Chapter 3: Refuge Environment and Management

In this chapter:

Introduction

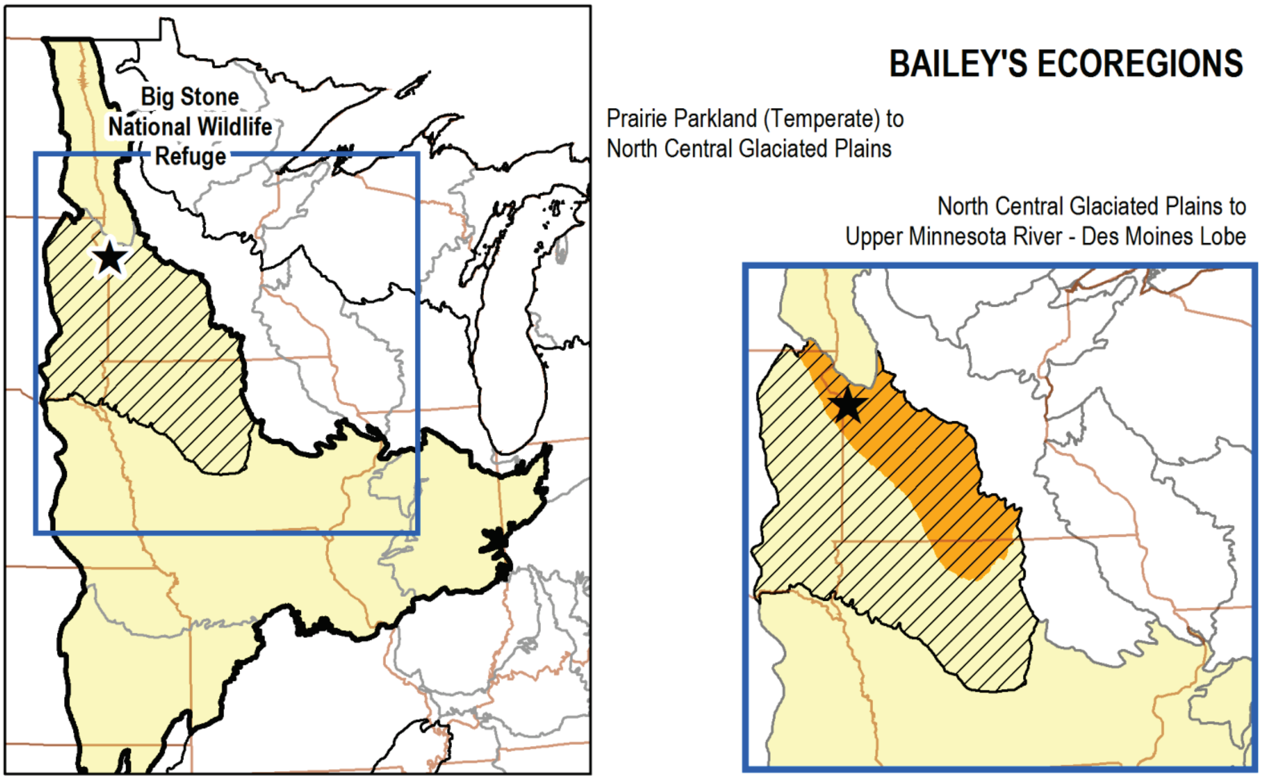
The Big Stone National Wildlife Refuge (NWR, Refuge) straddles the Minnesota River near its headwaters in west-central Minnesota, encompassing more than 11,500 acres of wetlands and grasslands dotted with granite outcrops that give the Refuge its name. Most of the Refuge is within Lac Qui Parle County with a little more than 1,000 acres in Big Stone County (see figure 1-1 in chapter 1). This chapter describes the environmental resources of the Refuge and its surrounding ecosystem.

Ecosystem Setting

An Ecological Classification System was developed by the Minnesota Department of Natural Resources (DNR) and the U.S. Forest Service for ecological landscape classification in Minnesota following the National Hierarchical Framework for Ecological Units. Four provinces (ecoregions) are identified for Minnesota. Provinces are units of land defined using major climate zones, native vegetation, and biomes. Big Stone NWR is within the Prairie Parkland Province (figure 3-1). The province traverses western Minnesota, extending northwest into Manitoba, west into North Dakota and South Dakota; south into Iowa, Nebraska, Kansas, Oklahoma, and Missouri; and east into Illinois and Indiana. In Minnesota, the province covers just over 16 million acres (6.5 million hectares), coinciding with the part of the State historically dominated by tallgrass prairie. Low winter precipitation, short duration of snow cover, and desiccating westerly winds promote severe spring fire seasons that favor grassland over forest vegetation. The land surface of the province was heavily influenced by glaciation. Ice sheets crossed the province several times during the Wisconsin glaciation. The last lobe of ice, the Des Moines Lobe, deposited calcareous drift in the southern part of the province.

