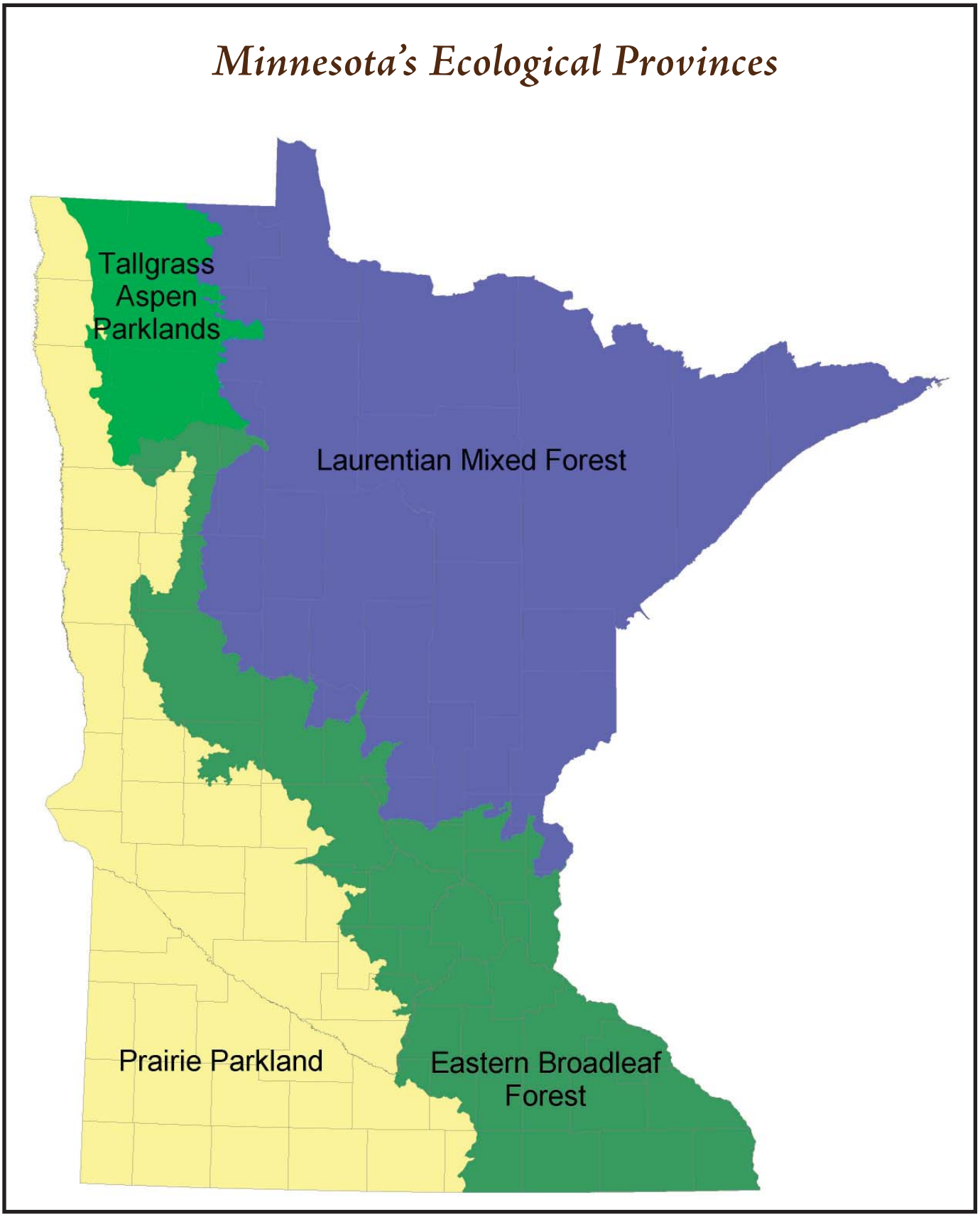

Figure 1: Minnesota is fortunate to contain parts of four major ecological provinces, with a resulting greater diversity of wildlife species than many similarly-sized neighboring states. Credit: Terry Brown, University of Minnesota.

