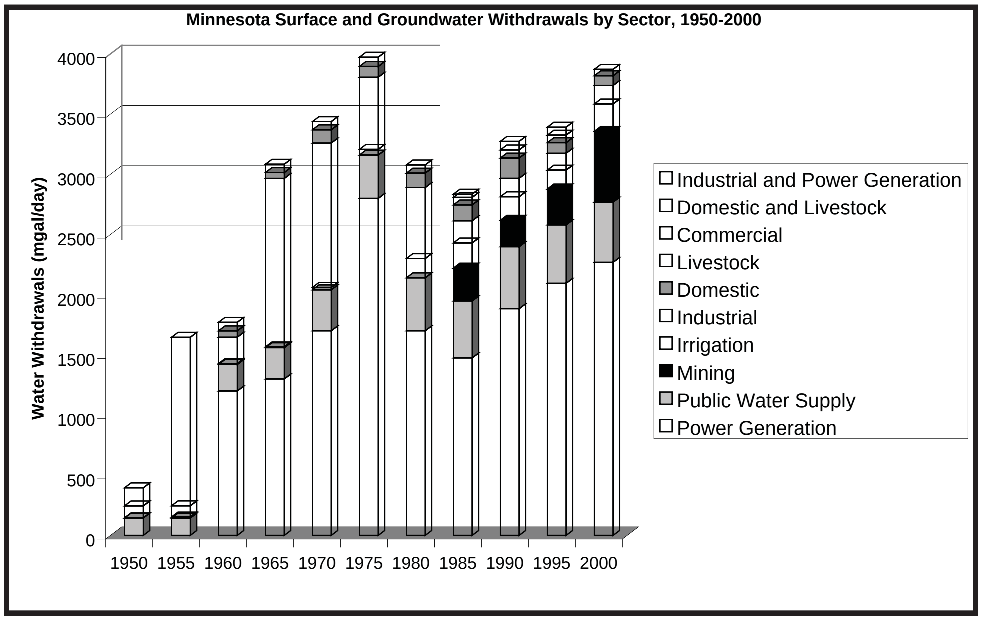


Figure 11: Surface and groundwater withdrawal rates by sector. Notes: For 1950 and 1955, domestic withdrawals were reported together with livestock withdrawals, and industrial and power generation withdrawals were reported together. Commercial withdrawals were not recorded in 2000 or before 1985. Mining withdrawals were combined with industrial withdrawals before 1985. 'Pubic Water Supply' category includes public water going to domestic, commercial, industrial and power generation sectors. Credit: Laura Schmitt, University of Minnesota.

Agricultural drainage systems similarly intercept precipitation and move it to surface water bodies. This can significantly reduce groundwater recharge in that this precipitation may not infiltrate the surface and become groundwater depending on where it is routed.

- Groundwater withdrawal (see Figure 11) by pumping wells, is another form of hydrologic modification. Pumping may induce an increase in the rate of recharge, or change the path of recharge, to groundwater aquifers. In addition, hydrologic modification occurs because the location of discharge may not be hydrologically connected to the aquifer from which the water was taken.
- Sinkholes: In some geologic settings the impoundment of water at the land surface can cause sinkholes to develop which catastrophically drain the impoundment. In the case of wastewater treatment ponds or stormwater ponds this can introduce a large slug of poor quality water into the groundwater system.

The impact of subsurface tile drainage on streambank erosion or groundwater recharge is not known, nor is the impact of impervious surfaces on groundwater recharge.

Consumptive Use

Water consumption is the use of water withdrawn from a water body, watercourse or aquifer that is not directly returned to its original source.

Water consumption reduces the volume of water available for other purposes within a water body, watercourse or aquifer. Because groundwater and surface waters are interconnected – they are one system – consumption of groundwater from an aquifer may reduce the amount of surface water in a stream, lake or wetland, and vice versa. Consumption alters the quantity and flow regime of water resources provided by a natural system and can adversely affect the unique natural features and ecosystem functions that depend upon them. In some cases, water consumption can alter water chemistry. In Wisconsin, for example, ground water withdrawal pumping has been shown to increase arsenic concentrations in groundwater.

Withdrawal of groundwater may lower the water level in an aquifer either temporarily or permanently depending on available recharge. Much of the ground water pumped is discharged at or near the land surface via irrigation systems, on-site waste treatment systems (septic tank systems) or municipal wastewater treatment systems. Large scale systems tend to move the water farther from its source laterally, potentially having greater effect on the water resource and the people and ecosystems that depend on it.

The primary drivers of water consumption are the people and businesses (see Figure 11, page 69) that require water for drinking, energy production, food production and commercial/industrial use. Minnesota's population, demographic characteristics and weather, as well as its land use, energy use, transportation and water use habits profoundly influence the amount and location of consumed water. In addition, climate change may exacerbate the problem in some areas by increasing water demand and reducing water storage.

Regional and global population also can be important drivers of water consumption. As regional and world populations increase, new demands for food and energy will increase water consumption in Minnesota. The water needed to grow crops is in effect transferred out of basin and state as virtual water in the form of food or energy.

Water consumption may affect and be affected by other drivers, such as hydrologic modifications, which change the amount and timing of flows or available supplies, and contaminants, which alter the suitability of water resources for human and ecosystem uses. Nutrient loading, in particular that of nitrates to groundwater, may also make water unsafe to drink. Erosion leads to sedimentation that may diminish the capacity of surface water reservoirs to store water. Finally, consumption of water supplies may degrade habitat by reducing low flows in streams and groundwater discharges important to fens and other wetlands.

Minnesota withdraws roughly 200 billion gallons of groundwater every year for domestic supply, industrial processing and irrigation. In addition, ethanol plants use a substantial amount of water for processing, and a large number of ethanol plants are located in areas where groundwater is scarce. The burgeoning ethanol industry in Minnesota currently uses roughly 2.4 billion gallons of water, mostly from groundwater supplies. Lack of adequate groundwater supplies has forced at least one ethanol plant in western Minnesota to close, and another was forced to curtail plans for expansion. Overpumping of groundwater in Dilworth, located in northwestern Minnesota, forced the town to seek other more expensive sources of water.

Because the location and characteristics of water resources vary across the state, as do the people and ecosystems that depend upon them, the effects of water consumption likewise vary. A 2007 Environmental

Water: Shared Resource Implications

National Obligations

The Mighty Mississippi begins in Minnesota, and rolls down through the heartland of the nation, emptying into the Gulf of Mexico. This vast river system contains the 16th longest river in the world. Its watershed is the second largest in the world, and drains 1.2 million square miles including parts of 32 states, and serves as a major artery for movement of commercial goods from the Twin Cities to New Orleans, as well as goods brought from far and wide to its many ports by train and truck. It is one of three major flyways for migratory birds traveling between South and Central America and North America. It is a defining icon of American history and heritage. In Minnesota, it drains 40% of the state of Minnesota, and ¾ of our population live in its watershed. Stewardship of the Mississippi River not only affects most Minnesotans, it affects the lives of many Americans, as well as providing a vast set of ecosystem services. What we discharge to the River in Minnesota can affect human health in New Orleans, and the half-billion dollar shrimp fishery in the Gulf of Mexico. We not only have an obligation to protect this river, we have an obligation to be a model for the rest of the country in providing stewardship for this great River who claims our state as its birthplace.

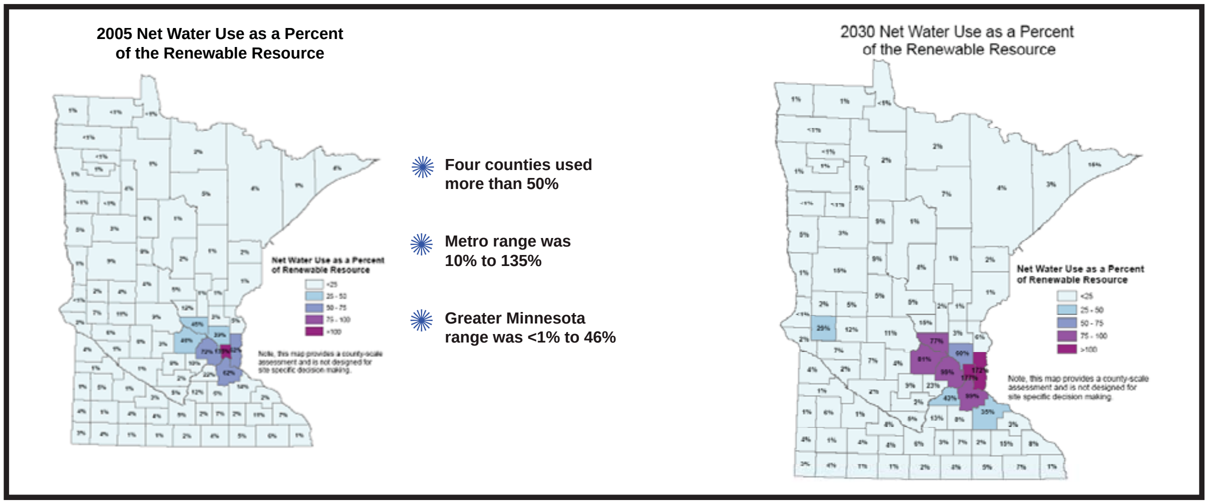


Figure 12: The assessment shown in these images worked with published methods describing recharge to the water table system (and, with one method, discharge from ground water systems). It used these as surrogates for sustainable supply values, developing five sets of renewable resource estimates. The analysis used the median volume of renewable water resources estimated for each county in making comparisons with demand for that county. The comparisons were made for reported and permitted use in 2005, and estimated use in 2030. In addition, the analysis adjusted appropriations from surface waters coming into a county, since resource estimates did not include such waters. It also removed non-consumptive water uses from the tally. The 2005 water use values were calculated by averaging each county's per capita demand for the years 1995 to 2005 in order to provide a baseline not artificially affected by a single year's climate. These same use rates were applied in estimating demand in 2030. Credit: Environmental Quality Board.

Quality Board-Department of Natural Resources assessment evaluated current and future water demand, as well as renewable water resources available at the county scale. While the analysis did not take into account those waters flowing into a county, the results signal that water allocation has already become a serious issue in some locations. The results indicate that water consumption in 2005 may exceed renewable supply levels in one county and take more than half of such supplies in three other counties, all in the metropolitan region. By 2030, the same four metro counties are expected to be at or above renewable resource levels and another three in the northwest quadrant of the growth corridor well above the 50 percent consumption level (see Figure 12). While the issue has obvious regional distinctions, most localities throughout the state encounter water supply and use conflicts. This is evidenced by the Department of Natural Resources suspension of surface water appropriations in 2006 to protect at risk aquatic communities and by the increasing concern with water use by ethanol production facilities.

The life history of many aquatic organisms is dependent on the variability of water across the landscape and through time. *Minnesota Statutes*, Section 103G.265 recognizes this in its call for the state to ensure an adequate supply to meet "long-range seasonal requirements" for various human and ecosystem uses. Yet to do this, water managers need to understand the timing, frequency and magnitude of supplies, the varying demands placed on them and potential use conflicts. For example, surface water appropriations can be expected to increase during the hottest and driest seasons and years when supply is the lowest and aquatic organisms are under greatest stress.

At present, the state has limited ability to:

- Quantify water consumption.
- Define the location and characteristics of ground water resources.
- Measure aquifer recharge rates and understand the impact of the redistribution of water.
- Understand what volume of water is renewable; that is, how much can be taken for use on a long-term, sustainable basis, seasonally and annually, without mining groundwater or harming ecosystems.
- Understand the impacts of drainage or other land use practices on rates of recharge, and

means to quantify these impacts.

- Understand the impacts of global warming on climate, rates of recharge and water demand.
- Characterize the interactions of surface and groundwaters, including both water quality and quantity implications.
- Quantify the seasonal and inter-annual variability of stream flow and quality of water needed to support basic ecosystem functions.

Future work should:

- Focus on geographic areas with supply and demand conflicts and evaluate resource management options, including how best to integrate use of surface and groundwaters.
- Evaluate how public water suppliers are integrating sustainability into the second generation of water emergency and conservation plans.
- Analyze water demand and availability on a seasonal or monthly basis; conduct analyses on watershed and sub-county, as well as county levels; and evaluate the current effects and future risk of water quality degradation on water supplies.
- Investigate new means to quantify sustainable supply or ways to build upon existing supply methods.
- Investigate the seasonally variable protected flow requirements needed to preserve aquatic communities
- Assess the results of historic mass water level measurements in the Twin City metro area and those planned for 2008.
- Evaluate Minnesota's "safe yield" concept for protection of ground water resources.
- Develop the comprehensive water management framework needed to manage water on a long-term, sustainable basis as required by law, including the routine water resource monitoring and assessment activities required to support the framework.

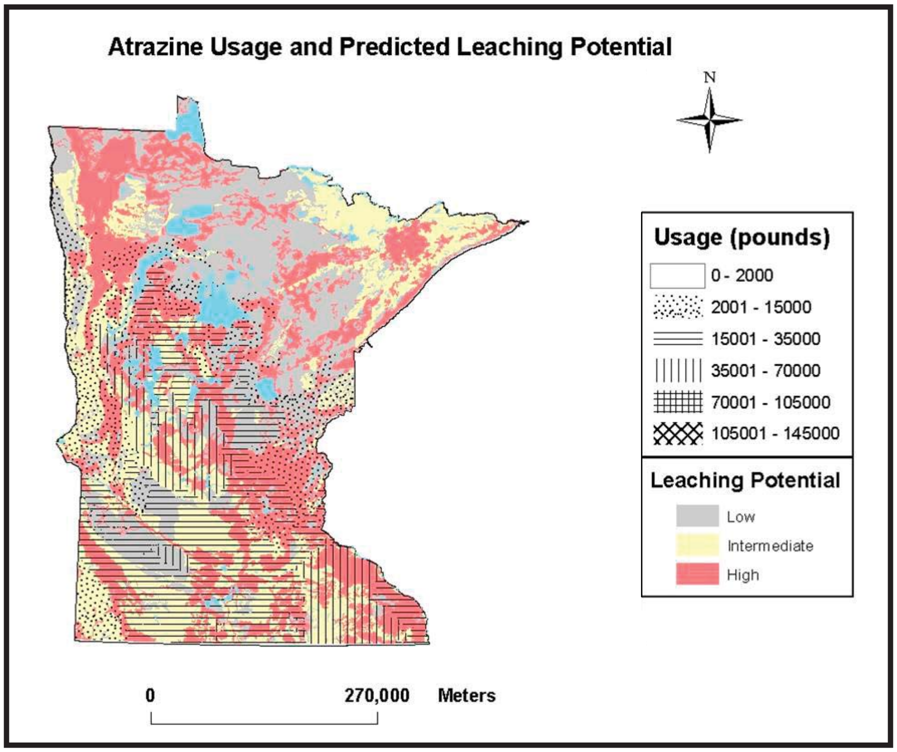


Figure 13: Atrazine usage and predicted leaching potential. Credit: David Mulla, University of Minnesota.

Contaminant Loading (pesticides)

Pesticide contamination results from the loading to surface or groundwater of chemical herbicides, insecticides, and fungicides. In a limited set of groundwater well samples taken in 2004 and 2005, 6 out of 19 wells and 14 out of 46 samples exhibited the presence of alachlor. Five out of 19 wells and 11 out of 46 samples exhibited the presence of metolachlor. In no cases, however, did concentrations of these pesticides in groundwater exceed federal or state health guidelines for drinking water.

Pesticide contamination leads to the degradation of surface and ground water, in some cases limiting the ability to use water. It can also result in negative impacts on aquatic ecosystems, wildlife, humans and pets. Degradation of water quality to a point that it can no longer be allocated to its designated use effectively limits the quantity of water available.

The primary driver of pesticide contamination is targeted land use, driven by the industries that use pesticides (such as industrial agriculture), turf management, road side vegetation maintenance, and private or residential consumption. Pesticide contamination may affect and be affected by other drivers including land use change, increased agricultural production, hydrologic modification and climate change, all of which may lead to increased pesticide use or more direct transport of the contaminant to the local water body.

The impact of pesticide loading to water bodies in Minnesota is broad, but largely limited to the zones of agricultural production from northwestern Minnesota to southeastern Minnesota. Minnesota's geology and hydrology, which vary across the state, determine the vulnerability of water resources to pesticide loading. For example, Figure 13 shows likely areas of potential concern for atrazine loading, overlaying use of the chemical with leaching potential to illustrate how sensitivity varies across the state.

Existing data gaps limit the state's ability to:

- Quantify pesticide loading to surface and ground water.
- Better define the location and characteristics of water quality degradation due to pesticides.
- Characterize seasonal fluctuations in pesticide loading rates.
- Describe short-term and long-term impacts to aquatic ecosystems, wildlife and humans.
- Understand the impacts of global warming on storm patterns and their resulting impact on loading rates.
- Characterize the interactions of surface and ground waters, including both water quality and quantity implications as they relate to pesticide loading.

Future work should:

- Develop a long-term water quality and quantity monitoring plan that brings together all state agencies involved in monitoring quality and quantity, so that there is consistency and overlap in spatial and temporal sampling.
- Support and expand upon the work of the Environmental Quality Board to evaluate long-term water quality trends in Minnesota.
- Evaluate whether additional sampling at specific locations would advance the work of other agencies with minimal extra effort or expenditure.
- Research the chronic and acute impacts of pesticides on aquatic ecosystems when coupled with the stressors of other pollutant loading (much research focuses on the impacts of single contaminants versus the impacts of multiple exposure).
- Increase the temporal resolution of pesticide

Water: Shared Resource Implications

International Obligations

Minnesota shares its northern border with Canada, and has three major watersheds that span that boundary. Lake Superior, the largest of the Great Lakes and the largest lake by area in the world, is shared by Minnesota, Wisconsin, Michigan, and Ontario. It contains 10% of the world's surface freshwater, supports a multibillion dollar recreational and commercial fishery, and is home to the largest commercial shipping port in the Great Lakes (Duluth-Superior). The Rainy River is the defining international boundary for much of Minnesota and Manitoba. The Boundary Waters National Canoe Area and the Quetico Provincial Park in Manitoba are two parts of the same vast stretch of connected lakes that knows no political boundary. The Red River flows north along the Minnesota-Dakotas border up to Lake Winnipeg and beyond, and ultimately empties into Hudson Bay. These are all immensely valuable bodies of water, providing economic, cultural, and spiritual benefits of priceless magnitude. We not only have an obligation to care for these waters for future Minnesotans, we have an obligation to protect and conserve these waters for the nation, the continent, and the world.

water sampling.
- Increase the number of sampling locations.
- Continue investigations of alternative means of pest and weed control.
- Continue research into more varieties of resistant crops needing lesser quantities of pesticide application.

Nutrient Loading

Nitrate(N) loading is the most widespread and common type of ground water contamination in Minnesota. Excess nitrate in groundwater used as drinking water is a health hazard for infants and young children. Concentrations greater than the drinking water standard can cause methemoglobanemia, or "blue baby" syndrome.

Groundwater nitrate loading is affected by several factors:

- Geology - karst, shallow aquifers in southwest MN
- Soils - alluvial soils very prone to contamination
- Well head and well casing construction - dug wells in southwest MN are very prone to contamination
- Land management, including the nutrient input rate.

Less permeable soils and geologic materials cause the nitrate to linger in the biologically active soil zone where they may be taken up by plants or denitrified by microorganisms.

Nitrate pollution in the environment is derived primarily from agricultural practices, wastewater treatment systems including septic systems, urbanization, and from energy production in the form of compounds released into the atmosphere from the combustion of fossil fuels.

Figure 14: Deer Lake, Itasca County. Credit: Jean Coleman, CR Planning

Nitrogen undergoes many transformations and is transported within the environment by many processes. Quantifying the spatial and temporal variability of processes such as uptake, removal, drainage, leaching, mineralization, nitrification, denitrification, volatilization, and ammonification is challenging. Developing watershed scale nitrogen budgets under alternative management scenarios is needed to help identify the best approaches for reducing nitrate losses to surface and groundwaters, and for balancing these reductions with the simultaneous need to reduce greenhouse gas emissions.

More effective best management practices are needed to reduce nitrogen inputs resulting from fertilizer applications. The effectiveness of riparian buffer strips, one of the primary Best Management Practices available for reducing sediment and nutrients to streams and rivers is not well quantified, especially in areas with extensive tile drainage.

"Here's a goal: Protect 75% of currently undeveloped shoreline and restore 50% of existing shoreline to provide better buffer."