The province is divided into two sections (Red River Valley and North Central Glaciated Plains). The Red River Valley lies in the north end of the province. The Refuge is in the North Central Glaciated Plains section (figure 3-1). The largest portion of this section is a level-to-rolling region of calcareous till deposited by the Des Moines Lobe. This region is bisected by the deeply incised Minnesota River Valley. The section also contains a highland region known as the Prairie Coteau, which flanks the southwestern edge of the Des Moines Lobe in Minnesota, South Dakota, and Iowa. The Prairie Coteau is covered with glacial till and loess predating the Wisconsin glaciation. Level-to-rolling till plains, moraines, lake plains, and outwash plains cover much of the section and supports mainly treeless fire-dependent communities, with upland prairie communities by far the most common, covering 82 percent of the section. These landforms also support smaller amounts of marsh, wetland prairie, and wet meadow communities. Rugged terrain and lands deeply dissected by rivers support a mosaic of prairie and wooded communities.

Figure 3-1: Ecoregions—North Central Glaciated Plains Section



The North Central Glaciated Plains section is further subdivided into three subsections (Coteau Moraines, Inner Coteau, and Minnesota River Prairie). The Refuge is located within the Minnesota River Prairie subsection, which consists of a gently rolling ground moraine about 60 miles wide. Most of this subsection is covered by 100 to 400 feet of glacial drift (Olsen and Mossler, 1982). Cretaceous shales, sandstones, and clays are the most common kinds of bedrock. The Minnesota River Prairie is drained by the Minnesota River, which splits the subsection in half. Smaller rivers and streams eventually empty into the Minnesota River or the Upper Iowa River. The subsection drainage network is poorly developed due to thousands of wet depressions or potholes that dot the landscape. Wetlands were very common before settlement. Most have been drained for cropland.

Historic Vegetation and Processes

The presettlement vegetation was primarily tallgrass prairie, with many islands of wet prairie (Kratz and Jensen, 1983; Marschner, 1974). Portions of the Big Stone Moraine supported dry and dry-mesic prairie (Wheeler et al., 1992). There were also dry gravel prairies. At the time of European settlement, the region was covered with dry mixed-grass and mesic tallgrass prairie. Trees were uncommon in the region, but there were narrow river-bottom forests and oak woods along the major river valleys and small patches of woodland in fire-protected areas (peninsulas, islands, isthmuses) at major lakes like Big Stone Lake and Lake Traverse. Only two wooded locations on the lands that now make up Big Stone NWR were identified and mapped during 1853-1874 (Marschner, 1974). These included a small wooded area near the Refuge headquarters and along the Yellow Bank River south of Lac qui Parle County Highway 40.

Grasslands were maintained by periodic drought, fires, and grazing by large herds of herbivores such as bison. Fires were ignited by both lightning and Native Americans. Lightning-set fires occurred primarily in July and August (Higgins, 1984), while Native American-set fires occurred both in the spring and the fall, with peaks in April and October (Higgins, 1986). Native Americans used fire for the purposes of hunting, signaling and communicating, threats, warnings, warfare, aiding theft, improving pasturage, attracting and herding wild animals, enhancing travel, masking and eliminating personal signs at camps and along trails, ceremonies, and pleasure (Higgins, 1986). The amount of vegetation available to burn was heavily influenced by bison (Higgins, 1986). Umbanhowar (1996) postulates how the elimination of bison prior to European settlement resulted in high fuel loadings, which is reflected in the peak of microscopic charcoal found in lake sediments dating to the period immediately preceding settlement. Regardless of the ignition source and the amount of fuel available, numerous personal accounts exist dating from the French exploration period of the late 1600s to the settlement era of the late 1800s/early 1900s telling of very frequent or even annual prairie fires (Higgins, 1986; Sparrow, 1981; Wulff, 1959; Dale, 1916). The same sources that described the frequency of the fires also told of the impact the fires had on vegetation composition, specifically how frequently occurring fires would prevent the growth of trees in the grassland. These forces created mosaics of habitat ranging from heavily disturbed to undisturbed (England and DeVos, 1969).

Aerial view of the region

Innumerable depressions were left when the glaciers retreated. These wetland basins, called prairie potholes, contain water for various lengths of time in most years (Stewart and Kantrud, 1971). The most ephemeral wetlands hold spring runoff or summer rains for only a few days. At the other extreme are lakes, which almost never go dry. In between are seasonal wetlands, which in a typical year contain water from early spring until mid-to-late summer, and semi-permanent wetlands, which in most years are wet throughout the frost-free season. Less common are alkali wetlands—large, shallow basins with such high alkalinity that salts are blown out when the wetland is dry, and where no emergent plants grow when it is wet. Another unusual wetland type is the fen, characterized by floating or quaking mats of vegetation caused by groundwater seepage. Different wetland types support different kinds of vegetation and, in turn, different animal communities (Johnson, 1996).