"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,

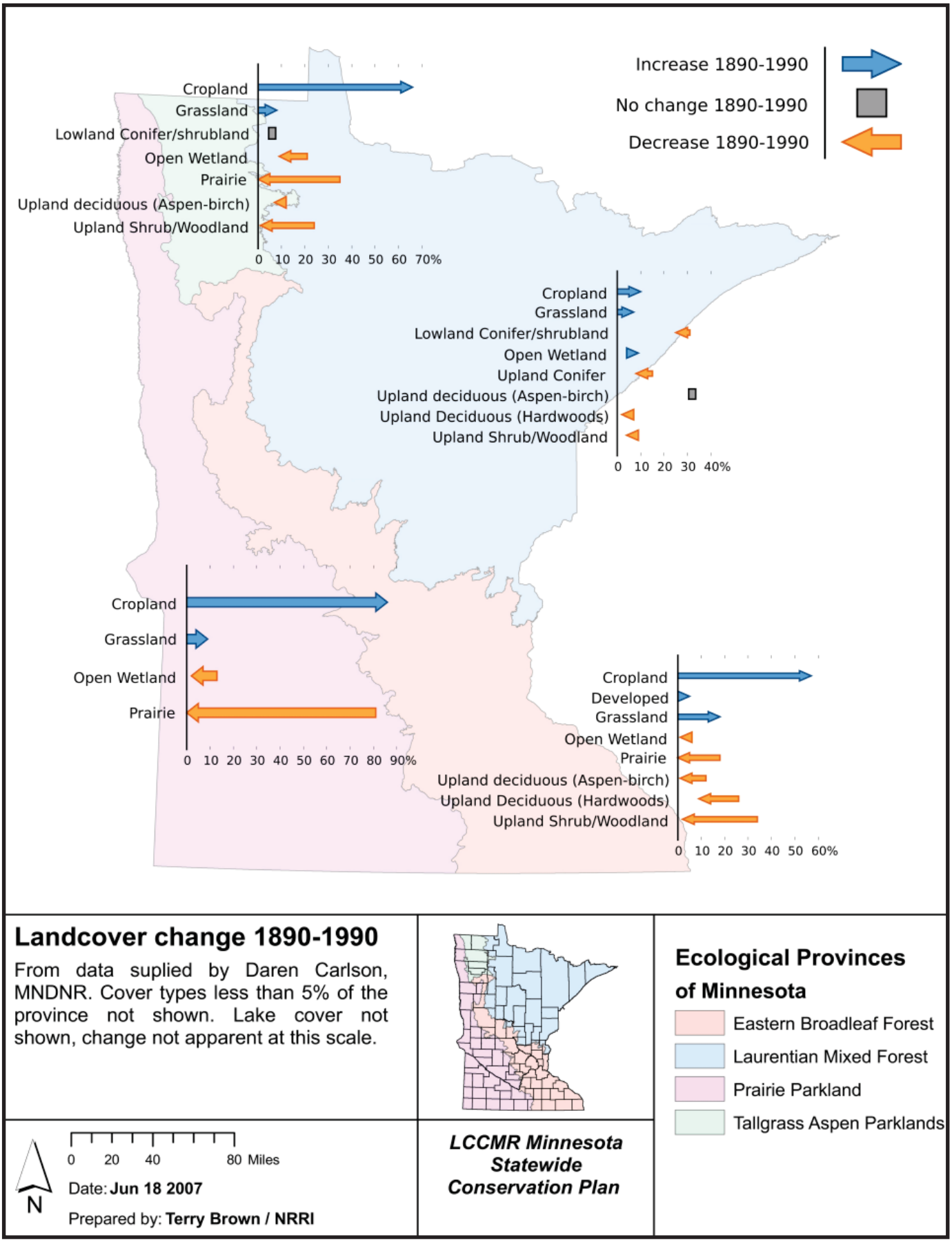

Figure 2: Landcover change 1890 - 1990. Credit: Terry Brown, University of Minnesota.

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.

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

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 **agriculture, 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.

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

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.