—Campaign for Conservation survey participant

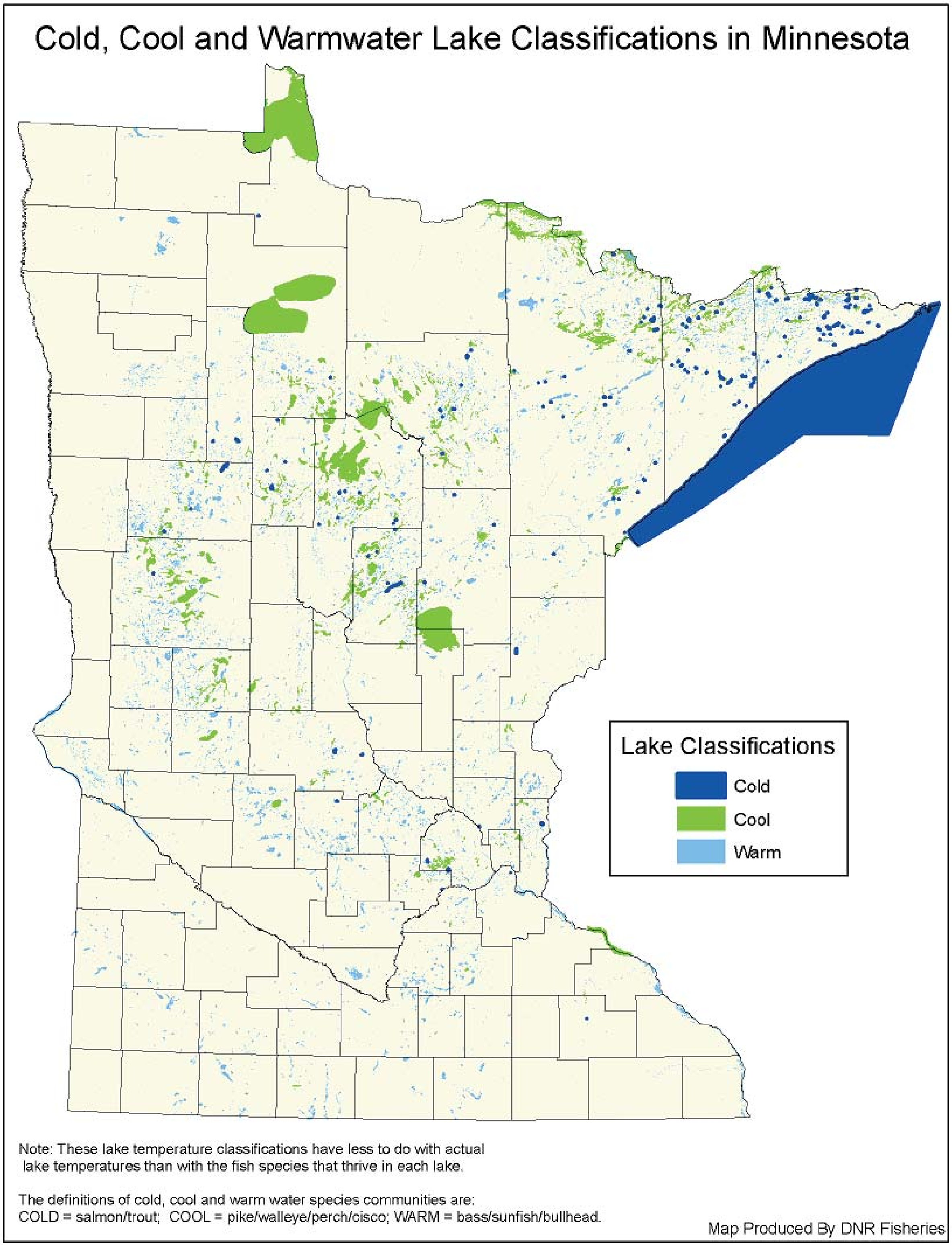


Figure 1: Minnesota is blessed with diverse lake and stream fish communities. This map shows three major classifications of lake fish communities, with cold water species mainly in the north, coolwater species in the north and central areas, and warmwater species ocurring throughout the State but dominating in the south. These communities and quality fishing depend on healthy environmental conditions in the water and on the surrounding lands. Credit: Minnesota DNR

"The sparkling trout streams, like silver ribands, thread their way across the verdure of the prairies… Only a few years ago…in all and every stream were to be found food fishes; not here and there one, but by myriads. The little brooks where leaped the speckled trout…the approach and contact of civilization has changed all this… let us call a halt; it is time. Let us make every effort, every man of us, to save this wonderful heritage from destruction. Let us spare something for coming generations."

—Letter to Governor Merriam from Robert Ormsby Sweeny, Sr., President, MN Game and Fish Commission, in 2nd annual report to the Governor, 1892

Figure 2: Good trolling – 362 pounds of trout from White Fish Narrows, Lake of the Woods circa 1915. Credit: Minnesota Historical Society.

History: Demise to Hope

The history of Minnesota's fish communities since European settlement is one of major declines. Early explorers described clear streams writhing with abundant brook trout and other fishes, flowing through prairie country alternating with heavily timbered areas. Brook trout were so rapidly harvested that as early as the 1870s one writer referred nostalgically to their "former" abundance. At the time of settlement, Lake Superior and its rivers had over 70 native fish species, including lake trout, brook trout, walleye, lake sturgeon, yellow perch, and northern pike. An 1865 account described an "abundance of brook trout, averaging over two pounds, [along] the entire rocky shore of the lake, along both coasts…". After settlement, many fish and other aquatic wildlife declined precipitously. In Lake Superior, the 'coaster' brook trout that were so abundant in 1865 disappeared from the North Shore, and arctic grayling disappeared from the watershed. Minnesota waters of the Mississippi River once sheltered a symbiotic relationship between huge schools of skipjack herring and millions of ebonyshell mussels, whose shells are an essential ingredient for the modern pearl industry. Construction of locks and dams blocked the herring runs from the Upper Mississippi and ebonyshell mussels, which depend on this fish to host its young, became so rare that they will likely disappear from Minnesota within 10 years.

In 2006, the DNR designated 32 percent of fish and 33 percent of mollusk species in Minnesota as being in greatest need of conservation. Early losses were due to unregulated fishing (see Figure 2) and massive changes to aquatic habitats. Later declines resulted from ineffective fishing regulations, water pollution, and massive land and shoreline development. Early cases of nuisance aquatic invasive species, such as sea lamprey and common carp, resulted from introductions or expansion of shipping, particularly into Lake Superior. A few hard lessons have been heeded. Minnesota today has broadly effective fishing regulations and cleaned up some sources of water pollution. Yet, it is hard to imagine society choosing to make the many changes required to restore Minnesota's fish communities to their once amazing abundance and quality. Fortunately, existing fish communities have many features worthy of conservation.

Experience since the mid-20th century shows that heavily impaired fish communities can be rehabilitated by implementing appropriate policies and embracing a decades-long commitment to achieve recovery goals. In the Upper Mississippi River, installation of sewage treatment plants restored a river that was nearly dead in the 1920s to healthy levels of dissolved oxygen for native fish species (see Figure 3). Another success involves lake trout along the North Shore of Lake Superior, whose numbers had plummeted due to heavy fishing, severe habitat destruction, and invasive sea lamprey impacts. Forty years of multiple actions to mitigate these harms led to re-establishment of naturally reproducing populations. In 2003, fisheries managers concluded Lake Superior's fish community is "reverting to a more natural state resembling historical conditions and requiring less management intervention and control."

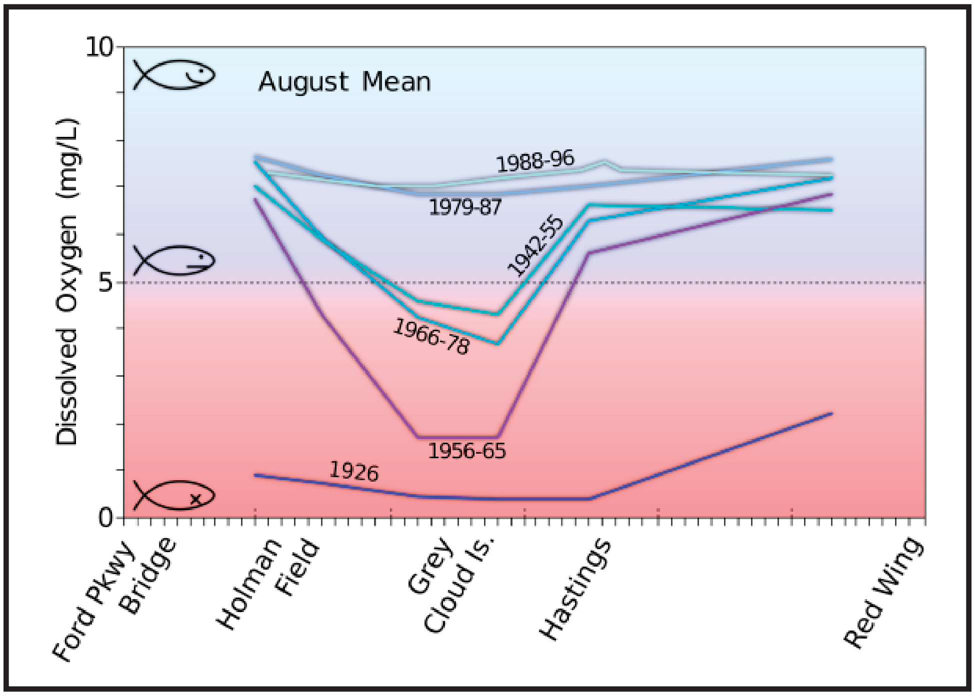


Figure 3: Long-term trends in dissolved oxygen levels in the Upper Mississippi downstream from the Metro waste treatment plant in Saint Paul.
Credit: Terry Brown, University of Minnesota, based on US EPA graphic.

Drivers of Change

Fish provide many benefits to people. Minnesota is nationally recognized for its successful fisheries management programs and quality fishing opportunities. However, the future is threatened by cumulative impacts to the resource. Fish live in the lowest part of the landscape – the streams, rivers and lakes of Minnesota. They are sensitive to a host of changes including climate change, land use, water resources, aquatic habitats and invasive species. This puts them at the receiving end of more human causes of environmental change than other natural resources. All these drivers of change are converging to degrade the habitats and productivity of fish communities statewide. The Fish Research Team used its analysis of past to present conditions of fish communities to suggest priority public investments to address these cumulative impacts (see Appendix II).

Aquatic Invasive Species

Minnesota has sixteen aquatic invasive species of serious concern (see Table 1, facing page) and many potential invaders. A deadly fish virus, viral hemorrhagic septicemia (VHS), kills many fish species and will likely soon invade Minnesota. Aquatic invasive species can directly affect native fish communities through predation, competition, modification of food webs and habitat. Once invasive species become well established, they are nearly impossible to eliminate, and often require a long-term control program. Restrictions to prevent introduction and spread of invasives can impede fishing and fisheries management, and many control measures can harm native fish communities and habitats.

Invasive species threaten a number of native fish and aquatic animals in Minnesota. The sea lamprey contributed to the decline of lake trout throughout the Great Lakes. Lake trout populations are now recovering in Minnesota waters of Lake Superior, but this has required continuous sea lamprey control since the 1960s, at a current annual cost of $13 million across the Great Lakes plus millions more in annual costs to rehabilitate lake trout populations. Zebra mussels threaten native mussels (some already threatened and endangered) in the St. Croix and Mississippi Rivers and will threaten other mussels if introduced elsewhere. The New Zealand mudsnail which is a recent introduction to Duluth Harbor can out-compete native animals and suppress the growth and condition of trout.

Invasive species can also disrupt fishing activities. The recent invasion of the spiny waterflea (see Figure 4) in the Rainy River resulted in restrictions on bait, water and hatchery fish transport. Control measures for invasive species can have negative effects on fish habitat and fisheries. New infestations of zebra mussels often go uncontrolled because available methods would kill most other fish and invertebrates in the area. The most effective control for carp and other invasive fish, are chemicals that will also kill most other fish and are expensive to apply over broad areas. Even somewhat selective aquatic plant chemical controls can have negative effects on fish communities and habitat. For example, whole lake treatments to control Eurasian watermilfoil can also kill native plants and the resulting lower water clarity persists for several years after treatment.

Figure 4: Spiny water flea on a fishing line. Credit: ©Jeff Gunderson, Minnesota Sea Grant Program.

Through laws, regulations and boater education, the spread of invasive species to inland lakes is slower in Minnesota compared to neighboring states, yet prevention is not perfect and new infestations are found each year. For example, curlyleaf pondweed has invaded over 700 lakes and Eurasian watermilfoil is now in over 190 water bodies (see Figure 5, next page). Although Eurasian watermilfoil infestations may have saturated Metro Area lakes, infestations are increasing in Greater Minnesota and more than 1,900 lakes have a higher potential to become infested. Meanwhile, several new invasive species are poised to enter the state. Asian carp are moving up the Mississippi River. There is grave concern about the expected arrival of an incurable viral disease, VHS to Minnesota. It has already invaded Lake Winnebago in Wisconsin. Many fish species are vulnerable including such sport fish as walleye, muskies, northern pike, trout and bass.

Table 1: Established aquatic invasive species of serious concern in Minnesota.

Fish	Aquatic Invertebrates	Aquatic Plants
Common carp	Chinese mystery snail	Curlyleaf pondweed
Ruffe	Japanese mystery snail	Eurasian watermilfoil
Sea lamprey	New Zealand mudsnail	Purple loosestrife
Round goby	Rusty crayfish	Flowering rush
Tubenose goby	Spiny waterflea	
White perch	Zebra mussel	

Better risk assessment approaches are needed to identify likely invaders and the pathways of entry so that they can be managed to prevent new introductions. Assessment and implementation of the most effective approaches to prevent the spread of invasives within the state is needed. Effective and environmentally-sound control measures for all current and potential invasive species must be developed. All of

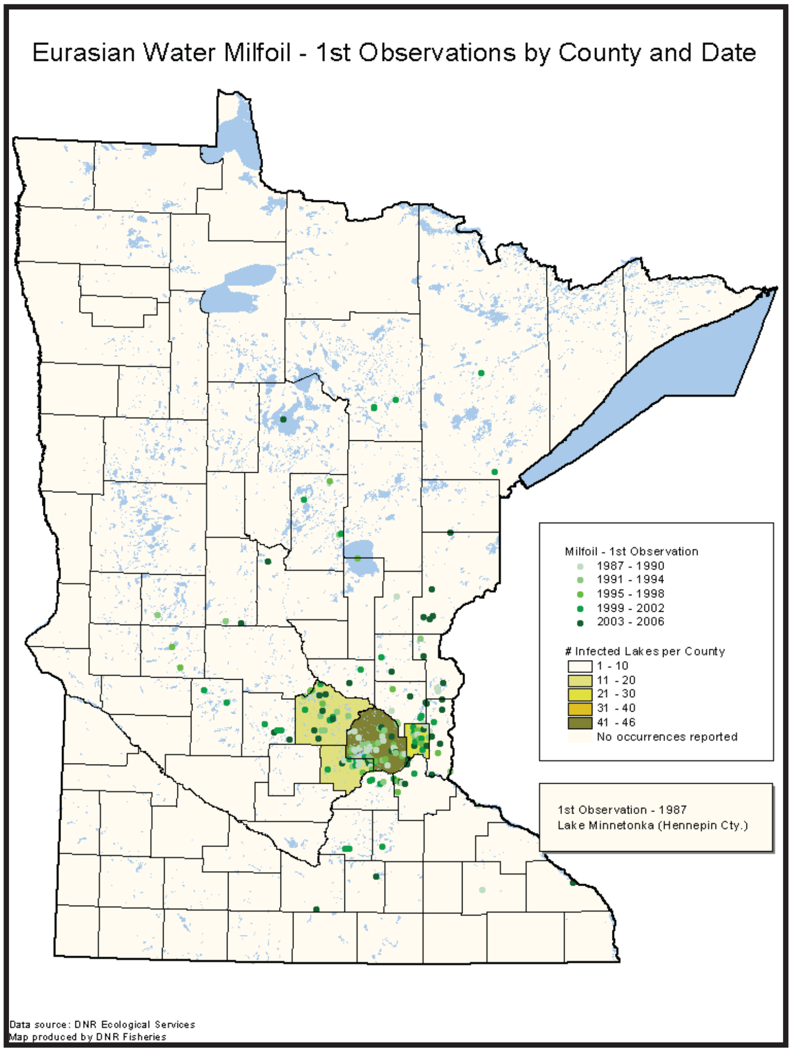


Figure 5: Eurasian watermilfoil – First Observations by County and Date. Credit: Minnesota DNR.

these require a good understanding of the basic life history, physiology and ecology of the invasive species.

Nutrient Loading

The loading of nutrients such as nitrogen and phosphorus above the natural levels in lakes, rivers, and streams can indirectly harm the fish community. Profligate nutrient loading in the past has severely harmed fish populations in many rivers and streams, notably the Mississippi and Minnesota Rivers. Contemporary pollution control regulations are limiting the input of nutrients and leading to some improvements in water quality and aquatic fish communities. Yet, a recent study found that one-third of Metro and central Minnesota lakes have significantly higher phosphorous levels than they did in 1800. Water clarity is a useful indicator of nutrient loading to lakes. Satellite imagery of water clarity of 481 Minnesota lakes showed that between 1973 and 1998, 6.8% improved, but 6.4% became less clear and the remainder did not change (see Figure 6, facing page).

Nutrients added to water are akin to adding fertilizer to an agricultural field in that they stimulate plant growth. This leads to increased production of all forms of aquatic plant life, from algae to rooted plants. Major sources of nutrients in water bodies in Minnesota are municipal sewage treatment plants, agricultural runoff, and industry discharges like food processing, pulp and paper. Increased algal production may provide additional food for organisms that fish depend on for their food but may also change the food web. Increased production of algae and rooted plants may also change the structure of the habitat for fish.

Lakes and their fish communities may be classified into three general types based on their nutrient load: oligotrophic (infertile and high water clarity), mesotrophic (moderately fertile and medium water clarity), and eutrophic (highly fertile and low water clarity). In Minnesota, lake trout, smallmouth bass, and walleye are characteristic of oligotrophic lakes; walleye, bluegills, northern pike, and largemouth bass are found in mesotrophic lakes; and in eutrophic lakes, walleye tend to disappear and carp become common, sometimes dominating the fish community. Nutrient enrichment will shift fish communities from oligotrophic to eutrophic types. Recent studies have shown that some fish species have disappeared in response to increases in nutrients in Minnesota lakes.

A similar phenomenon occurs in rivers and streams, but there it tends to result in a spatial change in the fish community, rather than a change over time. In the vicinity of the nutrient input, plant abundance increases and this changes the mix of fish species. If

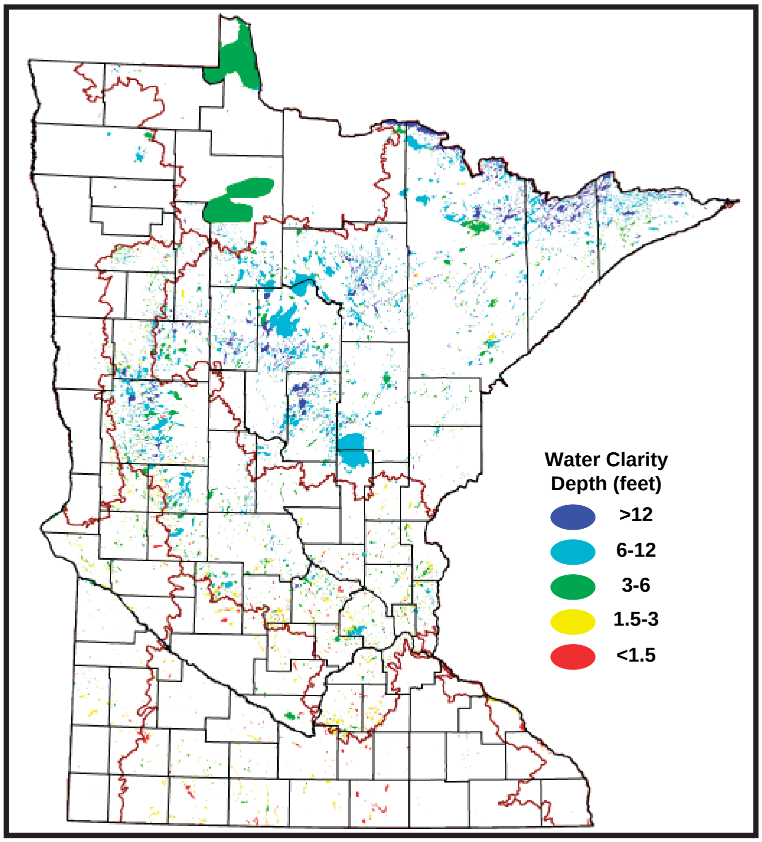


Figure 6: Year 2000 census of lake water clarity, a useful indicator of nutrient loading to lakes. Credit: University of Minnesota and LCCMR.

no additional nutrients enter the stream, the nutrient load is gradually assimilated as the water flows downstream until the stream returns to its original condition. If nutrients are added continually, the river or stream may never return to its original condition. Some stream fish communities are recovering in response to reductions in nutrient loads but others are still suffering. For example, between 1991 and 2001 the fish communities in the Minnesota River watershed improved in 14 streams, remained the same in seven, but declined in 10 streams.

Solids Loading

Sediment—primarily clay, silt, and fine sand— has been labeled the most important pollutant in the streams and rivers of the United States, both in terms of quantity and economic impact. Whereas some sediment is normal in the bottoms of streams, excess sediment resulting from human activity has caused degradation in streams and rivers across the nation. In the Midwest, the primary causes are row crop agriculture, livestock grazing and timber harvesting.

Laboratory experiments on suspended sediment at high concentrations have shown that sediment damage to the gills of fish and other aquatic organisms can cause death by suffocation. But the major impact of sedimentation on populations of fish and invertebrates has been by deposited sediment. It covers fish eggs during incubation and hiding places of aquatic insects and other invertebrates which are the primary food of fish. Deposited sediment also may fill the small spaces in bottom gravels that harbor the larvae and early life stages of many species of fish, particularly during winter periods when ice conditions may prevent normal feeding behavior.

In the mid-1960s, a massive sedimentation event into a small Minnesota trout stream from a poorly-located and designed housing development caused the loss of an entire year-class of trout. It decimated the population through loss of their major food source and contributed to a permanent change for fish species in the streams. Less egregious but still harmful sedimentation continues today. In 2004 and 2005 heavy runoff flushed sediment into some SE Minnesota streams and depressed trout reproduction.

Minnesota needs basic data on normal sediment loading in our prime recreational rivers. This data collection could be added to the many ongoing stream monitoring programs. Restoration of perennial vegetation on shorelands surrounding streams and lakes is also essential.

Dissolved Oxygen

Dissolved oxygen is critical for fish. Without sufficient oxygen, all aspects of a fish's life history are affected: survival, growth, reproduction, and behavior. Although low dissolved oxygen sometimes occurs naturally, human activities often cause or exacerbate the effects of low oxygen on fish.

Nutrient additions often decrease the oxygen content of the water bodies due to decomposition of the nutrient material itself and increased respiration or decomposition of the more abundant plant life stimulated by the nutrients. As available oxygen declines, fish species intolerant of low oxygen levels disappear and are replaced by more tolerant species. The gradient of oxygen tolerance by Minnesota fish communities is similar to their tolerance of nutrient loading, as discussed above. Past changes to fish communities in Minnesota's large rivers receiving municipal and industrial wastes were due in large part to reduction in oxygen concentrations, particularly during the summer. Current pollution control regulations have reduced this cause of low oxygen.

A looming threat to Minnesota fish communities involves the relationship between high temperature and low oxygen. As temperatures rise, oxygen loss from water bodies increases, due to increased rates of decomposition and respiration. As temperatures rise, fish require more oxygen, due to decreased solubility of oxygen in warmer water, and this causes them even greater stress. Ongoing DNR studies show that as lakes become warmer due to climate change, habitat with suitable temperatures and sufficiently high oxygen concentrations is declining for coldwater fish species. Lake herring, an important food for large walleye, northern pike and lake trout, have declined in the last 20 years in some large Minnesota lakes and may disappear as these lakes get warmer (see Figure 7).

Contaminant Loading

Contaminants have been present in Minnesota waters since the establishment of towns and industry. Primary sources are municipal sewage, agriculture, and industry. Some of the most common and insidious toxicants that affect fish and other aquatic organisms are decomposition products of organic wastes (e.g., ammonia), heavy metals (e.g., mercury, zinc, cadmium), pesticides (e.g., insecticides, herbicides), endocrine disrupting compounds (e.g., estrogens, surfactants, insecticides), and pharmaceuticals (e.g., antibiotics, analgesics). Additional sources of toxicants are from atmospheric transport, such as mercury, PCBs, and acidifying materials (e.g., sulfur dioxide).

Sub-lethal effects of contaminants to fish communities are the dominant concern today. Although many toxicants found in Minnesota waters can be lethal to aquatic organisms at high concentrations, fish kills rarely occur except from accidental releases. Sub-lethal effects of toxicants cause subtle physiological, biochemical, and genetic changes, which may ultimately depress the abundance of some species.

Fish may accumulate and concentrate mercury, PCBs, pesticides and other toxicants within their bodies making them dangerous to wildlife and humans consuming them. Fish consumption advisories for many Minnesota lakes indicate the widespread nature of this problem.

Over the past 50 years, a tremendous amount of research has documented the effects of toxicants on fish and other aquatic organisms. Consequently, the U.S. Environmental Protection Agency developed

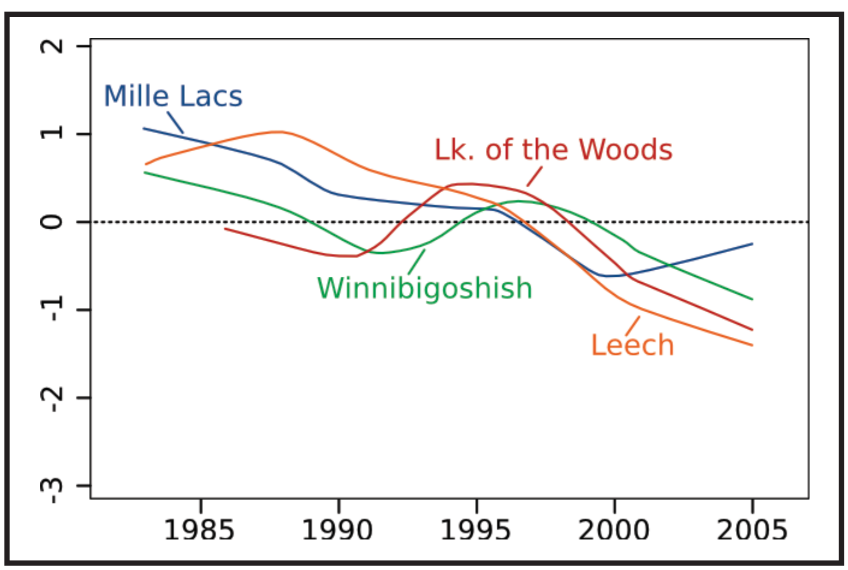


Figure 7 : Declines in abundance of lake herring (tullibee/cisco), an important food for large walleye, in Minnesota's large lakes in the past 20 years.
Credit: Don Pereira, Minnesota DNR

water quality standards for keeping toxicants below concentrations that harm aquatic organisms. Despite these advances, several problems persist. Enforcement of the standards is mixed. For example, the Minnesota Pollution Control Agency has only assessed ambient water quality in 10% of the river miles and 14% of the lakes that the Federal Clean Water Act mandates it should assess. For many toxicants, there is still insufficient information to set water quality standards.

Toxicants such as endocrine disruptors and pharmaceuticals are a concern though little is known about their effects on fish populations and aquatic communities. Endocrine disrupting compounds have been found in many Minnesota waterways and changes in the physiology of fish have been noted at several of these sites. Laboratory studies at the University of Minnesota found that reproductive behavior of exposed fish is affected. But we don't know if such individual fish effects have depressed fish populations in Minnesota waters. A recent experimental exposure of fish to endocrine disrupters in a Canadian lake did lead to near disappearance of fathead minnows, an important food for game fish and a popular bait species. Pharmaceuticals have also been found in many Minnesota waters, but their direct effects on fish are understood even less than those of endocrine disrupting compounds.

Temperature

Fish and aquatic invertebrates are cold-blooded, so their growth and reproduction are greatly controlled by temperature. As temperature increases, so does fish activity, demand for food and need for oxygen. Fish communities can be divided into three groups based on the summer maximum temperatures each can tolerate: coldwater, cool water and warm water. Thus, summer water temperatures often determine the fish community supported in a lake or stream, such as coldwater trout communities, cool water walleye-perch communities, and warm water bass-panfish communities (see Figure 1, page 76). Human activities that alter water temperatures can lead to short-term or more widespread and persistent harm to fish communities. Sudden, local changes in water temperatures can be lethal, such as the fish kill associated with the abrupt shutdown of the Monticello Nuclear Power Plant in winter 2007. Such instances are well regulated and failures of compliance should have only short-term, localized, impacts on fish communities. Land use changes, such as the removal of riparian vegetation associated with agriculture or riparian forest harvesting, are more widespread and can elevate stream temperatures beyond the tolerance levels of coldwater fish. These changes can eliminate certain species, such as brook trout, and prevent their restoration until riparian vegetation and thus a cooler summer water temperature is re-established.

Climate change now poses the greatest threat to suitable water temperatures for fish communities in streams and lakes. Increased temperatures associated with climate change will results in the loss of suitable stream habitat for trout in a number of streams in Minnesota. Researchers at the University of Minnesota indicate that suitable lake habitat for coldwater fish communities will be reduced by 45%. An example of how these communities might unravel, mentioned in the discussion of dissolved oxygen, is through the loss of lake herring that provide food for large lake trout, walleye and northern pike in coldwater lakes. Suitable habitat for coolwater communities will be reduced in more southern shallow and moderate depth lakes, and will increase in northern lakes at the expense of coldwater communities. Habitat for warmwater fish communities will increase, facilitating a major expansion of warmwater fish populations.

Temperature changes due to climate change will increase the effects of other stressors, such as dissolved oxygen (which is also exacerbated by nutrient loading), riparian vegetation loss, and invasive species. Warmer temperatures will potentially allow many invasive species to expand their ranges into and within Minnesota. Asian carp could be able to expand their range and number, and invasive plants such as hydrilla will find a more suitable climate in the state. Fish not currently considered invasive, such as smallmouth bass, will be able to expand their range and likely alter coldwater fish communities. Integrative research is needed to refine and test predictions of fish community changes due to climate change combined with other drivers, such as nutrients, habitat degradation and invasive species.

Hydrologic Modification

Ditching and drainage tiles, dams, and water-level regulation have modified the hydrology of the Minnesota landscape over the past two centuries. Perhaps the most extensive modification was caused by building drainage systems, ditches and tiles, for agriculture in western Minnesota. This type of drainage has transformed nutrient cycling and hydrologic dynamics, including changes in structure, function, quantity and configuration of stream and wetland ecosystems. Straightening and deepening of natural channels to build drainage ditches degraded habitat for fish and other aquatic organisms by altering floodplain and riparian connectivity, and sediment dynamics. Large-scale conversion of an original checkerboard of wetlands into linear systems resulted from connecting formerly isolated wetland basins to extensive drainage networks and constructing main channel ditches through millions of acres of formerly low-lying marsh or wet prairie. This conversion reduced surface water storage, increased water movement, and concentrated water into main channels. The result was increased flows and flooding in larger streams and rivers. Cumulative changes in hydrology, geomorphology, nutrient cycling, and sediment dynamics have contributed to the decline of aquatic communities including fish, waterfowl, and other aquatic wildlife.

Strategies to reduce negative effects of drainage ditches and tiles on aquatic ecosystems vary widely in their effectiveness as well as their contemporary economic and political feasibility. Minnesota needs multiple strategies to mitigate the undesirable effects of altered hydrology on aquatic ecosystems including fish communities. These include changes to cropping systems and nutrient management, off-site wetland and riparian habitat protection, and restoration in critical areas across the landscape.

Lowhead dams dot Minnesota's landscape and block fish migrations to spawning areas. For example, a series of dams built in the early 1900s disconnected the Red River into segments and disrupted migrations of lake sturgeon and other fish. Today, we know it is possible to reconnect the river by employing a technique developed by Luther Aadland of the Minnesota DNR. In one demonstration, the Riverside Dam at East Grand Forks was modified from a low-head dam into a gently sloping bed of rocks. It still functions as a dam, but new pools and eddies formed by the rocks provide habitat for walleyes, channel catfish, and other fish. The fish now have access to miles of habitat formerly blocked by the old dam.

Water-level regulation of reservoirs can change lake dynamics in ways that harm fish populations. Shoals

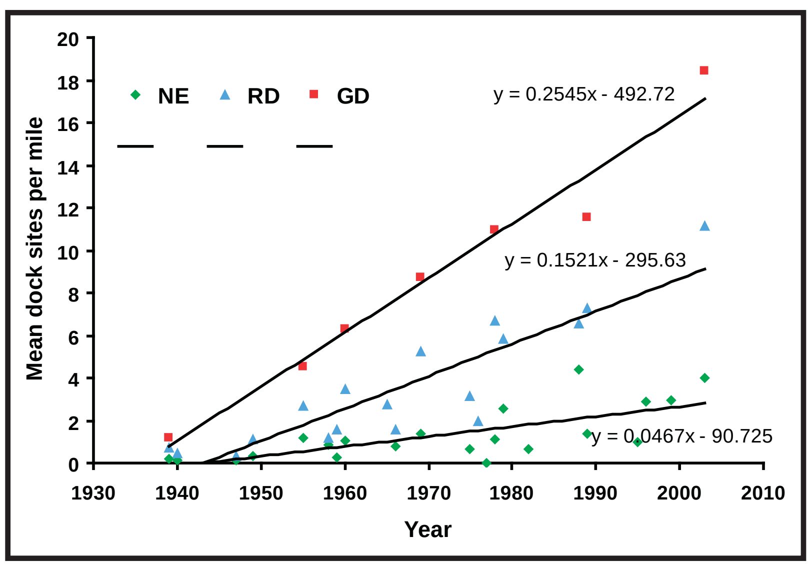


Figure 8: Development around north-central Minnesota lakes, as dock sites per mile, from DNR aerial photos. General development (GD) lakes have a faster rate of development than recreational development (RD) lakes, whereas natural environment (NE) lakes are just beginning to be developed. In 2003, mean development density was 18.5 homes per mile for GD lakes, 11.2 homes per mile for RD lakes, and 4.0 homes per mile for NE lakes. Credit: Paul Radomski, Minnesota DNR.

used by fish and aquatic plants may be exposed or inundated and nutrient cycles modified. For example water level fluctuations affected the commercial catch of walleye on Namakan Lake and Rainy Lake. Plans for regulation of water levels need to assess and reduce potential harms to fish communities.

Aquatic Habitat Degradation and Loss

Shoreland developments are changing Minnesota's lake ecosystems. Development pressure is increasing with more dwellings and docks per lake each year (see Figure 8, facing page) in Minnesota that has led to a cumulative effect on fish habitat.

Shoreline habitat losses include removal of downed trees, aquatic vegetation, and the removal of riparian wetlands. Shoreline alterations include planting riprap, constructing walls and planting sod to the waters edge. A recent study documented aquatic vegetation losses, an important component of shoreline habitat, from 1939 to 2003 in Minnesota lakes (see Figure 9). It is estimated that between 20 to 28 percent of the near-shore emergent and floating-leaf coverage has been lost due to development in bass and walleye lakes. On average there is a 66 percent reduction in aquatic vegetation coverage with shoreland development. These declines in aquatic vegetation coincide with lower fish production in lakes. Woody habitat losses are also occurring in Minnesota lakes but have not been quantified. Studies in other states give some insight: researchers found less submerged woody habitat from fallen trees along developed shorelines in Wisconsin and Michigan, and predicted that recent losses would affect fish communities for centuries.

Not all shorelines are created equal. This is true both for people and fish. For many of us, the perfect lakeshore has a gentle slope, clean and clear water, a sand beach with no aquatic vegetation, and a reasonable distance to deep water for boat access. Lakeshore lots with these characteristics command a high price. Fish have no regard for our economics and do not generally share our shoreline preferences.

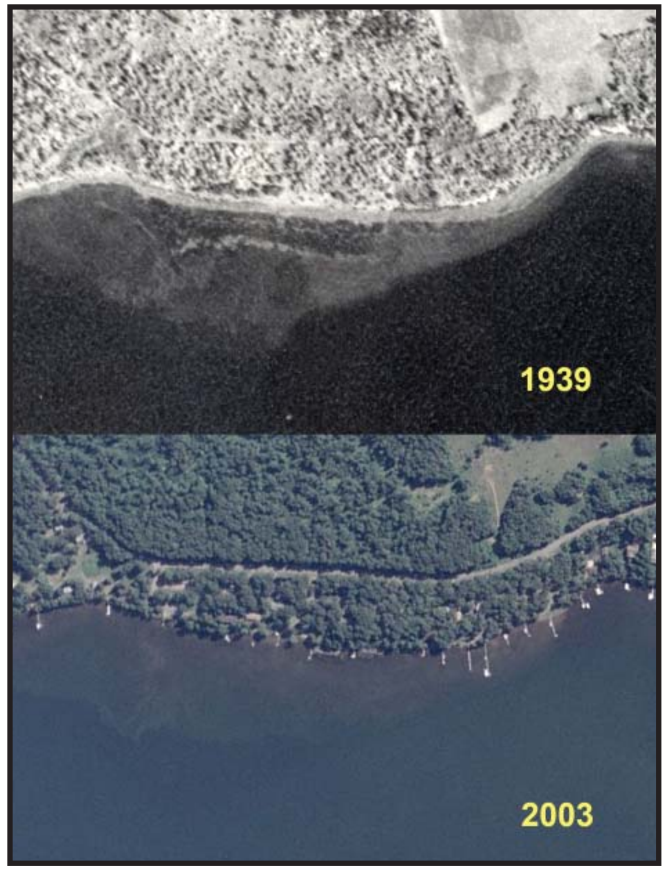


Figure 9: Aerial photographs show the same shore of a Minnesota lake 64 years apart. Note the disappearance of aquatic vegetation along the lakeshore in the 2003 photo. Credit: 1939: U.S. Department of Agriculture, 2003: U.S. Department of Agriculture, Farm Service Agency.

Clean water is important to fish but they need more than water just as birds need more than air. Floating-leaf and emergent vegetation assures a good food supply for fish because one of their main foods, aquatic invertebrates, use the vegetation as habitat. Many fish depend on aquatic vegetation and the shoreline to provide spawning habitat, cover, and refuge from predators. While sought after by humans, a sand beach is unsuitable habitat for many fish species. Walleyes, for example, select clean, wave-washed gravel and cobble shorelines for spawning. Near-shore dredging and adding sand for beaches damages walleye spawning areas.

Human activities that change shoreline habitat can alter ecological processes and energy flow within lakes, thereby reducing their ability to support diverse and healthy fish communities. Intact, undisturbed shorelines provide many environmental benefits to our lakes and rivers, such as absorbing nutrients that reduce water quality, reducing erosion from waves and current and defining the high ecological qualities of our state.

There are three major knowledge gaps about shoreline habitat loss in Minnesota. First, the extent of and the ecological consequences of removal of fallen trees from lakes are poorly understood. Second, a better understanding is needed of the rate of dock development, size of in-water structures, and associated impact on aquatic habitats and fisheries production. A couple facts illustrate the importance of this issue. Average dock size has increased 51 percent from 1978 to 2003; and an estimated 20 percent of the shoreline in Crow Wing County was affected by docks in 2003. Finally, research on shoreline habitat protection and restoration with regard to social and economic barriers and incentives is also needed.

Stocking

Fish stocking can provide many economic, social and conservation benefits, but can also harm fish communities. Stocking has introduced new species, enhanced existing populations, and rehabilitated depleted or locally extinct populations. Stocking fish in Minnesota began in the 19th century with the introduction of the now-reviled common carp and the more appreciated brown trout and steelhead. Among a dozen species stocked presently, walleye alone are stocked into about 950 lakes. Economic benefits of sport fishing are enhanced by the reality or perception of improved fishing due to stocking. Many of Minnesota's current fisheries would not exist without stocking. For example, many southern lakes now contain walleye where conditions are poor for their natural reproduction and urban ponds now contain hybrid tiger muskie, splake, and catfish. Inappropriate stocking can cause ecological harm through introduction of new species that disrupt the existing fish communities. It can also alter genetic diversity when stocked fish interbreed with native fish and it can introduce diseases carried by the stocked fish.