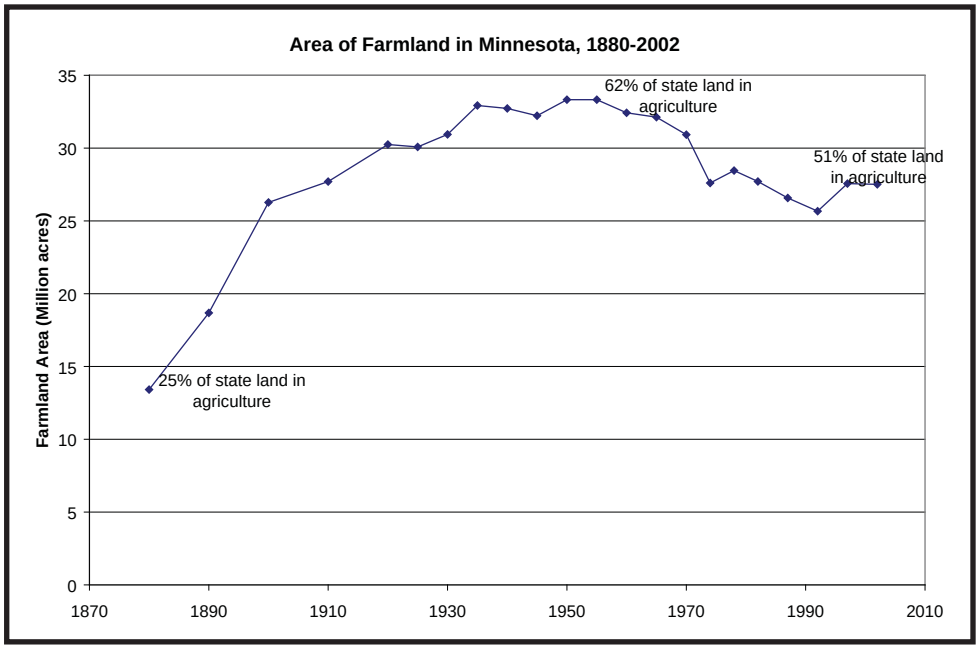

Figure 5: Area classified as farmland in Minnesota. Credit: Laura Schmitt, University of Minnesota

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.

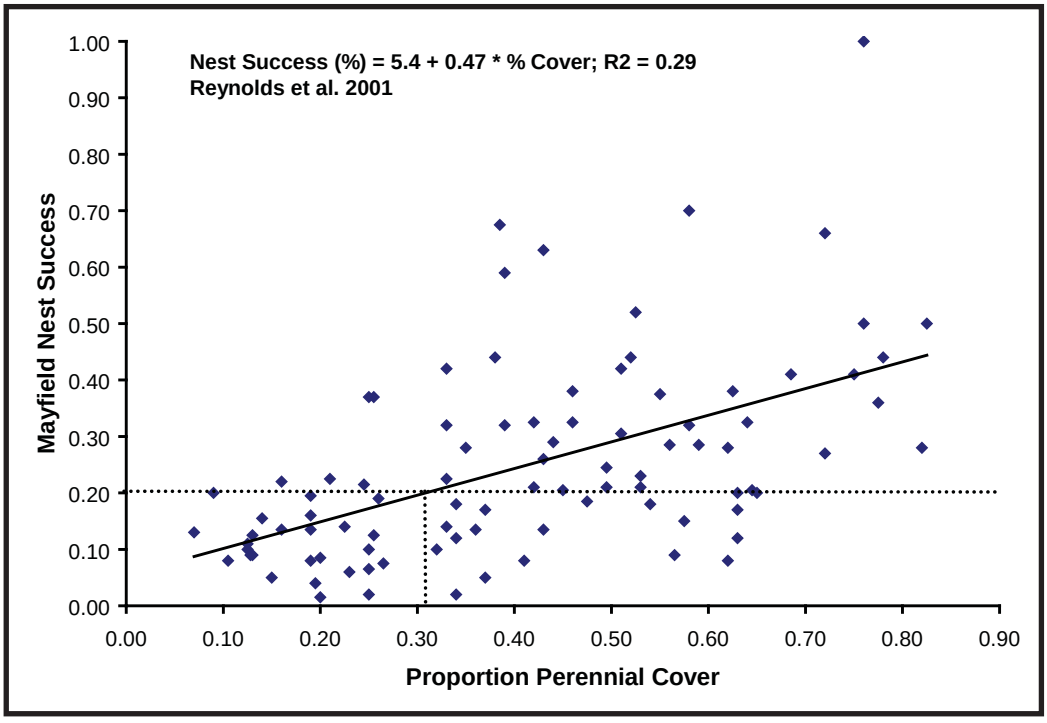

Figure 6: Nesting success of dabbling ducks as a function of % perennial cover in the surrounding 2 x 2 mile landscape in ND, SD, and MT. Credit: Reynolds et al. 2001

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.

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

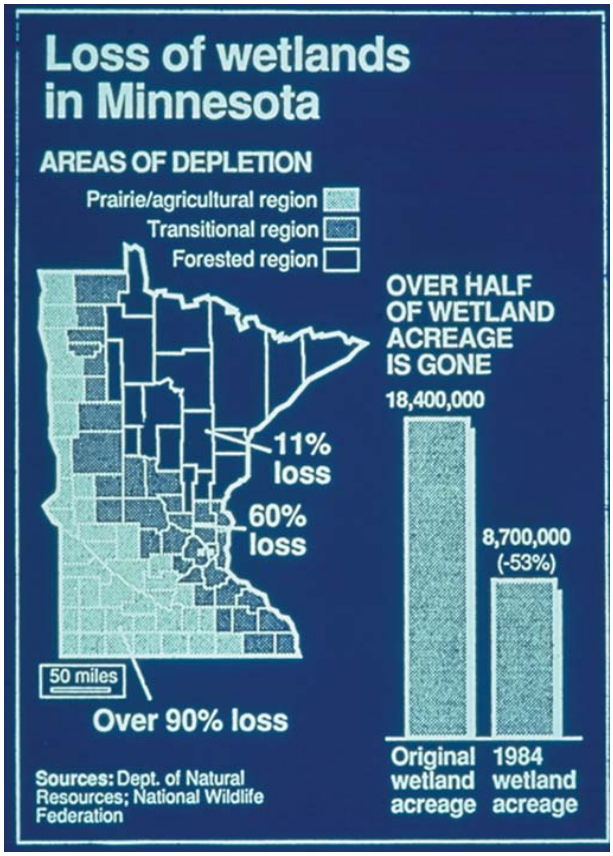

Figure 7: Wetland losses in Minnesota since Euro-American settlement times. Note that prairie losses are 90%. Credit: Minnesota DNR and National Wildlife Federation