Minnesota provides many examples of positive, negative, and mixed outcomes of stocking. Stocking has established non-native species, including rainbow trout, brown trout and carp. Although many view brown trout stocking as a success story, studies indicate these fish may limit the production of brook trout, the native species. Stocking has helped rehabilitate depleted populations such as lake trout in Lake Superior and walleye in Red Lakes. In Upper and Lower Red Lake, three recent large stocking events over five years were so successful that the fish population recovered enough to resume fishing only eight years after a complete closure.

Many attempts to increase fish abundance through stocking have been unsuccessful, and potentially caused harm. In decades past, many brook trout originating from the eastern U.S. were stocked widely in southeastern Minnesota streams. Recent genetic data found no descendants of these eastern fish in the tested brook trout populations. But we don't know how many populations experienced declines from continuous stocking of these genetically unfit brook trout. Effects of genetically unfit fish were documented along the North Shore of Lake Superior, where naturalized steelhead (migratory rainbow trout) were shown to have much higher survival than a stocked rainbow trout strain. Mating with stocked trout drastically reduced the survival of the hybrid offspring. In the Minnesota muskie program, three decades of stocking a Shoepack strain turned out counterproductive to maintaining a trophy fishery. The DNR discontinued stocking the Shoepack strain when they were found to have less genetic potential for growth than other muskie strains. Unfortunately, new genetic data show that Shoepack genes still persist and affect growth in some populations twenty years after stocking ended. Fish stocking is ubiquitous in Minnesota but generally lacks direct monitoring of its consequences. This makes it hard to distinguish positive and negative effects statewide and thus to wisely direct funds and, as appropriate to improve practices for stocking.

The Fishery

Minnesota has long been known for the exceptional quality of its recreational fisheries of walleye and northern pike, but largemouth bass, crappie, sunfish, and trout are also well regulated. Fish populations respond to the removal of individual fish, by any fishing method, by increasing the growth rates of those not caught. This is a "density-dependent" response where the exploited fish populations "compensate" for the individuals removed by changes in their biological characteristics. In previously unfished stock, the removal of fish (catch) within a very few years, will cause a temporary reduction in numbers of fish, average size, average age, and mean age of first spawning. If the fishing pressure continues or intensifies only moderately, after a few generations, the increased growth rate often results in a greater abundance of fish, a narrowing of size and age distributions, and an increase in reproduction. When this occurs, the population is said to have come into "equilibrium" with the fishery, and may endure for many years without showing major changes in catch rate (expressed as Catch Per Unit of Effort, or, CPUE). If the fishery increases in intensity, fish may reach their maximum biological growth capacity and attain maturity at their minimum spawning age and size. In this condition, the population may experience sudden changes in numbers or reproductive capacity due to relatively minor changes in fishing pressure or environmental quality. This vulnerability often increases year-to-year variability of populations that had previously been stable. Immediate reductions of fishing effort may not immediately restore the fisheries to a stable pattern of production. Fishing can induce these changes without other stresses acting upon a population, but these effects are often exacerbated and sometimes masked by the confounding effects of changes in water quality and the introduction or invasion of non-native species.

Minnesota's fisheries have gone through three distinct phases:

- The pre-settlement Native American fisheries
- Early Euro-American settlement up to World War II
- The post-WWII era

The first phase almost certainly existed in equilibrium between human and fish populations with many species caught and consumed at sites of opportunity. Changes in productivity were likely small or modest, with little alteration of physical or biological characteristics of watersheds. Fisheries in the second phase declined in quantity and quality in response to rapidly increasing human densities and changes in forest cover and prairie agriculture. During this time, fisheries were predominantly used as a supplemental food resource and secondarily as a recreational resource. In the third phase, including contemporary times, virtually all of Minnesota's fishery resources are being subjected to at least a modest level of exploitation. During this period, many important stocks of recreationally valuable species have declined in individual body size and abundance (low CPUE) and have experienced widely variable year-class strength. In the future, additional fisheries management controls and surveillance will be required to protect, maintain and restore high-quality fisheries. Effective management of fishing and stocking can only go so far to achieve high quality fishing. In order to maintain and improve fish communities, Minnesota must reduce cumulative effects of the more pressing drivers of change, discussed above, to assure quality fishing for future generations.

Major Data Gaps for Minnesota Fish Resources

The fish team has identified a number of major data gaps that impede efforts to sustain or restore the quantity and quality of fish communities in Minnesota's lakes and rivers.

1. Invasive Species - Much better tools are needed to predict, prevent, reduce and manage the harmful effects of aquatic invasive species. An urgent issue is preventing the spread of a devastating new fish virus. Statewide data are missing on total public and private annual expenditures to control aquatic invasive species and economic value of harm they cause.

Explanation: Research is needed on species-specific control methods and tools to evaluate the effectiveness of current management strategies. Also needed are better methods for risk assessment of new invaders to determine their potential adverse effects on native species, outdoor recreation, and other natural resources. There is very little known about the total economic impact in Minnesota related to aquatic invasive species. Control and management of them is thought to be extensive.

We lack ways to reduce mortalities from a destructive fish viral disease that will likely arrive soon in Minnesota. Called viral hemorrhagic septicemia (VHS), this disease has caused large fish kills in the lower Great Lakes and is spreading westward to Minnesota. Many Minnesota fish species are vulnerable including prime sport fish such as walleye, muskies, northern pike, trout and bass. Once it arrives in Minnesota, reducing the spread of VHS within the state will be a major challenge.

2. Land Disturbance - How much land disturbance can occur before there is a negative impact on fish communities?

Explanation: Scientific information indicates that increased land disturbance is correlated with degradation of fish communities but fisheries managers need a predictive tool to help quantify and manage. A predictive tool would make it possible to quantify tolerable types and amounts of disturbance in shorelines, stream banks and uplands. A more sophisticated predictive model would help to assess cumulative impacts of all disturbances within an entire watershed rather than dealing with each lake or stream in a piecemeal fashion. Baseline data is needed on normal sediment loads in rivers that still have high water quality. These data will inform the design of effective policies to prevent increases in sediment pollution due to future land use changes in these watersheds. The collection of sediment samples could be added to existing stream monitoring programs in Minnesota.

3. Aquatic Habitat Loss - How much aquatic habitat can be lost in lakes before harming the productivity of fish populations? What are effective social and economic incentives for shoreline habitat protection and restoration?

Explanation: This question refers to habitat provided by floating and emergent plants, woody material and other natural structures within different kinds of lakes. Although scientists can reasonably predict the minimum habitat needed for productive trout populations in streams, data gaps make it impossible to do the same for most fish species in lakes. It would be most helpful to develop a predictive tool to answer questions such as: how much dock development can occur without degrading the fish community in a lake?

Good data on major incentives and barriers to get people to protect shoreline habitat would inform the design of effective policies to prevent additional shoreline changes and restore shoreline habitat for heavily impacted lakes and rivers. This will require social science research linked to development of feasible policy options.

4. Climate Change - How will climate change affect fish communities in Minnesota, especially how it will exacerbate effects of existing stressors? Addressing this question requires filling major baseline data gaps and restarting bathymetry mapping of Minnesota lakes.

Explanation: Some human-caused climate change is now irreversible and the state needs to anticipate how it will affect our fish communities. This irreversible level of climate change will exacerbate land use changes and the other major drivers of change to aquatic habitats and aquatic food chains that already harm fish in Minnesota. Decision makers need reliable predictions of effects of climate change on fish communities, which take into account interactions with other drivers of change. This requires integrated quantitative analyses that compare lightly stressed with heavily stressed lakes and incorporate data on surface water quality, groundwater, the aquatic food chain and all fish species. In turn, this requires filling key data gaps, such as information on non-game fish (there is better data on game fish), natural foods of fish (zooplankton and invertebrates), and more comprehensive data on lake temperatures and water levels. Accurate data on lake bottom depths and contours are also needed. This requires restarting lake mapping surveys by the DNR, which were recently stopped due to lack of funding. Finally, better compilation of existing data is needed, building on ongoing efforts such as integration of aquatic plant databases.

5. Fish Stocking - What are the overall effects of fish stocking on anglers' fishing experience, the target species, and fish communities?

Explanation: The state lacks comprehensive data on which fish stocking programs lead to a net increase in the quality and quantity of fish caught by anglers and which ones do not provide measurable benefits or cause harm. Existing data cover only a few species in a few bodies of water or over a relatively short time frame. We also lack information on genetic effects of stocking, except for a few recent studies. Two important genetic data gaps are whether stocked fish are genetically fit or unfit to thrive in the receiving lake or river and whether fish stocking erodes genetic diversity of wild populations of the same species. Genetic diversity is the 'principal' in nature's bank that will generate long-term, high 'interest' rates -- productive fish populations far into the future. The coming climate change makes it more important than ever to protect genetic diversity in our wild fish populations. Finally, virtually nothing is known about when stocked fish have positive, negative or neutral ecological effects on the entire fish community in the stocked habitat.

6. Endocrinal Pharmaceuticals - We do not know whether endocrine disrupters and pharmaceuticals in the sanitary waste stream are harming the productivity of fish populations. Also, we lack the data required to set water quality standards for impacts of most contaminants on entire fish communities.

Explanation: We need more comprehensive information on the distribution of endocrine disruptors and pharmaceuticals in Minnesota waters and whether they affect fish health and entire aquatic communities. Although we know how some long-existing contaminants affect individual fish, we don't know how they affect aquatic communities as a whole and whether existing water quality standards need to be modified based on community impacts. Little is known about whether contaminants erode genetic diversity in wild fish populations.

Figure 10: Happiness on Mille Lacs.
Credit: John Cannon, University of Minnesota.

"A big reason I live here is...the fishing."
— Minnesota 2050 Project participant

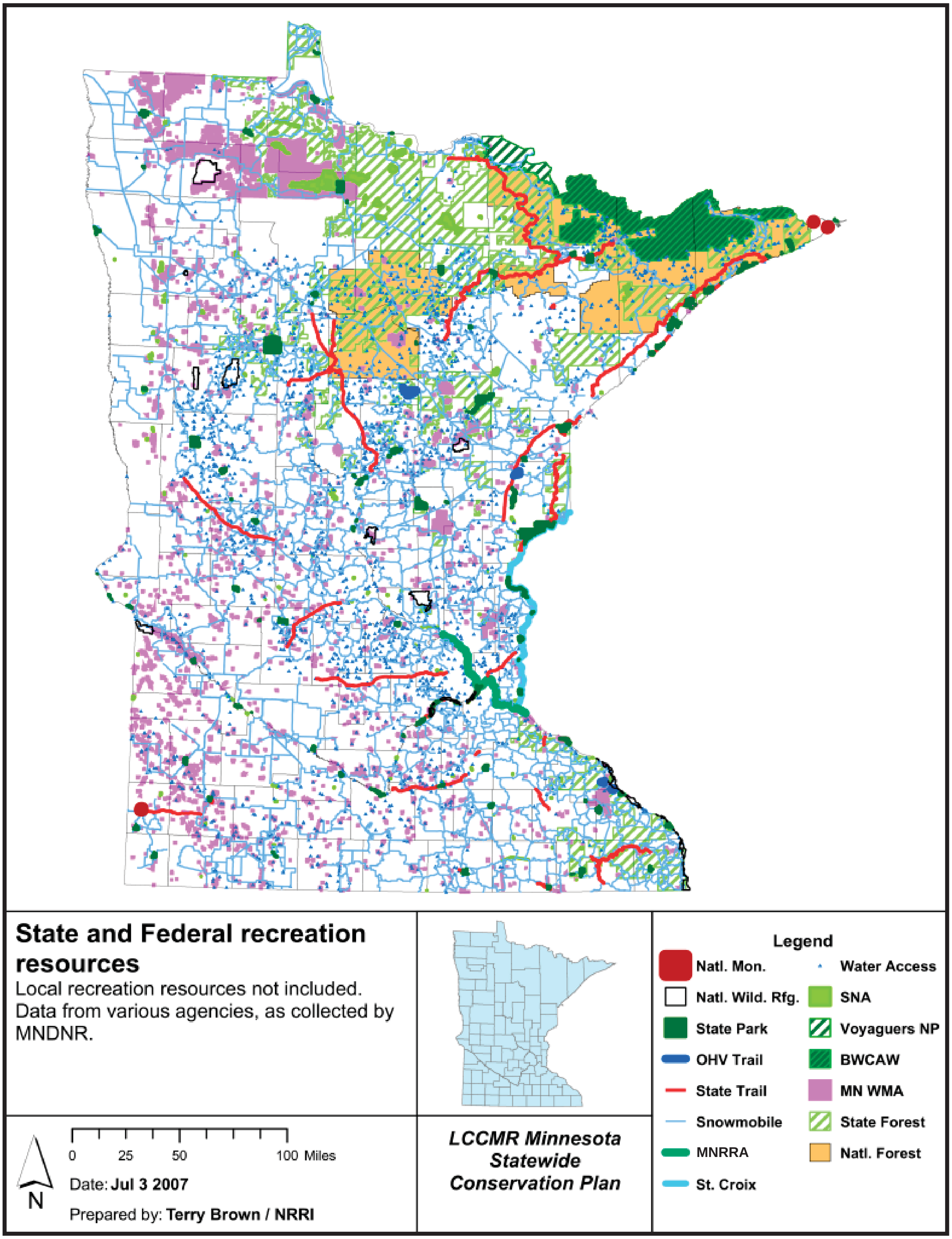


Figure 1: State and Federal recreation resources available in Minnesota. Credit: Terry Brown, University of Minnesota.

OUTDOOR RECREATION

"Recreational development is a job not of building roads into lovely country, but of building receptivity into the still unlovely human mind."

—Aldo Leopold

History

Outdoor recreation and tourism have a long history in Minnesota. While we can document the start of various park and recreation systems across the state (see Figure 1, facing page), actual recreation participation data is anecdotal through the mid-1900s. Nonetheless, we can be sure that outdoor recreation contributed to individual and community well being prior to and during settlement in similar ways in which it does today by providing individual, social and economic benefits. Pre-settlement conditions of the natural resources on which outdoor recreation and tourism depend are found elsewhere in this report (see Water, Wildlife, Fish, and Land).

We consider recreation resources as those areas and facilities that provide opportunities for recreation and tourism experiences, regardless of ownership including public or private owned.

In Minnesota, residents typically participate in some form of outdoor recreation (see Table 1). Outdoor recreation and tourism experiences provide opportunities for important personal, social and economic benefits. On a personal level, individuals report mental restoration, physical enhancement as well as improved skills and self-competence as a result of recreation experiences. Socially, benefits accrue as social cohesion builds from recreation and tourism experiences and the population is healthier due to mental and physical restoration. Economically, recreation and tourism bring new dollars to communities as well as contribute to community pride.

Minnesotans recognize that recreation is important for them and their economy. The majority of Minnesotans (82%) believe outdoor recreation

	Percent of Population Participating Annually			*Number of Annual Hours of Participation (000s)*		
Activity	**2004**	**2014**	**Change**	**2004**	**2014**	**Change**
Boating of all types, excluding fishing from a boat	35.50%	31.40%	-11.50%			1.80%
Fishing of all types	30.20%	24.70%	-18.40%			-6.20%
Visiting outdoor zoos	27.50%	20.70%	-24.70%	5,822.60	5,040.90	-13.40%
Visiting historic or archaeological sites	20.70%	16.20%	-21.60%	6,198.60	5,585.50	-9.90%
Viewing, identifying or photographing birds and other wildlife	20.40%	15.90%	-22.00%			-10.30%
Hunting of all types	16.00%	14.20%	-11.20%			
Offroad ATV driving *	10.30%					304.70%
Snowmobiling	9.80%	8.20%	-16.80%		9,817.00	-4.30%

Table 1: Particpation figures and projections for outdoor recreation by activity.
Note: Off-road driving revision coming from Minnesota DNR July 2007. Credit: Minnesota DNR.

is important to their lives and believe tourism is important for the economy (94%). The economic impact of recreation and tourism is documented and significant. For example, spending associated with state parks is $178 million of which $144 million originates with Minnesota visitors. Similarly, our 28 million tourists spent $11.786 billion in the state while enjoying the natural and cultural resources. Half of these tourists are Minnesotans traveling within the state. These tourism dollars support 286,000 full-time-equivalent jobs, $6.9 billion in resident income (wages, salaries and proprietary income), $1.5 billion in state government revenues and $0.5 billion in local government revenues.

The conditions of facilities and areas upon which recreation and tourism depend vary greatly. We lack consistent information across administrative sectors and geographic areas. From a recreation standpoint, the resource conditions are subject to what is acceptable for the visitor. The 'limits of acceptable change' are applied to understand if and when a resource approaches unacceptable conditions. Known or baseline conditions in these areas are limited to select site specific studies. In terms of facilities, a 2004 study of perceived recreation and facility needs of cities, counties and school districts consistently found the highest demand for trail-related facilities. Beyond the need for trails, the organizational desires varied widely between metro and outstate as well as by county. Local recreation providers consistently related lack of funding and land protection as problems.

To optimize the benefits of outdoor recreation and tourism for Minnesota, attention to and research on several key factors is required:

- land use patterns
- health concerns
- demographic changes
- climate change
- water quality
- aquatic habitat degradation

Existing evidence in each of these areas is presented below, followed by research recommendations. Information from the forthcoming Statewide Comprehensive Outdoor Recreation Plan (expected December 2007) will be informative on these issues as well.

Drivers of Change

Land Use Patterns

Lakeshore Development - Increased lakeshore residential development impacts recreation resources in terms of access, ecological quality, aesthetics and economics. First, lake access is more restricted for nonresidents, who must rely more heavily on select public access points for lake use. In addition, the aesthetics of a lake and the recreation experience is altered when the shoreline is no longer "natural" scenery but lined with housing. The type of lakeshore development permitted also impacts recreational resources. For example, a lakeshore resort will have different impacts than a single-family vacation home or a single-

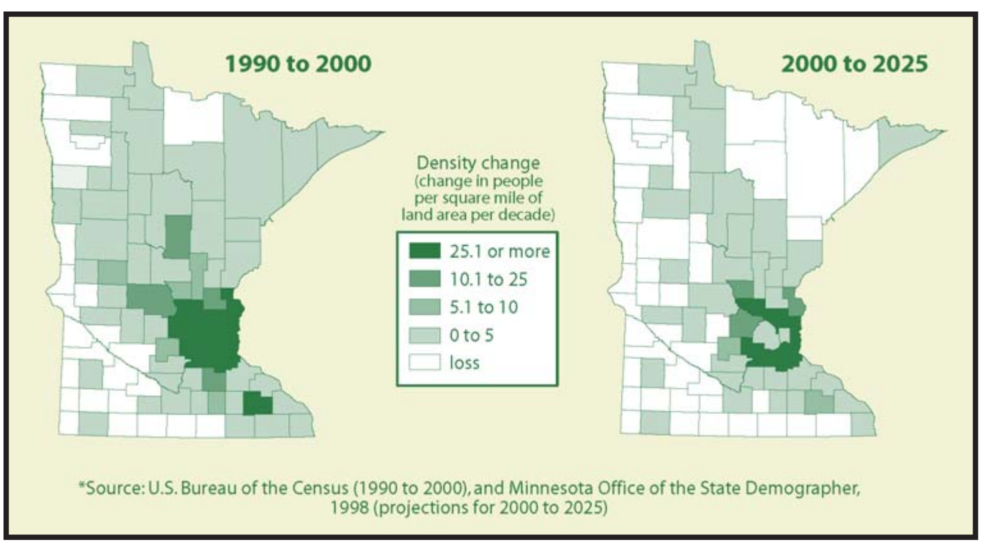


Figure 2: Population change in Minnesota - recent history (1990 - 2000) and projections (2000 - 2025). Credit: SCORP 2003-2008

family year-round home. The decreasing number of resorts in Minnesota influences the severity and duration of these impact changes. Recognizing these issues, the Minnesota Environmental Quality Board updated their thresholds for environmental review as applicable to lakeshore development in 2004.

Increased lakeshore development also affects recreation resources indirectly. As General Development and Recreational Development Lakes become fully developed, demand increases to develop around ecologically sensitive Natural Environment Lakes.

Expansion of Urban Areas and Land Use Conversion - In Minnesota, the Twin Cities area and regional urban centers have seen significant growth and this growth is expected to continue. Population density in the Twin Cities metro area collar counties is expected to increase by 50.1 people per square mile between 1990 and 2025 (see Figure 2, facing page). Other regional urban centers predicted to expand in the coming decades include St. Cloud, Rochester, Baxter/Brainerd, Western Lakes Region (Alexandria to Detroit Lakes), Bemidji, and Wilmar. According to the 'Regional Parks for Minnesota's Outstate Urban Complexes' study, people tend to be attracted to these areas because of their natural resources and outdoor recreation amenities. However, few of these areas have sufficient land set aside to maintain their natural and recreation resources. By 2030 an additional 26,750 acres of land would have to be set aside to provide outstate urban areas with a comparable ratio of regional parkland per person as in the seven county metro area. If these areas want this level of parks and open space these lands need to be purchased soon, before land prices become prohibitive. Furthermore, the report observes that 26,000 regional parkland acres will not be enough to maintain the scenic rural character of quickly developing urban areas, and that other tools such as stricter zoning and innovative land conservation measures will be necessary.

In a recent DNR report on recreation facility needs, land acquisition was rated as a problem by both city and county officials. For example, as new land is developed for housing, there is more demand for recreational opportunities in those areas.

Ownership of Forest Lands - Some of Minnesota's forested recreational lands are presently held in large, privately-owned parcels by average citizens. The average recreational land owner is 62 years old, retired, and uses their property approximately 55 days per year. In the past, many of these land owners have left their land undeveloped and allowed hunters and other individuals access to their land, thereby providing a benefit to the general public. However, as property changes ownership, the new owners may not allow this access and/or sub-divide the parcel and thus, potentially reduce the public recreational benefit. An estimated one million acres of large, mostly undeveloped tracts of land in Minnesota are at risk of being sold.

Demographics

Aging Population - The Minnesota population of people 65-85 is expected to more than double between 2005 and 2035. In suburban counties, those 85 or older will increase 115%. As recreation users age, recreation resources, particularly public resources must be accessible to older users and will be increasingly assessed for compliance with the

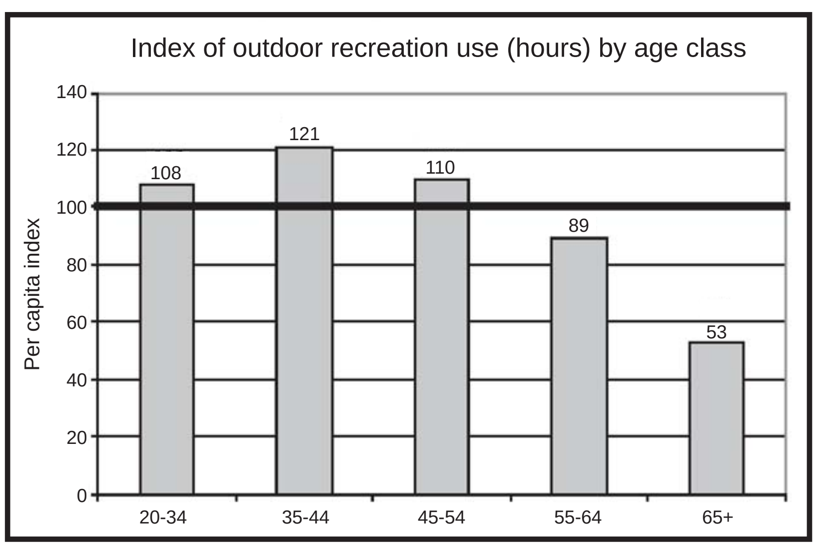


Figure 3: Index of outdoor recreation use by age class. Credit: Minnesota DNR

Figure 4: Fishing off a launch on Mille Lacs. Credit: Explore Minnesota Tourism

Americans with Disabilities Act. Activities that are inexpensive, convenient, and accessible are stable across various age groups and, as such, increases in activities that meet these characteristics are likely. As Minnesota's population ages, per capita use of outdoor recreation facilities may decrease (Figure 3, page 95). In addition, as the population ages, public policy decisions such as funding for recreation resources and their management will likely be increasingly influenced by voting patterns associated with older voters.

Cultural Diversity - According to the US Census Bureau, the foreign-born population increased by 57% from 1990 to 2000 and their annual births account for 75% of all US population growth. In Minnesota, the State Demographics Center predicts that by 2025, 17% of Minnesotans will be people of color. Specifically, the non-white population growth will outpace others with a tripling of Latinos by 2030 and a 121% increase in Asian groups. Of the 16 Asian ethnicity groups, one of the largest in Minnesota is Hmong (46,352).

Resource use, development, and maintenance will increasingly be influenced by cultural preferences for activities and site attributes. For example, research indicates Latino visitors have larger travel party sizes, prefer more developed facilities and engage differently in picnicking and other activities than non-whites. Similarly, Hmong appear to feel more comfortable and secure hunting, fishing, camping, and picnicking in larger groups. Outdoor recreation activities strongly associated with non-white Minnesotans included in the DNR research include nature observation, outdoor court sports (tennis, basketball, volleyball), and sledding. However, a survey of Minnesota adults showed that non-white Minnesotans tend to participate in outdoor recreation less often than white Minnesotans. Reasons for this differential participation demand may be related to access, information (non-English information), discrimination or the fact that the facilities and resources simply do not meet the non-white needs.

Disposable Income - Minnesota's income ranked 9th in the U.S., although incomes vary widely by county with higher incomes in the more densely populated areas. Since 1990, personal income in Minnesota is becoming more unevenly distributed, meaning there are substaintial differences in disposable incomes. As participation in outdoor recreation opportunities increases with disposable income, greater pressures on recreation resources are possible. More management attention will likely be required to meet demand and to avert environmental degradation.

Lifestyle and Recreation Preferences

Concern for Physical and Mental Health - Health benefits are a primary motivation for and benefit of outdoor recreation. In Minnesota, survey research indicates that health is the second highest motivation for outdoor recreation, following the opportunity to enjoy nature. In terms of physical health, inactivity is a serious problem as nearly 30% of U.S. citizens are completely inactive and only 25% engage in the recommended amount of physical activity. Leisure time physical activity on public lands is important to examine as public parks offer free to low cost places for physical activity and are accessible to individuals from culturally and socio-economically diverse populations, all age groups, and all abilities. Federally, this issue has been recognized by a Presidential Executive Order in 2002, which mandates federal land agencies to promote the use of recreation areas for improved health. The MN Department of Health's Cardiovascular State Plan addresses the connection between access to green space and health. Similarly, the National Parks and Recreation Association and their state offices are encouraging 'healthy parks, healthy people' initiatives. The City of St. Paul, for example, has partnered with local health providers to provide information on the health benefits of outdoor recreation. Among the many outdoor recreation areas that provide opportunities for physical activity, trails provide a 'green treadmill' which Minnesota, city and county officials have identified trail facilities among their top ten needs.

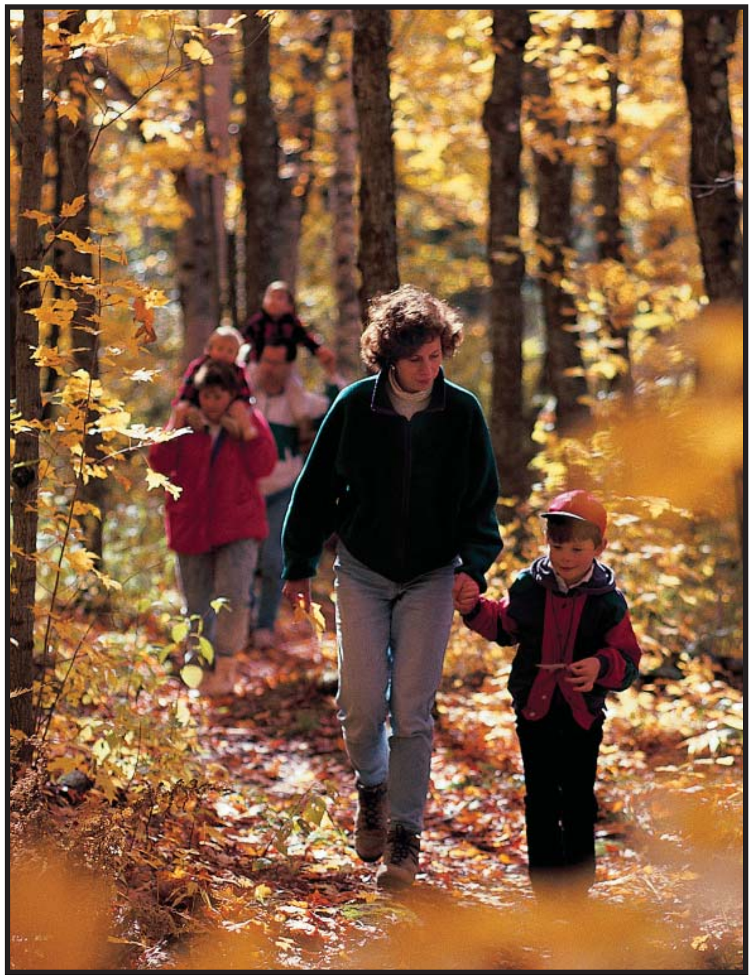


Figure 5: Family hike on the Superior Hiking Trail.
Credit: Explore Minnesota Toursim

Declining Participation - At the same time that the average age is increasing (see Demographics, page 95), there is decreasing participation in outdoor recreation by youth. In the past, young adults (20-34) have had the highest per-capita recreation hours compared to other adult age groups. However, in a recent survey of Minnesota adults, young adults reported fewer per-capita recreation hours than adults age 35-44 and 45-54.

The reasons for this change in participation are many and complex. However, we do know that outdoor recreation participation is often introduced by older family members: fishing with a parent, hiking with the family (see Figure 5), hunting with an uncle or appreciating nature with an older sibling. Given the change in participation by young adults, such introductions to outdoor recreation experiences are less likely and, subsequently, disconnects with nature may occur leading to reduced recreation participation and outdoor engagement overall. The increasing urbanization of Minnesota may exacerbate this issue whereby youth have increasingly limited access to outdoor recreation areas. Richard Louv's 'Last Child in the Woods' has popularized this idea and raised the idea of a 'nature deficit disorder' to a prominent position among federal land management agencies. The state of California created and received gubernatorial endorsement for a children's bill of rights which seeks to 'encourage California's children to participate in outdoor recreational activities and discover their heritage' (www.calroundtable.org).

Recreation Participation Patterns - Both the types of and time for outdoor recreation is changing. Since

2006, both national and state participation in fishing and hunting has declined. Similarly, expenditures related to fishing and hunting has also declined. This trend is expected to continue where fishing of all types is expected to decrease 18.4% and hunting of all types decline 11.2% by 2015 (see Table 1, page 93).

In contrast, wildlife viewing has increased 13% nationally in the last decade. In 2001, Minnesota ranked second in the nation for wildlife viewing. Minnesota's wildlife viewing participation rate increased 53 percent from 1996-2001 and spending rose 36 percent in the same time frame to $523.5 million. Given the national trends in wildlife viewing, Minnesota participation and expenditures are likely to follow suit (see Table 2 - State results from the USFWS are expected July 2007).

Beyond wildlife-related recreation, outdoor recreation activities have varying participation levels. In 2004 Minnesota adults reported participating in new activities that included boating (10%), followed by biking, camping, off-road driving (ATV) and fishing. In contrast to these other activities, ATV sales have increased substantially since 1995 resulting in 2004 unit sales estimated at 914,000. Minnesota is already among the top 10 states for ATV riding participation, and this participation is expected to increase.

Indicators of nature-based outdoor recreation participation changes over the last 10 years for U.S. and MN
(June 14, 2007)

Activity	Per-capita change in number of participants or visitation, 1996 to 2006	Change in number of participants or visitation, 1996 to 2006
U.S.		
Fishing participation (age 16+)*	-25%	-15%
Hunting participation (age 16+)*	-21%	-10%
National park visitation**	-19%	-10%
Away from home wildlife-watching participation (age 16+; "away from home" is over one mile from home)*	-15%	-3%
Total wildlife-watching participation (age 16+; includes "away from home" and "around the home")*	-1%	13%
BWCAW use (May-September overnight groups)****	-27%	-19%
MN		
Resident anglers licensed in MN (age 16+)***	-16%	-6%
Resident hunters licensed in MN (age 16+)***	-9%	3%
MN State Park visitation, all parks***	-10%	-1%
MN State Park visitation, same parks over period***	-12%	-3%
Away from home wildlife-watching participation (age 16+; "away from home" is over one mile from home)*	*(data do not appear reliable for MN, perhaps due to sample size; the MN trends for fishing and hunting from this source do not compare well with the more reliable trends from license certifications, which are the basis of the trends shown in this table for MN anglers and hunters)*	
Total wildlife-watching participation (age 16+; includes "away from home" and "around the home")*		
MN use of BWCAW (May-September overnight groups)****	-27%	-20%

* Source: USFWS and U.S. Census Bureau. National Survey of Fishing, Hunting and Wildlife-Associated Recreation. 2006 data are preliminary at this time (6/14/07)
** Source: National Park Service visitation records (www2.nature.nps.gov/stats/)
*** Source: MN DNR data on certified licensed hunters and anglers, and park visitation from Division of Parks and Recreation
**** Source: Data compiled form USFS records of May-September quota group permits.

Table 2: Indicators of nature-based outdoor recreation participation changes over the last decade for the U.S. and Minnesota. Credit: US Fish and Wildlife Service

Not only have recreation activities undergone participation changes, but so has the length of time we spend on vacations that include outdoor recreation. Vacations have transitioned from single week trips to several 3-4 day getaways. Almost 30% of Americans have taken 5 or more weekend trips in the past year and 40% of weekend travelers report they are taking more day trips and/or weekend trips, 38% more today than five years ago. Minnesota travel data supports this vacation length as the majority of visitors were on trips of 3 to 4 days in duration.

Such shorter timeframes change the distance people can travel and subsequently the pressure and impact on resources nearest to population centers. Interest in nature based tourism and travel to areas that sustain their natural geographic character is high and growing. In fact, eco tourism may be the fastest growing market in tourism. As such, it is essential that Minnesota maintain its highly valued tourism product of natural resources.

Climate Change

Lack of Snow and Safe Ice - Snow and ice conditions are variable and appear to be decreasing in duration and longevity. These conditions change the spatial distribution of traditional winter recreational activities. Winter recreationists may be displaced and go farther north within Minnesota or leave Minnesota as they seek appropriate snow and ice conditions. Users may also alter their recreation activities, choosing those that are not snow and ice dependent.

Lower Water Levels Due to Evaporation - Recreational boating is one of the most frequently engaged in outdoor activities in Minnesota: ranked second only to walking as an outdoor pursuit among Minnesota adults. An increase in boating is consistent in the metro, Brainerd and Central Lake Regions. Most of Minnesota boating is motorized, but one-in-five registered boats in Minnesota is a canoe or kayak. However, as temperatures rise, water levels will decrease and influence the types of water-based recreation that is appropriate and safe. Subsequently, the types of activities pursued in water bodies will change and activities will be spatially distributed to those water bodies that accommodate watercraft and activities. Changes in water level also influence the type and amount of fishing that can be done due to changes in fish habitat (see Fish Natural Resource Profile).

Lengthening Shoulder Seasons (Spring and Fall) - Changes in seasonal temperatures will lengthen springs and falls. Subsequently, more opportunities for moderate-climate recreational activities such as biking, hiking, and golf will be available. For example, a Canadian study used climate modeling to predict future golf season durations and found that the Great Lakes region of Canada is projected to experience substantial growth in golf participation: the climate-change-adapted golf season could extend 16 days longer in the 2020s, 37 days longer in the 2050s, and 68 days longer in the 2080s creating an opportunity for a potential 260 day golf season. It is reasonable to suggest that Minnesota, located in an already milder climate than the Canadian Great Lakes region, could endure the same, if not more extreme, scenario.

Figure 6: Blue Mounds. Credit: Explore Minnesota Toursim

The longer use of resources increases pressure on them, during particularly critical times for wildlife mating and

Figure 7: BWCA campground. Credit: Explore Minnesota Tourism

nesting. In addition, changing habitat created by the changes in seasons impacts opportunities for hunting, fishing, and wildlife viewing. From a Minnesota standpoint the greatest shift in birding emphasis is that the anticipated shrinkage of boreal forest habitats in northern Minnesota and other northern states. It could place boreal birding experiences with a higher priority to see black-backed woodpeckers, boreal chickadees, great gray owls, northern hawk owls, evening grosbeaks, pine grosbeaks, spruce grouse, and some of the northern warblers like the Connecticut warblers. There is already a strong birding tradition for avid birders to travel to northern Minnesota to see these species. To the extent that we retain the opportunities to see those species, the northern regions will become even more significant nationally and internationally as a major birding destination.

More Intense Summer Temperatures - Summer temperatures appear to be becoming more intense. Such temperature changes impact recreation resource use in terms of participation in water based activities, travel patterns and opportunities themselves. First, there is increased demand for water recreation, creating more pressure on water recreation resources and subsequent pressure on water quality. Such impacts are felt statewide and across recreation providers. Second, there is also increased demand to travel to cooler locations that are farther north, resulting in increased pressure on recreation resources in those areas and a loss of activity and economic impact in locations farther south. Third, hunting, fishing, and wildlife viewing opportunities will be altered in the short term as species respond to higher temperatures, and in the long term as species are displaced to other climate zones.

Major Data Gaps/Recommendations

Given the importance of outdoor recreation to Minnesotans, their quality of life and the state economy, attention to data gaps and changes in recreation are necessary. Among the many opportunities to further our knowledge of the recreation resource, we offer several key areas for research:

Engage All Minnesotans in Outdoor Recreation - Identify how to engage Minnesotans of all ages and racial/ethnic backgrounds in outdoor recreation and conservation.

- Implement targeted environmental education programs and evaluate their effectiveness on long term nature appreciation, conservation behaviors and recreation engagement among different generational and racial/ethnic groups.
- Create panel studies to assess changes in recreation participation throughout people's life course and factors influencing the changes.

- Initiate or continue research on beliefs about and preferences for outdoor recreation experiences among emerging non-white population groups.
- Identify and emulate innovate engagement efforts to increase recreational participation.

Diversity Preferences - Assess preferences for and constraints to recreation among racially/ethnically diverse population segments and various generational groups.

- Inventory the type and intensity of constraints to recreation preference formation and participation by racial/ethnic group and implement programs that meet non-white population groups recreational preferences.
- Inventory the type and intensity of constraints to recreation preference formation and participation by generational groups and implement programs that address the constraints.
- Inventory existing facilities for ADA compliance.

Land Use Patterns - Assess how changing land use patterns affect demand for, and supply of, the recreation resource.

- Identify spatial and temporal changes in recreation patterns in relation to the supply of desirable recreation areas and the subsequent impacts on natural resources, community economies and the experience itself.
- Monitor changes in visitation to recreation areas and facilities in relationship to population density changes, as well as the available access.
- Examine policies that encourage land owners to maintain public access, regardless of parcel size and ownership and implement land owner incentives that maintain public access.

Degraded Resource and Reduction in Participation - Assess the limits of acceptable change in the natural recreation resources and facilities that support Minnesota's recreation system.