habitat 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

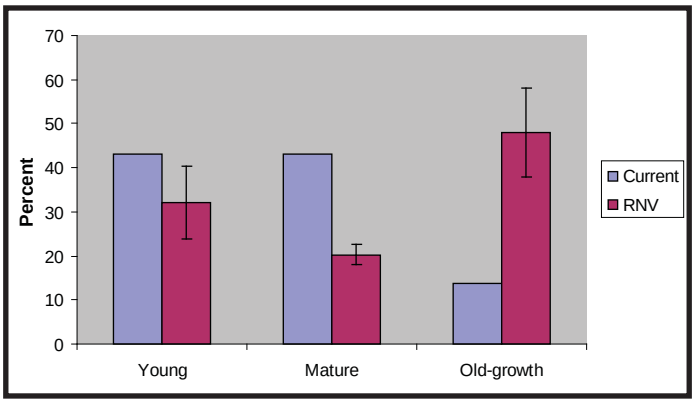

Figure 9: Percentage of forest by age class, current vs. range of natural variation (RNV). Credit: Minnesota DNR.

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

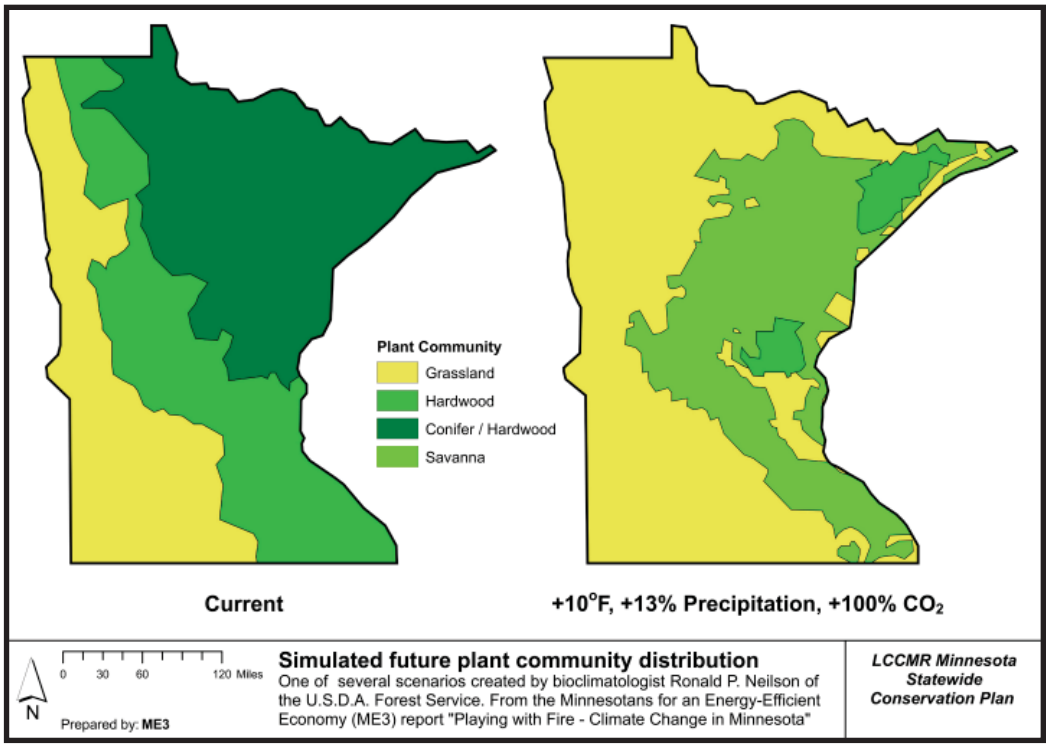

Figure 11: This map projects what Minnesota vegetation cover might look like if average temperatures in the state rise 10 degrees Farenheit and precipitation increases 13% at double historical CO2 levels. This is one of several scenarios created by bioclimatologist Ronald P Neilson of the U.S.D.A. Forest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

Figure 12: Bobolink on the prairie. Credit: Anonymous

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.

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