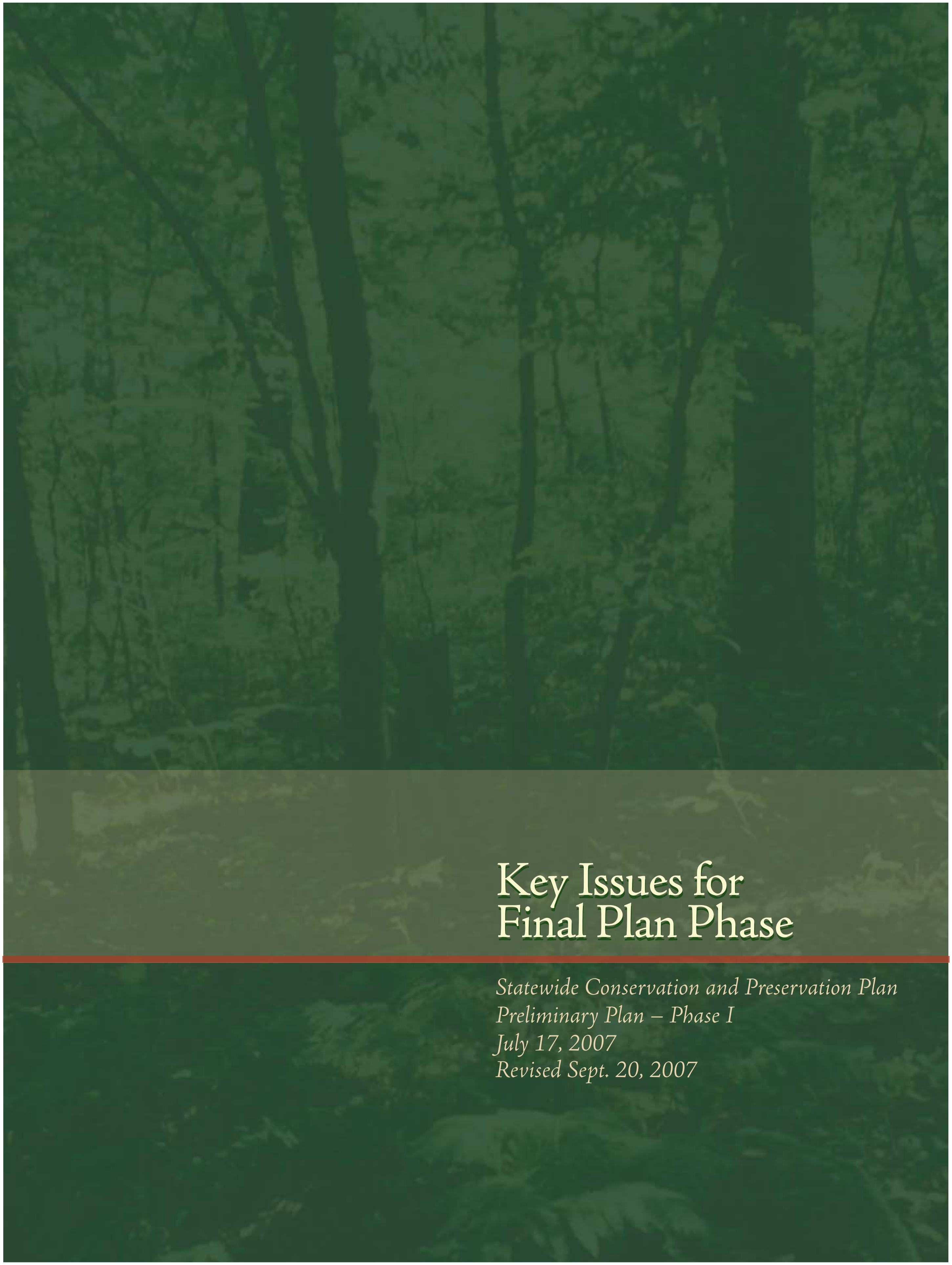
Physical and Mental Health - Measure physical and mental health benefits of outdoor recreation:

- Measure perceived and attained benefits of outdoor recreation at individual and community levels.
- Measure physiological changes, both on and offsite, associated with outdoor recreation in partnership with health related organizations.

Climate Change Implications - Research how the effects of climate change will affect recreation users and recreation providers in Minnesota, including:

- Changes in snow and ice conditions
- Changing water levels
- Change in land cover and water quality/quantity
- Higher summer temperatures/humidity
- Longer spring and fall seasons

> ***"We need to plan for and offer recreational opportunities for a changing population (less campers, but more day trippers)."***
>
> **—Campaign for Conservation survey participant**



Key Issues for Final Plan Phase

Statewide Conservation and Preservation Plan
Preliminary Plan – Phase I
July 17, 2007
Revised Sept. 20, 2007

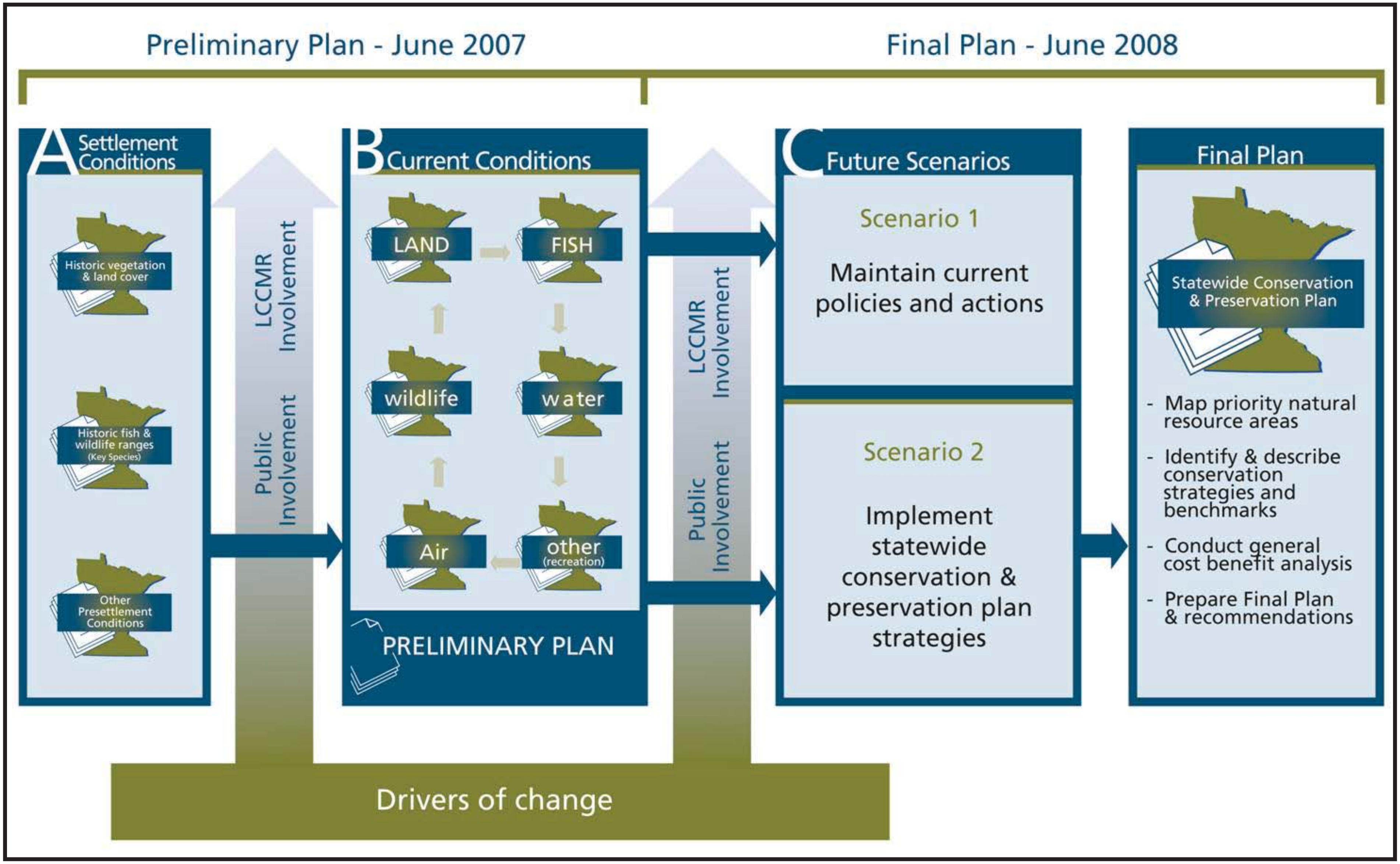


Figure 1: Statewide Conservation and Preservation Plan project timeline. This report culminates the Preliminary Plan phase. This section contains the project team's recommendations for issues to focus on during the Final Plan phase. Credit. SCPP Project Team

Key Issues for Final Plan Phase

The Statewide Conservation and Preservation Plan project has two phases (see Figure 1, facing page). This report closes the first phase, and we now turn to the trends analysis and the development of policy and investment recommendations that comprise the final Plan. The challenge as the project moves forward is to examine the many drivers of change identified in the first phase and narrow the field to the few key issues to be investigated during the final Plan.

To assist the LCCMR in choosing these key issues, the project team prioritized the drivers of change by applying its collective expertise with the following questions in mind:

- Does the driver affect multiple resources
- How extensive is our current knowledge base about the driver
- How quickly will a resource respond to a change in the driver
- What are the implementation challenges to changes in policy or investment for this driver
- Are there public acceptance challenges to a change in policy or investment for this driver
- What is the relative public urgency for the driver
- Does the driver affect adaptation to climate change or mitigation to climate change by the state

As a result of this exercise, the project team offers the following list of potential issues for further investigation by the project, in priority order:

Land and Water Habitat Fragmentation, Degradation, Loss, and Conversion

Habitat fragmentation, degradation, loss and conversion are a concern for land, lakes and streams. On land, fragmentation refers to changes in the landscape pattern resulting from human activities, primarily as a result of habitat conversion to agriculture, residential, and commercial/industrial development as well as road construction, forest harvest patterns, and numerous other factors.

Fragmentation results in smaller patch sizes, increased edge, and an overall 'simplification' of the landscape. The nature of fragmentation varies across Minnesota, from the characteristic checkerboard pattern of farm fields with isolated woodlots in agricultural regions of the state, to broadleaf forests perforated by 1-5 residential acre lots in the broadleaf forest region of the state, to aspen-conifer forests with interspersed 40-80 acre clear cuts in northern Minnesota.

In aquatic ecosystems, fish habitat fragmentation and outright loss result from removal of downed trees, aquatic vegetation (fish habitat), alteration of shorelines (e.g. installing rip rap) and removal of riparian wetlands.

Often associated with fragmentation is habitat degradation, defined as a reduction in the quality of remaining habitat. Habitat fragmentation and, degradation, loss, and conversion add up to greatly reduced complexity of habitat structure.

Land Use Practices

Land use practices includes the full spectrum of human activities on the land from conservancy and restoration through agricultural, extraction, alteration and all forms of urban and shoreland development and redevelopment. The previous issue deals directly with fragmentation, conversion, degradation and loss of land and water habitat, as one distinct set of consequences associated with human activities. In this context, land use practices refers to the manner in which a use, or activity is conducted on a particular parcel of land and its affect on the natural environment.

Impacts of Resource Consumption

The ways in which land is used to support human activities have both direct and indirect effects on all of the natural resource systems. Land conservation and restoration activities are known to yield positive effects on the environment.

Some forms of extraction and land alteration can permanently destroy preexisting natural resources. It is also true that the patterns and density of development, the interrelationships between different uses and construction and development practices combine to have major effects on energy consumption, air and water quality, and transportation.

Toxic Contaminants

Contaminants are chemicals regulated because of human or wildlife toxicity. For our purposes, the definition of contaminants also includes the Criteria air pollutants, "legacy" toxic chemicals, emerging toxic chemicals including endocrine disruptors (EDCs) and pharmaceuticals, pesticides including herbicides and insecticides, and mercury.

Transportation

Transportation includes infrastructure networks that enable and support personal (passenger) and commercial (freight) traffic. From the perspective of natural resources, transportation networks and the vehicles they carry directly or indirectly cause impacts on land, water and air.

Energy Production and Use

Energy production and use are human activities related to the extraction, production and consumption of energy, including fossil fuels and renewable energy sources.

Invasive Species

Invasive species are undesirable aquatic and terrestrial species, accidentally or intentionally introduced into Minnesota disrupt native plants and animals and their habitat, or are a nuisance to human activities. Serious invasive species in the state span many taxonomic groups, such as terrestrial and aquatic plants, insects and aquatic invertebrates, fish, and pathogens.

Please see Appendix IX for a detailed description of these issues, the research questions associated with them, available data, and the expected value and outcomes from further investigation.

Appendices

Statewide Conservation and Preservation Plan
Preliminary Plan – Phase I
July 17, 2007
Revised Sept. 20, 2007

Project Participants - Preliminary Plan Phase

Project Team

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Key Participant Credentials

Deborah Swackhamer, PhD, University of Minnesota

Dr. Swackhamer is Professor of Environmental Chemistry in the Division of Environmental Health Sciences, School of Public Health. Dr. Swackhamer is an international expert in the chemical and biological processes that control the fate of toxic organic contaminants in the aquatic environment, particularly bioaccumulation of persistent compounds in fish in the Great Lakes; the processes that control exposure to environmental estrogenic compounds; and the development of contaminant indicators of ecosystem health. Dr. Swackhamer is Interim Director of the Institute on the Environment, and co-Director of the Water Resources Center, and currently sits on the Science Advisory Boards of the US EPA and the International Joint Commission of the US and Canada. She also serves on the Advisory Board for the National Undersea Research Program of NOAA for the North Atlantic-Great Lakes region, and the Board of Scientific Councilors of the US EPA. She was appointed by Governor Pawlenty to serve in the Clean Water Council in 2007. Dr. Swackhamer is a member of the Editorial Advisory Boards for the journals Environmental Science & Technology and JEM: Journal of Environmental Monitoring.

Jean Coleman, JD, MA, Project Coordinator, CR Planning, Inc.

Ms. Coleman has proven skills in managing complex teams over tight timeframes and extensive knowledge of using natural resource information in land use planning and zoning. In addition to serving on the core management team, Ms. Coleman will serve as the consultant team project coordinator. Her primary role is to manage internal communication, document creation, and supervise project support personnel. Ms.Coleman has extensive experience in natural resource and farmland protection, preparing comprehensive land use plans and zoning ordinances, group process facilitation, and growth management. Her work combines her interests in planning and law by using public participation and conflict resolution techniques to develop policies, ordinances, and programs. She enjoys working in a variety of landscapes and has managed multiple projects at the neighborhood, township, county and regional scale.

Todd Arnold, PhD, University of Minnesota

Dr. Arnold is Associate Professor of Fisheries, Wildlife and Conservation Biology. He has also worked extensively with environmental NGO's, including stints as Senior Scientist for Ducks Unlimited Canada and Scientific Director for Delta Waterfowl Foundation. His research focuses on prairie- and wetland-dependent wildlife, especially waterfowl. He has worked on numerous regional issues in waterfowl management, including development of a Decision Support System for conservation planning in the Canadian Prairie Pothole Region.

Paul Bockenstedt, MA, Bonestroo

Mr. Bockenstedt has over 23 years of experience in the natural resources field including 13 years of experience with State and County agencies in Iowa and Minnesota, and most recently nine years working throughout the upper Midwest at Bonestroo. He has been involved with natural resources inventory, conservation, management and planning at the local, county, regional, watershed and state levels in Minnesota and Iowa since 1992. He has served as the project manager and/or lead ecologist for over 100 natural resource and recreation/parks planning projects and botanical inventories and written over 125 ecological restoration plans during his career. In addition, he has numerous publications and presentations to his credit.

George Host, PhD, University of Minnesota

Dr. Host is a Senior Research Associate and Landscape Ecologist with the Natural Resources Research Institute at the University of Minnesota - Duluth, and Director of the Natural Resources Geographic Information System laboratory at UMD. He currently is principal or co-principal investigator on 15+ research projects distributed across the fields of forest ecology, ecological assessment and indicator development, plant response to atmospheric pollutants, linkages between terrestrial and aquatic systems (particularly with respect to stormwater issues), and data visualization and spatial analyses for land use planning. Dr. Host has over 50 refereed publications, and has served on advisory panels for the MN Dept of Natural Resources, the MN Forest Resources Council, and numerous county and municipal groups. George Host is currently involved in a GIS analysis to identify lands of high conservation value for the development of conservation easements through the Forest Legacy Program.

Anne R. Kapuscinski, PhD, University of Minnesota

Dr. Kapuscinski is Professor of Fisheries, Wildlife and Conservation Biology and co-leads the Ecosystem Science and Sustainability Initiative funded by the Bush Foundation. She has broad expertise on how technologies from dams to fish hatcheries to genetic engineering affect fish conservation and is active in analysis and formulation of policies fostering sustainability of aquatic biodiversity. She holds a Pew Marine Conservation Fellowship, the world's preeminent marine conservation award, has advised three past Secretaries of Agriculture and serves on advisory committees to the FDA and various agencies of the United Nations.

Lance Neckar, MLA, University of Minnesota

Professor Neckar is Professor of Landscape Architecture and conducts applied research on the relationships between urban development and the sustainability of water and other resources. His current teaching focuses on sustainable infrastructure. He also brings over 20 years of experience as a registered landscape architect with several award-winning urban design projects. He is acting Director of the Metropolitan Design Center.

Randy Neprash, BS, Bonestroo

Mr. Neprash is a Stormwater Regulatory Specialist and Engineer with the Water and Natural Resources Group at Bonestroo. He has served as the technical/administrative consultant for the coalition of more than 100 cities regulated under the NPDES MS4 Stormwater Permit program for more than four years. In this capacity, he has represented cities on the Minnesota Stormwater Steering Committee (MnSSC) and its Operations Subcommittee since its conception. The MnSSC is charged with informing, advising, and coordinating stormwater management efforts across the state. It also provides support for other programs that include stormwater components such as: impaired waters, shoreland management, drinking water source water, wetland management, MN Nonpoint Source Management Plan, federal funding programs, groundwater recharge, watershed organizations, surface water management plans.

Gerald Niemi, PhD, University of Minnesota

Dr. Gerald Niemi is Professor of Biology and Director of the Center for Water and the Environment at the Natural Resources Research Institute at the University of Minnesota, Duluth. He also was a Fulbright-Hays scholar to Finland. His primary research interests include birds, Great Lakes ecosystems, conservation biology, and sustainability of natural resources. He has written over 200 articles, publications, book chapters, and technical reports. He has received more than $18 million in research funding. Dr. Niemi regularly teaches Ornithology and Conservation Biology.

Ingrid Schneider, PhD, University of Minnesota

Dr. Schneider is an Associate Professor in Forest Resources and Director of the University's Tourism Center. She has broad experience in visitor behavior in outdoor recreation management and sustainable tourism with particular emphasis in visitor attitudes, conflict and constraints. She is a member of the Governor's Council on Tourism.

John Shardlow, BS, Bonestroo

Mr. Shardlow is past president and co-founder of DSU. He has extensive and wide-ranging experience serving clients in both the public and private sectors, and has led many multi-disciplinary teams of consultants in large, complex planning projects. His skills include comprehensive and community planning, project planning, re-development planning, regulations, and environmental assessments. He is a faculty member of the Government Training Service, and is a member of the America Institute of Certified Planners, the American Planning Association, Minnesota Planning association, and past president of the Minnesota chapter of the Community Association Institute. He is a past president of the Sensible Land Use coalition, and currently serves on the executive Committee of the Twin Cities Chapter of the Urban Land Institute (ULI).

Matt F. Simcik, PhD, University of Minnesota

Dr. Simcik is an Associate Professor of Environmental Health Sciences in the School of Public Health. He has broad expertise on air toxics and their interactions with aquatic and terrestrial systems. He is currently President of the International Association of Great Lakes Research.

Sangwon Suh, PhD, University of Minnesota

Dr. Suh is an Assistant Professor focusing his research on environmental and economic systems analysis in the interface between engineering, economics, ecology and public policy. His expertise lies on building and management of database, mathematical modeling and systems analysis. For the last five years he authored or co-authored around 30 peer reviewed journal articles, 2 books and 2 commercial databases. He is an Associate Editor of the International Journal of Life Cycle Assessment and serves on the editorial boards of economics and engineering journals. He advises Eco-Industrial Development Council (EIDC) and the European Commission's Directorate General, the Environment on its Integrated Product Policy (IPP).

Preliminary Recommendations for LCCMR Funding Priorities

This appendix contains the same information handed out to the LCCMR on June 20th, 2007 by the Statewide Conservation and Preservation Plan project team. Below are our top preliminary recommendations for funding priorities, and list of the most pressing issues facing Minnesota's natural resources, and details on key drivers of change for each resource area.

Recommendations that would provide benefits to multiple natural resources

- Identify, protect and manage Strategic Land Areas that contribute relatively more to conservation
- Establish statewide habitat corridors using consistent methodology and criteria
- Acquire important data on a regular basis (e.g., LIDAR, parcel and land cover)
- Manage development to decrease effects on resources
- Increase understanding of potential effects of climate change on resources
- Increase understanding of effects of contaminants on resources

Overview of most pressing issues

- Land use change/development/land disturbance
- Habitat fragmentation/loss/erosion
- Climate change
- Contaminants
- Consumptive use
- Invasive species
- Energy production
- Transportation
- Demographics
- Human health

Primary Drivers of Change

A major focus of the first phase of the project has been identifying the key drivers of change affecting each natural resource area. Each research team began by identifying proximal drivers, those acting most closely upon the resource, and then mapping them to higher order drivers (see Figure 1, facing page).

The teams, with the assistance of outside experts from relevant state agencies, then ranked these drivers by their relative impact on a common set of "elements of sustainability" (see Table 1, facing page). As an example, for the Fish resource, the proximal driver Nutrient Loading affects sustainability elements Water Quality (medium), Fish Health (high), and Human Health (low), among others.

The rankings were mathematically analyzed to rank the proximal drivers in order of total impact (integrated across elements of sustainability) on the resource. The resulting list of top-ranked drivers (i.e. those with the most overall impact on the resource) forms the backbone of this report as well as the recommendations to the LCCMR on high-impact areas to focus on in the current-year Request for Proposal.

Following is a list of primary drivers of change for each resource area, and below each, the recommendations related to each driver.

Air – Drivers of Change

Climate Change

- Invest in projects similar to projects traded on the Chicago Climate Exchange
- Study effects of biofuels on greenhouse gases

Energy Production

- Assess the effects on air of changing from coal to natural gas
- Study effects of biofuels on air pollution

Transportation

- Encourage greater use of natural gas, hybrids, biodiesel and electric vehicles
- Increase the use of public transportation and make it less polluting
- Assess barriers to the use of public transportation
- Increase bike paths for commuting

Land – Drivers of Change:

Strategic Land Areas

- Identify land areas that contribute disproportionately to conservation
- Protect and manage these lands

Soil Erosion

- Acquire high resolution elevation data (using LIDAR) to gain accurate slope information and measure erosion rates
- Develop better estimates of erosion from gullies, ravines, and streambanks
- Evaluate watershed scale impacts of erosion control practices
- Restore annual surveys of crop residue cover after planting

Land Use Change

- Establish habitat corridors statewide using consistent methodology and criteria
- Obtain and regularly update GIS land parcel data – make it comprehensive and broadly available, and establish a method for consistent updating
- Obtain and regularly update current land cover data – ensure consistent and frequent updating, and include all native plant communities
- Improve updating of soil surveys
- Create a GIS portal interface integrating land cover, soils, and bedrock geological information

Habitat Fragmentation

- Research the effects of fragmentation on species and genetic diversity
- Conserve native genetic material
- Understand GMO effects on native plants – literature review
- Integrate and assess information on contaminated sites and contaminant sources (landfills, brownfields, pesticide spills, pollutant sources, etc.)
- Expand scope of monitoring for contaminants in the landscape

Wildlife – Drivers of Change

Land Use Change and Fragmentation

- Perform land cover mapping at regular intervals to understand changes in wildlife habitat
- Identify priority natural areas and corridors (hubs and connections) to preserve for wildlife - statewide
- Identify how to make all aspects of the land network (urban to agricultural to natural) more supportive for wildlife

Development

- Determine how to build urban and exurban areas and retain the highest possible species diversity

Disease and Invasive Species

- Research the (currently unknown) effects of diseases and invasive species and human structures on wildlife

Water – Drivers of Change

Land Use Change

- Invest in management and protection of Strategic Land Areas that affect water
- Manage development to reduce erosion and pollutant loading
  - » Focus on shoreland development
  - » Focus on fast-growing urban areas
  - » Promote shoreline buffers
  - » Promote urban and construction Best Management Practices (BMPs)
- Support research to quantify the benefits of BMPs and Low Impact Development (LID)
- Support water quality monitoring and assessment

Contaminants

- Assess the impacts of emerging contaminants discharged to surface waters (pharmaceuticals, perfluorochemicals, pesticides, endocrine disruptors)
- Assess the impacts of contaminants from urban activities (construction, transportation, impervious areas)
- Support research on how to reduce, minimize, remove, or remediate contaminants

Consumptive Use and Energy

- Measure the impact of water withdrawals on ground water – focus on the relationship between withdrawal vs. recharge
- Determine the impacts of different renewable energy options on water quantity and quality

Fish – Drivers of Change

Aquatic Invasive Species

- Develop effective ways to stop or reduce spread of harmful invaders – urgently needed for VHS!
- Develop more effective methods of controlling aquatic invasive species
- Improve risk assessments for potentially harmful new invaders
- Create solutions to restore native communities after invasive species are under control

Land Disturbance

- Invest in protection of Strategic Land Areas to reduce nutrients and solids loading to surface waters
- Create tools to predict when cumulative land disturbances will alter fish communities
- Evaluate consequences of land use policies for fish communities

Aquatic Habitat Loss

- Create tools to predict reductions in fisheries productivity due to lake habitat losses
- Evaluate effectiveness of BMPs for shoreline habitat restoration
- Create tools to predict effects of shoreline development with and without BMPs on fish communities

Climate Change

- Fill crucial data gaps to predict and monitor effects of climate change, including effects on lake and stream water and nutrient budgets, temperatures linked to other climate data, and on-game fish, aquatic invertebrates, and aquatic plants
- Develop methods to predict the effects of climate change combined with other stressors on fish communities

Fish Stocking

- Develop guidance on environmentally appropriate source populations and species for stocking to:
    - » Restore fish communities
    - » Adapt to climate change
    - » Support fishing
- Evaluate effects of stocked fish on:
    - » Genetic diversity and fitness of wild fish (same species)
    - » Entire aquatic communities (other species)
- Evaluate effects of current fish stocking on anglers' experience – quality and quantity of fish caught

Contaminants

- Monitor endocrine disruptors and pharmaceuticals:
    - » Distribution in surface waters
    - » Effect on fish health
    - » Biological response in fish in contaminated waters

Outdoor Recreation – Drivers of Change

Land Use Change

- Assess how changing land use patterns affect demand for, and supply of, the recreation resource

Human Health

- Measure physical and mental health benefits of outdoor recreation:
    - » Perceived and attained benefits
    - » Measure actual activity via biophysical data

Demographics

- Assess preferences for, and constraints to, recreation among racially/ethnically diverse population segments and inter-generational groups

Climate Change

- Research how the effects of climate change will affect recreation users and recreation providers in Minnesota, including:
    - » Lack of snow and ice
    - » Lower water levels
    - » Change in land cover and water quality/quantity
    - » Higher summer temperatures
    - » Longer spring and fall seasons

Appendix IV
Sources

Sources

This appendix lists sources used in identifying and evaluating the drivers of change in each natural resource area. The references are listed by driver within natural resource area.

Air

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Appendix V
Documents, Policies and Plans

Summary of Documents Collected

A key element in the project's planning process was a *directed* literature review by each research and analysis team. A directed literature review, as the name implies, is not meant to be exhaustive, but rather is targeted at specific areas of interest. In this case, the review was targeted at natural resource data related to current conditions, resource trends and drivers of change.

While these documents were used as a basis for the Preliminary Report, they will also be valuable during phase II as the project emphasis shifts toward projecting key trends into the future, and addressing policy and investment issues that emerge from this analysis.

A full listing of the documents collected by each team to date is available for download from the project website: www.mnconservationplan.net (click on Plan Progress, then Preliminary Plan Addenda)

Note: the process of collecting relevant data will continue, and this listing will be periodically updated.

Survey of Existing Plans and Policies

Toward the end of phase I of the project, the research and analysis teams began to identify and collect information on existing plans and policies directed at Minnesota's natural resources – this process will continue throughout phase II.

When completed, this survey will provide a robust framework for the Final Report's recommendations for policy and investment additions and/or modifications. These recommendations will be based on trend analyses and condition projections for the key issues being looked at, as well as a consideration of the alternatives available.

A copy of the Survey of Existing Plans and Policies as of this report can be downloaded from the project website:www.mnconservationplan.net (click on Plan Progress, then Preliminary Plan Addenda)

Suggestions welcome!

While the project team's experience and expertise related to Minnesota's natural resources is both broad and deep, the universe of documents, plans and policies is no doubt broader and deeper. The project team welcomes any and all suggestions for items that can usefully be added to either list. See the website for contact information.

Public Engagement Partners

Minnesota 2050 project

The Minnesota 2050: Pathways to a Sustainable Future project is funded by the Bush Foundation and coordinated by the UMN's Ecosystem Science and Sustainability Initiative. In its first phase, the project has collaborated with the UMN Regional Sustainable Development Partnerships to convene a series of workshops designed to develop possible visions of Minnesota in the year 2050, and are focusing the energy and experience of citizens across the state on the importance of preserving Minnesota's natural heritage.

Through five sessions in greater Minnesota, more than 150 farmers, business owners, teachers, local government officials and other citizen leaders (invited by the Regional Partnerships) have shared their visions for the future of our state. A sixth session convened in St. Paul gleaned insights about the future of the metro region from leaders in local governments, employees of state and regional agencies, and University faculty among others. Almost without exception, participants have been inspired and challenged by the workshops and by their contemplation of our state's future. One participant said, above all, the workshop instilled hope that will counter the sense of anguish he feels about the decline of our environment and the loss of Minnesota's natural heritage.

More information at: http://www.sustainability.umn.edu/research/

Campaign for Conservation – 50-year vision project

The Campaign for Conservation, with the assistance of the University of Minnesota Extension Service, held 2-3 workshops in each of 14 ecologically-based regions in the state to solicit the aspirations and viewpoints of local residents. The goal of these sessions was to formulate a conservation vision for each region that could be coalesced into a comprehensive conservation 50-year vision for all of Minnesota. In preparation for these meetings, the Campaign for Conservation reviewed more than 90 natural resource management plans written over the past 15 years, recalibrated the data so they were pertinent to each of the 14 Conservation Regions, and then summarized this information and distributed it to each of the participants in advance of the first meeting. This allowed each participant to review the planning that had been done, thus giving them a better understanding of the environmental conditions of their region and a foundation for moving forward. Their input was then used to create a Conservation Planning Template for each Conservation Region that will be compiled into a comprehensive 50-Year Vision for Minnesota that will be completed in 2007.

More information at: http://www.campaignforconservation.org/

List of Acronyms

AOC - Area of Concern
AQI - Air Quality Index
ATV - All Terrain Vehicle
BMPs - Best Management Practices
BWCAW - Boundary Waters Canoe Area and Wilderness
CPUE - Catch Per Unit of Effort
CRP - Conservation Reserve Program
DDT - Dichloro-diphenyl-trichloroethane
DEET - N,N-diethyl-meta-toluamide
DNR - Department of Natural Resources
EDCs - Endocrine Disrupting Compounds
FDA - Food and Drug Administration
FIA - Forest Inventory and Analysis
GEIS - Generic Environmental Impact Statement
GIS - Geographic Information Systems
GMO - Genetically Modified Organism
Hg - Mercury
IPCC - Intergovernmental Panel on Climate Change
LCCMR - Legislative-Citizen Commission on Minnesota Resources
LID - Low Impact Development
LIDAR - Light Detection And Ranging
MDA - Minnesota Department of Agriculture
MDH - Minnesota Department of Health
ME3 - Minnesotans for an Energy Efficient Economy
MnDOT - Minnesota Department of Transportation
MNEQB - Minnesota Environmental Quality Board
MPCA - Minnesota Pollution Control Agency
MTSH - Mt. Simon/Hinckley
NAAQS - National Ambient Air Quality Standards
PAHs - Polycyclic aromatic hydrocarbons
PBDEs - polybrominated diphenyl ethers
PCBs - Polychlorinated biphenyls
SGCN - Species of Greatest Conservation Need
SCORP - Statewide Comprehensive Outdoor Recreation Plan
TMDLs - Total Maximum Daily Loads
TP - Total Phosphorous
UMN - University of Minnesota
USDA - United States Department of Agriculture
USEPA - United States Environmental Protection Agency
USFWS - United States Fish and Wildlife Service
USGS - United States Geological Survey
VHS - Viral Hemorrhagic Septicemia
VMT - Vehicle Miles Travelled
VOCs - Volatile Organic Compounds

Appendix VIII
List of Figures and Tables

List of Figures and Tables

Project Progress to Date

Natural Resource Profiles

Introduction

Air

Land

Wildlife

Water

Fish

Outdoor Recreation

Key Issues for Final Plan Phase

Land & Water Habitat Fragmentation, Degradation, Loss and Conversion

Definition

Habitat fragmentation, degradation, loss and conversion are a concern for land, lakes and streams. On land, fragmentation refers to changes in the landscape pattern resulting from human activities, primarily as a result of habitat conversion. The land is converted to many different uses and activities, including: agriculture, forest harvest, residential, road construction and numerous other factors. Fragmentation results in smaller patch sizes, increased edge, and an overall 'simplification' of the landscape. The nature of fragmentation varies across Minnesota, from the characteristic checkerboard pattern of farm fields with isolated woodlots in agricultural regions of the state, to broadleaf forests perforated by 1-5 acre lots in the broadleaf forest region of the state, to aspen-conifer forests with interspersed 40-80 acre clear-cut sections in northern Minnesota. In aquatic ecosystems, fish habitat fragmentation and outright loss result from removal of downed trees, or aquatic vegetation, alteration of shorelines (e.g. installing rip rap) and the removal of riparian wetlands.

Issue

Habitat degradation is also frequently associated with fragmentation, resulting in a greatly reduced complexity of habitat structure, functions and values. There are many known effects, and probably an equal number of unknown effects of habitat fragmentation, degradation and loss. Among these are a direct loss of habitat for species that require large tracts of prairie, or forest land ("interior" forest is required by many bird and some mammal species) and for fish species that require floating vegetation or wetlands for breeding and juvenile rearing, increased predation associated with increased edge (for terrestrial species) and with loss of floating and submerged vegetation (for aquatic species), and increased opportunities for the spread and establishment of invasive species. Presently, the loss of lake shoreline habitat is a major issue regarding aquatic habitat. As the patch size of fragments become smaller, the population sizes of organisms living within the fragments also decreases. Population size is the critical factor in maintaining viable plant and animal populations and as they decline, species become more susceptible to local or regional extinction. Less well understood are the long term consequences of fragmentation, including the resilience of natural communities to respond to environmental stress, and in particular their ability to adapt to climate change (e.g. maintain overall species composition and productivity).

Key Questions

- What is the relationship between the remaining large intact tracts of land and the ongoing changes in land ownership patterns?
- What parts of the forest, agricultural and aquatic resources of Minnesota are most 'at-risk' in terms of increasing rates of habitat fragmentation?
- What are effective social and economic incentives for aquatic and land habitat protection and restoration?
- What policies are needed to reduce habitat loss, degradation, and fragmentation?

Data Sources

There are numerous data sets available to assess these habitat and landscape fragmentation issues, including the classified Landsat imagery available statewide through the MN DNR Gap program, the NRRI and UM forest classifications, and the airphoto-based land classification of the Twin Cities region available through the Metropolitan Council. The DNR has some data and spatial information on aquatic habitat, with some limited data on floating and rooted vegetation and shoreline habitat. The DNR also has lake bathymetric maps, although these need to be updated.

Outcome

The identification of 'at-risk' land and aquatic habitats in the agricultural, forested, and mixed land use regions of the state, as well as trends in habitat fragmentation over time. Recommend changes to land and aquatic habitat management policies that promote multi-owner coordination to maintain large parcels, reduce rates of habitat fragmentation and loss in key areas through conservation easements and other policies, and link changes in landscape structure to key land, water, fish and wildlife resources.

Value

High. Habitat fragmentation, degradation and loss are arguably the most important issues facing the conservation and preservation of Minnesota resources. The issue is complicated by the fact that large habitats are already highly subdivided and are managed by many public and private landowners, with vastly different management objectives. Moreover, fragmentation associated with changes in infrastructure is largely irreversible: roads, docks, and building developments become persistent features of the landscape. Consequently, it is critical to understand these fundamental changes to Minnesota's habitats. Moreover, if Minnesota is to maintain its native biological diversity and provide sound decision-making for its natural resource extractive industries, a solid understanding of the distribution of its land and water habitats base is critical.

Land Use Practices

Definition

Land use practices includes the full spectrum of human activities on the land from conservancy and restoration through agricultural, extraction, alteration and all forms of urban and shoreland development and redevelopment. The previous issue deals directly with fragmentation, conversion, degradation and loss of land and water habitat, as one distinct set of consequences associated with human activities. In this context, land use practices refers to the manner in which a use, or activity is conducted on a particular parcel of land.

Issue

The ways in which land is used to support human activities have both direct and indirect effects on all of the natural resource systems. Land conservation and restoration activities are known to yield positive effects. Some forms of extraction and land alteration can permanently destroy preexisting natural resources. It is also true that the patterns and density of development, the interrelationships between different uses and construction and development practices combine to have major effects on energy consumption, air and water quality, and transportation.

Key Questions:

- What additional opportunities exist for acquisition and management of land conservancies throughout Minnesota and which are the best approaches for financing conservation strategies?
- Are current regulations adequate to mitigate for the loss of natural resource systems due to extraction and land alteration activities?
- Can the benefits of compact and higher density developments be sufficiently quantified to overcome local political opposition?
- Which of the many low impact development (LID) practices are the most effective and how can local officials and the development community be encouraged and motivated to implement them?
- How can the new Green Star Energy code be best implemented and what are realistic expectations for its effects?
- Within the existing Federal regulatory framework, how can we structure a set of regulatory and policy pressures along with systems of Best Management Practices (BMPs) to achieve responsible and sustainable development and redevelopment patterns that minimize and mitigate environmental degradation?

Data Sources

The Minnesota Land Cover Classification System (MLCCS) is available to many communities within the Twin Cities Metropolitan Area and in other select areas in the State. Where available, this tool provides excellent information regarding the existing pattern of natural resource systems, and opportunities to establish key linkages in multi-purpose greenway corridors. The MnDNR has some information on the effects of mining on natural systems. The Urban Land Institute (ULI) has extensive information on urban land patterns and ULI and the APA and the AIA and others have a rapidly growing body of information about the benefits of conservation development, and low impact development techniques. The MPCA and the Builders Association of the Twin Cities have reference materials on the costs and benefits associated with energy conservation in buildings. The MPCA, builders, cities, and watershed districts have experience and data on shaping regulations and implementing BMPs.

Outcomes

- A better understanding of the economic costs and ecological benefits of strategic conservation investments;
- A critical evaluation of the opportunities and benefits associated with improved regulation of major land altering uses and activities;
- A clear, objective compilation of the benefits of compact development patterns and conservation development practices to support local land use policy makers;
- Solid documentation of the costs and benefits associated with specific low impact development techniques and references to model standards and ordinances that have been proven effective in different contexts;
- Information to support the wide scale application of energy saving building and development practices.

Value

High. There is a rapidly expanding volume of information in each of these areas, but it has not been distilled, synthesized and packaged in ways that will make it accessible and understandable to local governments, builders, developers and regulators. The potential for affecting significant reductions in the adverse effects of land use practices are very significant.

Impacts on Resource Consumption

Definition

Non-sustainable Resource Consumption is specifically defined as follows:

- the consumptive use of groundwater at extractive rates that exceed the rate of recharge;
- the irretrievable loss, exceeding natural soil replacement rates, of land due to wind and water erosion that is the result of human industrial, agricultural, and land use practices.
- the extraction of materials such as minerals, sand, and gravel are considered inherently non-sustainable where these practices cause irretrievable loss of native habitats such as forest, prairie or unique wetland/stream areas or cause loss of land function that can not be reversed in the time scale of human generations.

Impacts to wildlife, land, and water quality due to the non-sustainable extraction of timber resources and irretrievable loss of land due to changes in land use are addressed under other key issues (e.g. Land &Water Habitat Fragmentation, Degradation & Loss).

Issues

The results of recent studies show that water consumption is expected to exceed the renewable supply in multiple Minnesota counties in the foreseeable future. Large-scale production of corn-based ethanol currently places significant demand on groundwater resources in some areas of Minnesota. Future biofuels production is expected to make significant new demands on groundwater sources. Non-sustainable consumption of groundwater can negatively impact water chemistry, low flows in surface waters, and important discharges to fens and other wetlands. Climate change is expected to exacerbate the problems by increasing water demand and reducing water storage.

A significant amount of land is lost due to anthropogenic causes. Industrial, agricultural, and development practices frequently result in the loss of soil at rates that exceed the capacity for natural processes to replace those losses. Changes in the intensity of agricultural practices due to increased production of biofuels and other public policies may result in increased soil erosion. Development patterns, agricultural practices, and public policies will also affect streambank and shoreland erosion and loss. Soil erosion is a major concern in some areas of Minnesota including the southeast, the Coteau, as well as river bluffs and steep slopes throughout the state. Wind erosion is significant in western Minnesota, especially the Red River Valley. Climate change is expected to exacerbate these problems because of more frequent severe storms.

Mining can be a temporary use of land. However the degree to which the land is changed varies depending on the size and depth of the mining operation. Mining, in its various forms, has the potential to permanently destroy diverse native plant communities (which can not be replicated/reconstructed through mining reclamation processes), change landform characteristics, impact and change watersheds and water quality, as well as significant viewsheds.

In Minnesota, gravel mining operations are generally under the jurisdiction of local government. The township, city and/or county in which the operation is located may have specific regulations for development, operation, or reclamation of a pit. There are no statewide requirements or funds for the reclamation of gravel pits in Minnesota. Sand and gravel operations, including reclamation, are most directly handled at the local government (township, city, and/or county) level. Plans for the reclamation of currently active gravel operations may be included as part of the mining plan developed by the pit operator, and may (or may not) be required by a local government. While there are no state funds for gravel pit reclamation, 28 counties administer the Aggregate Material Tax (Minn. Stat. 298.75). In these counties, 10 percent of the tax raised from current gravel operations is set aside for the reclamation of abandoned gravel pits on public land. (Source: MN DNR Land & Minerals Division).

Key Questions

- Address critical data gaps, such as:
  - » Improved quantification water consumption rates
  - » Better define the location and characteristics of groundwater resources
  - » Better understand what volume of water is renewable
  - » Understand and quantify the impacts of drainage and other land use practices on rates of recharge
- Understand and quantify the impacts of climate change on water demand and rates of recharge
- Understand and quantify the impacts of new demands on groundwater sources because of large-scale biofuel production (overlap with Energy Production & Land Use)
- Focus on geographic areas with supply and demand conflicts and evaluate resource management options
- Investigate new means to quantify sustainable supplies
- Develop the comprehensive water management framework needed to manage water supply on a long-term, sustainable basis as required by law, including the routine water resource mapping, monitoring, and assessment activities required to support the framework
- Understand and quantify the impacts of climate change on soil loss and related agricultural practices
- Address data gaps to facilitate modeling of soil erosion and loss
- Identify critical areas and regions where soil loss is greatest and can best be reduced through policy changes
- Evaluate the soil erosion and loss impacts of public policy options related to biofuels, agricultural practices, shoreland development, and land use Best Management Practices
- Map the intersection of high quality natural areas and other sensitive/unique resources and high value mineral resources
- Development of consistent mine reclamation standards and enforcement at the local, regional, and state level that balance extraction and preservation of sensitive/unique natural features for metallic (iron & non-ferrous) and industrial (sand, gravel, kaolin, etc.) mining operations.

Data Sources

- Data of water supply and demand is available through a number of federal, state, and other agencies, including:
  - » U.S. Geological Survey (USGS)
  - » MN Environmental Quality Board

- » MN Department of Natural Resources
- » MN Geological Survey (MGS)
- » MN Department of Health
- » Met Council

The most current and relevant document on this subject is from the EQB – "Use of Minnesota's renewable water resources: Moving toward sustainability": Biennial state assessment of the availability of water to meet the state's long range needs, April 4, 2007.

- The University of Minnesota, Environmental Quality Board, USGS and others have extensive Geographic Information System data that support identification of areas sensitive to soil erosion (e.g. a map is included in the Land section of the Preliminary Plan for this SCPP project). Remote sensing data and air photos, including LIDAR data, can also be instrumental for soils and crop management, as well as natural area identification and management.
- There are a variety of existing data sources directly or indirectly related to mining that can serve as resources, including:
  - » MnDNR Lands and Minerals Division, including the Hibbing Drill Core Library (one of the finest facilities of its kind in the world.)
  - » University of Minnesota - Minnesota Geological Survey and Natural Resources Research Institute Information on mineral resources. The MGS and NRRI have a wide variety of data at the local, regional, and state level on geology/mineral resources, including the County Geologic Atlas series. These data sets can be particularly helpful in GIS format, which allows cross-referencing of other GIS data (e.g. quality natural areas).
  - » United States Geological Survey has Minnesota state minerals information
  - » Minnesota Department of Revenue: The latest edition of the Minnesota Mining Tax Guide, which contains information on many aspects of mining production and taxes.

Outcomes

- To better understand:
  - » the location, extent, and characteristics of groundwater resources,
  - » new and existing demands for water from various sectors,
  - » the interaction between various public policies and their impacts on water supply and demand,
  - » the effects of climate change on water demand and rates of recharge.

Based on this understanding, recommend changes to public policies and move toward the comprehensive water management framework needed to manage water supply on a long-term, sustainable basis as required by law.

- Address research gaps and improve modeling approaches to support and estimate the impacts of recommended changes to public policies to reduce and minimize soil loss due to anthropogenic causes.
- Develop a clearer understanding of the areas where there is an intersection between high quality natural areas and other sensitive/unique resources, and high value mineral resources. Development of consistent mine reclamation standards and enforcement at the local, regional, and state level that balance extraction and preservation of sensitive/unique natural features for metallic (iron & non-ferrous) and industrial (sand, gravel, kaolin, etc.) mining operations.

Value

- The importance of water supply to human health and economic activities cannot be overstated. A 2007 EQB-DNR assessment evaluated current and future water demand, as well as renewable water resources available at the county scale. While the analysis did not take into account those waters flowing into a county, the results signal that water allocation has already become a serious issue in some locations. The results indicate that water consumption in 2005 may exceed renewable supply levels in one county and take more than half of such supplies in three other counties, all in the metropolitan region. By 2030, the same four metro counties are expected to be at or above renewable resource levels and another three in the northwest quadrant of the growth corridor well above the 50 percent consumption level.
- The importance of soil is obvious. Changes to public policy have the potential to change trends in soil loss fairly quickly. Overall improvement to the resource will take some time to be manifest.
- Understanding where the potential conflicts between mining and sensitive/unique natural features occur and proactively planning for them enables balance between the need for raw materials for human economic purposes and sustaining areas that support high concentrations of biodiversity/unique values.

Toxic Contaminants

Definition

Chemicals regulated because of human or wildlife toxicity. For our purposes, the definition of contaminants also includes Criteria air pollutants, "legacy" toxic chemicals, emerging toxic chemicals (including endocrine disruptors (EDCs) and pharmaceuticals), pesticides (includes herbicides and insecticides), and mercury.

Issue

Depending on the dose, all these chemicals can cause harmful effects in humans and wildlife. For example, mercury occurs in fish, and excess fish consumption (above that of Minnesota Department of Health (MDH) advice) places one at risk for neurotoxicity. Other contaminants can cause cancer, reproductive effects, respiratory disease, developmental and behavioral deficits, and birth defects. While we have some regulatory structure to manage many of these compounds, the emerging contaminants are of most concern since they are not regulated and the risk they pose are not fully understood. For example, we have clear evidence for estrogenic effects on fish caused by environmental estrogens in water and it is likely that other contaminants have comparable effects.

Key Questions

- Are current policies protective of public health and wildlife, i.e. are exposures to these chemicals causing excess risk to humans and to fish/wildlife?
- What policies are needed for emerging contaminants to protect the public and ecological health?

Data Sources

The Minnesota Pollution Control Agency (MPCA) has data on Criteria air pollutants; also some data on water and sediments for legacy and emerging contaminants. MDH has fish concentration data, and drinking water concentration data. MDA has data on pesticides in groundwater. USGS has data on pesticides in air, rain, water, and fish. Data gaps include actual exposures of these compounds, and effects on populations (as opposed to individual) of wildlife.

Outcomes

- » To provide a trend of contaminants over time and to compare these trends to benchmarks and/or health outcomes. Based on this research, recommend changes to:
- » agricultural policies (MDA regulates pesticides; they could also regulate animal operations for pharmaceuticals in their wastewater discharges);
- » drinking water policies (e.g. MDH can require monitoring of emerging contaminants and set max contamination levels);
- » other environmental policies under the purview of the MPCA (e.g. discharge permits for effluents containing pharmaceuticals and endocrine disruptors).

Value

High. While the state agencies collect significant amounts of data, none has compiled the "big picture" across media, or extended the overall picture to evaluate the effectiveness of state policies on contaminant exposures.

Transportation

Definition

Transportation includes infrastructure networks that enable and support personal (passenger) and commercial (freight) traffic. From the perspective of natural resources, transportation networks and the vehicles they carry directly or indirectly cause significant impacts on land, water and air.

Issues

In 1900, there was a total of 11 miles of paved highways in the United States, all of which were on the east coast. After World War II, widespread economic prosperity, relatively inexpensive fuel and new lifestyle choices enabled people to choose greater distances between work, home and other needs such as the grocery store – the new scale of human life was now measured by the automobile.

This has resulted in a remarkable expansion of transportation networks to accommodate increasingly longer and more frequent vehicle trips. Over the course of the last 100 years in Minnesota, the transportation network has expanded to meet the needs of urban and agricultural economies, as well as the desire to recreate and build second homes closer to "wilderness".

Expansion of transportation infrastructure has also directly or indirectly resulted in substantial alteration of natural areas, including the fragmentation of land/habitat, alteration of natural water movement, and other affects. For example, vehicular traffic is responsible for significant contributions to particulate and greenhouse gas pollutant loads. Passenger cars and light trucks account for about 2/3 of all emissions. Every gallon of gasoline burned produces almost 20 pounds of CO_2. According to the Environmental Protection Agency (EPA), the average minivan emits almost 16,800 pounds of CO_2 into our air each year.

Vehicle miles of travel (VMT) are also increasing. According to the US Environmental Protection Agency between 1996 and 2007, VMT and related emissions increased by a factor of 25%. In the United States and in Minnesota, cars and light trucks emit 25% of the human-caused CO_2 emissions (estimated to be 81% of all greenhouse gas emissions) as well as a suite of other contaminants related to the combustion or partial combustion of fuels. This growth in emissions is projected to triple by 2030. (Source: http://www.epa.gov/ttn/naaqs/ozone/areas/vmt/vmtmngf.htm.)

general characteristics of types of transportation and vehicles:

- Cars and trucks generally carry 1 - 6 on a fixed network of roads independently to numerous destinations.
- Commercially-operated trucks move 2 or more tons freight on the same network in a relatively systematic scheduled pattern.
- The majority of buses in operation are diesel powered and run on relatively fixed routes and schedules, carrying 1 -100 people.
- While recent improvements to diesel engines have allowed retrofits to occur in some metropolitan systems, not all Minnesota systems can afford these cleaner and more fuel efficient busses.
- Light and heavy rail transportation carry 1 - 100 people by diesel and electric power on a fixed track network running on integrated schedules to a fixed and relatively limited number of destinations.
- Air traffic creates carbon, hydrocarbon, and particulate matter emissions in the air and nearby water bodies. Airport areas also generate noise and vibration impacts.
- Motorized water travel includes both passenger and freight modes:
  - » Motorized recreational watercrafts have wave surface water impacts and contribute to shoreland erosion.
  - » Boaters also bring invasive exotic species such as Eurasian milfoil which impacts fish and aquatic plant life
  - » Water freight service potentially transports invasive species to the Mississippi River and Lake Superior, which are critical continental transportation corridors that provide access to both aquatic and marine environments.

Research Questions

While one can look at many things related to transportation since its impacts are so pervasive, our questions focus on the following areas: greenhouse gas emissions related to road transportation; other land and air based issues in relation to 2020 benchmarks (items 1-5 following); and the issue of water-based transportation enabling the introduction or expansion of invasive species (item 6 below).

- Comprehensive Policy
  - » Are emissions reduction benchmark goals sufficiently supported by other transportation policies to realize expected reductions and their associated benefits?
- Fuels Fix
  - » Will it be sufficient to provide an ecological 'fuels-fix' (e.g. the adoption of subsidies for cellulosic fuel production from perennial polycultures such as prairie/Conservation Reserve Program lands and the stabilization or reduction of subsidies for corn-based ethanol) by the time of the benchmarking in 2020? Will the public and commercial vehicle owners replace their vehicles soon enough to enable widespread use of that are adapted to the use of new fuels?
  - » Will newer vehicle or fuel technologies such as plug-in hybrids have greater or lesser overall benefits (e.g. mercury-based technological challenges to recycling) for ecological, land and hydrological conditions?
- Integrative Scenarios – Beyond Fuels
  - » What other scenarios need to be assessed relative to integrative changes to re-balance in the transportation infrastructure, that would support the achievement of these CO2 and other emissions reductions and also realize composite enhancement to the environment and public health intended

by the adoption of the benchmarks? For example, in the current context of climate change and enlarged populations moving over networks, can these benchmarks be met without transit-enhanced, and logistics-controlled freight policies?
    - » If benchmarks are met, will these reductions allow for the adaptation of resources to maintain ecological and human health, while preserving access, freight service, and mobility? Or is it necessary to examine some measure of integrated planning and design for efficiency and a targeted reduction in resource consumption?
- Climate Change, Growth, Adaptation, Mitigation
    - » What policies are needed to examine the impacts of expanding the roadway transportation network and enlarging transportation corridors in the context of adaptation and species conservation vs. mitigations of species movement?
- Modal Mix – Fuel for the movement of the many from the network
    - » What role can transit, especially in metropolitan areas and especially fixed rail and non-gasoline/electrically-powered modes/vehicles, play in reducing all environmental impacts stemming from the increase in vehicle miles of travel (VMT) that is part of urban and suburban growth, both on greenfields and in existing neighborhoods and communities?
- Continental and International Transport: Invasive Species
    - » What (if any) new policies, monitoring, or enforcement are needed to control interstate and international transport of invasive species into the Mississippi River and Lake Superior?
    - » What issues relative to transport of invasive species are emerging as result of changing regional and global economies?

Data Sources

MnDOT has data on centerline VMT for certain classifications of roadways based upon land coverage data and other research about urbanization and road construction. We may be able to model VMT for roadways and streets not measured by types and acres of urbanization. VMT trends are organized by county by the US EPA for Ozone depletion estimates. http://www.epa.gov/ttn/naaqs/ozone/areas/vmt/vmtmngf.htm. http://www.mnclimatechange.us/ewebeditpro/items/O3F11914.pdf (Minnesota emissions data based on FHWA Highway Statistics).

Outcome

- To identify or create transportation modeling protocols and outline the factors needed for modeling.

Value

High. The value of conducting this research will be very high if the research results in clear policies and implementation strategies on a statewide level and in key areas where transportation infrastructure and the environment are vulnerable.

Energy Production and Land Use

Definition

Human activities related to the extraction, production and consumption of energy, including fossil fuels and renewable energy sources.

Issue

Energy extraction, production and consumption have an important influence on natural resources in Minnesota. Fossil fuel derived energy is a major contributor of carbon dioxide (a greenhouse gas) and other pollutants that influence climate change, as well as nutrient loading, and air quality issues. In turn, energy-related by-products influence human health, the condition of natural areas, and fish and wildlife they support. As humans continue to consume a finite and diminishing amount of fossil fuels, biofuels such as cellulosic ethanol are being considered among the alternatives to partially replace them. Commercial demonstration of cellulosic ethanol is expected by 2012, with cellulosic ethanol viewed as the only viable alternative to replace 30% of current U.S. petroleum use (Source: National Renewable Energy Laboratory).

However, there is much that we do not know about the potential influence of the type and extent of biomass cropping systems and renewable energy production on Minnesota's natural resources and recreational opportunities. Important questions need to be answered in order to properly plan for these changes. Minnesota is in a unique position as a leader in biofuel research and development of diverse perennial cropping systems and to lead the nation in maximizing multiple benefits from this new opportunity.

Key Questions

- What are the potential effects of biomass energy production systems on Minnesota's fish, wildlife, land and water resources, and recreation opportunities? Including:
  - Monoculture stands (native or nonnative species)
  - Diverse perennial cropping systems, especially diverse prairie plantings
- What are the effects of renewable energy production structures such as large wind turbine (farms) and related infrastructure on wildlife?

Data Sources

Biomass and other sources of renewable energy are receiving dramatically increased attention in recent years. Biomass and biofuels research is evolving quickly, resulting in rapid changes in knowledge and available technologies. The University of Minnesota Initiative for Renewable Energy and the Environment (IREE) was launched in 2004 and serves as a center point for data and research in the upper Midwest. Dr. David Tilman from the U of MN has also conducted important research into the multiple benefits of utilizing diverse prairie plantings for biomass fuel production and carbon sequestration. Likewise, the U. S. Department of Energy National Renewable Energy Laboratory (NREL) conducts research, funds pilot projects, and compiles existing data on renewable energy subjects.

Numerous studies document that wind turbines cause direct mortality of birds and bats through rotor (blade) strikes. However, the indirect impacts of wind turbines, as well as utility tower structures on grassland wildlife mortality (e.g. wind turbines providing aerial predator perches) or avoidance of otherwise suitable habitat appears to be poorly understood. Pending improved research, the U.S. Fish & Wildlife Service published Interim Guidance for Avoiding & Minimizing Wildlife Impacts from Wind Turbines (2003): http://www.fws.gov/habitatconservation/wind.pdf .

Outcomes

- To gain a clearer understanding of potential biomass cropping systems and wind energy production on Minnesota's natural resources, recreational opportunities, and climate change. Fully achieving the potential multiple benefits of biofuels will also require consideration of economic benefits, as well as adaptation of the state's infrastructure network and policies.
- Through monitoring of wind turbine/farms constructed in planted grasslands and/or remnant prairie, it could be determined whether they influence grassland bird species mortality (by providing aerial predator perches) and/or cause avoidance by wildlife of otherwise suitable habitat (effectively fragmenting habitat).

Value

High. The value of this research is high since the potential for multiple benefits to Minnesota's natural resources appears to be remarkably significant. Strategically planting perennial cover has the potential to greatly benefit land, water, fish, and wildlife in the state and provide expanded recreational opportunities in addition to producing fuel and fostering economic vitality.

Invasive Species

Definition

Undesirable aquatic and terrestrial species, accidentally or intentionally introduced into Minnesota, that either disrupt native plants, animals and their habitat, or are a nuisance to human activities. Serious invasive species in the state span many taxonomic groups, including terrestrial and aquatic plants, insects and aquatic invertebrates, fish, and pathogens.

Issue

Invasive species are a growing threat to Minnesota's fish, wildlife, and land resources. Some invasive species displace or kill native species and others become so dominant in aquatic or land habitats that they degrade habitats of desirable species.

Prevention, eradication and control are the three main options for addressing this issue. It is extremely difficult to prevent entry of new invasive species into the state and also quite challenging to stem the spread of new invaders within the state. It is rarely possible to eradicate a new invader. Methods for environmentally sensitive, effective and affordable control of established invasive species are few and usually require long-term commitment of financial and human resources.

Invasive species tend to be more successful than native species in disturbed environments. Therefore, other drivers of change discussed in the Preliminary Plan can exacerbate invasive species problems. For instance, climate change may increase the spread and harmful effects of invasive species. Other issues we might investigate in the Final Plan, such as habitat fragmentation, degradation, and loss, would also relate to the spread and impacts of invasive species.

Key Questions

- How can Minnesota strengthen current efforts to prevent the entry of new invasive species into the state?
- What are policy options for reducing the spread of invasive species within Minnesota? Work on this question should focus on major pathways of spread.

Data Sources

DNR and MDA databases on occurrence of invasive species include: DNR—aquatic invasive species, terrestrial invasive species (mostly plants), and the agency keeps track of sightings of terrestrial invasive animals; MDA—terrestrial invasive plants (extensive for noxious weeds, now adding emerging weeds), and terrestrial invasive insects. DNR has been collecting occurrence data on state managed lands, with the data most complete now for state parks and trails and much left to collect for state forests (i.e., the majority of state managed acreage) and wildlife management areas. State parks and trails are beginning to use existing data to develop invasive species management plans. General pathways of spread are known for many invasive species, state agencies have limited data on pathways (e.g., DNR water craft inspections), and the federal Animal and Plant Health Inspection Service (APHIS) maintains some information on pathways for weeds and insects. For invasive species that may enter the state through the Great Lakes, Minnesota Sea Grant has major programs on public education, reporting of new invaders, and monitoring of federal policy developments. A major gap is the lack of statewide data on total public and private annual expenditures to control invasive species and economic value of harm they cause to natural resources.

Outcome

- Recommend changes to policies and outreach efforts to reduce entry and spread of invasive species.
- Recommend priorities for improving data collection on economic impacts and pathways of spread.

Value

High. A fresh look at state-wide policy options would help address the rapidly growing frustration that current efforts are failing to reduce entry and the in-state spread of invasive species. This would complement fundamental scientific research, funded by a variety of agencies, on new methods for environmentally sensitive control of established invasive species.

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