Critical to understanding the prairie is recognizing its dynamic nature, particularly as driven by recurring droughts. Prairie occurs primarily under semi-arid conditions. Precipitation is generally inadequate for growth of most woody vegetation, and the herbaceous vegetation favored fires and supported large herds of grazing herbivores, both features that further discouraged woody growth. Drought is essential to wetlands as well as uplands. The periodic drying of wetland basins facilitates nutrient cycling and results in high productivity when water returns (Murkin, 1989).

Since settlement much of the grassland habitats have been cultivated for crops. Less than one percent of the native tallgrass prairie remains in scattered fragments across the region (Samson and Knopf, 1994; Noss et al., 1995). Less mixed-grass prairie has been cultivated for crops. This is largely because the terrain is rougher and precipitation is lower and less predictable where mixed-grass prairie is found. However, irrigation has in many places rendered lands more suitable to cultivation. Corn, soybeans, sunflowers, and potatoes are the dominant crops.

European settlement brought major increases of woodlands. Tree claims were planted to protect farmsteads from the ever-present winds, and shelterbelts were established along field borders to reduce soil erosion, especially after the drought of the 1930s. Also, inadvertent increases of woody vegetation resulted from fire suppression by settlers (McNicholl, 1988).

Prairie wetlands, likewise, have been altered in a number of ways. Prairie wetlands may have fared better than uplands in the early stages of European settlement, but as population density increased and drainage techniques were improved and encouraged, many potholes were incorporated into the agricultural effort. In general, prairie wetlands were seen as undesirable, unproductive wastelands that needed to be reclaimed and improved. In the late 1800s it was still believed that wetlands released disease-causing gases, a belief that persisted into the twentieth century. Wet prairie regions were desirable for settlement, as they were flat, generally did not need to be cleared, and, once drained, could be agriculturally valuable. Drainage of basins to facilitate cultivation was very common. Sometimes several small wetlands were drained into a larger one, which eliminated the smaller wetlands and altered the hydrology of the receiving wetland. The Minnesota DNR estimates that over 90 percent of the wetlands in the prairie have been lost since settlement times. Smaller, more temporary wetlands were more susceptible to drainage than were the larger, more permanent basins. Since European settlement the landscape has become highly altered and fragmented to the detriment of prairie habitats and the wildlife populations that depend on them. The prairie wetlands that remain, like the remnant prairie grasslands, are tiny islands in a sea of agriculture and are invariably influenced by the surrounding land management practices.

Physical Environment

Geology

The upper reaches of the Minnesota River Valley have an interesting geological history. Glacial activity was the vector for landform creations in this geographic area.

The last ice age ended about 20,000 years ago, but during its peak, the massive Laurentide ice sheet covered over 5 million square miles of North America and stretched from the Arctic through eastern Canada to the northern half of the United States. One of the lobes of the ice sheet called the Des Moines Lobe blanketed portions of western Minnesota and extended down to Des Moines, Iowa. As temperatures warmed, the ice sheet began to melt, and as it receded a huge lake was formed, called Lake Agassiz. Lake Agassiz may have been the largest freshwater lake to ever have existed.

When the lake levels rose, Lake Agassiz would overtop the glacial moraine at its south boundary and flow southward. Approximately 9,000 years ago, these torrents of water called the Glacial River Warren eroded down through the landscape and created the Minnesota River Valley. At maximum size and depth, the River Warren was 2 miles wide and 130 feet deep. As the river cut down through the landscape three terraces were created. These terraces are better developed on the north side of the river valley. As waters receded, sediment dropped out and large granite boulders were left behind. The lowest terrace has the most spectacular boulder field. Over time water elevations in Lake Agassiz diminished, and the flows were cut off near Browns Valley, MN. Only a remnant of this great glacial river remains and is now called the Minnesota River. The river valley is 1.5 miles wide on the west end of the Refuge and 4 miles wide on the east end.

The extensive erosion also exposed the granite bedrock in several areas. The granite bedrock "granite outcrops" in this valley is of Precambrian origin and is estimated to be approximately 2.7 billion years old. These "crystalline" rocks first formed as igneous rocks from molten magma that cooled very slowly deep below the earth's surface billions of years ago (Grant, 1972). Once formed, these early rocks underwent extreme heat and pressure over the next 1 to 1.5 billion years, which altered their crystalline structure and transformed them into metamorphic "gneiss and biotite" rock (Minnesota County Biological Survey, 2007).

Lichens quickly covered the exposed granite outcrops. Over time thin layers of soil formed on portions of the granite outcrops, which created conditions for the establishment of plants. However, because of the thin soils (0.5 to 3 inches), only certain types of plants can grow in this unique habitat. The vegetation on the outcrops consists of remnant native shortgrass prairie plant species.

On both sides of the river valley vast plateaus existed that were reshaped. Thousands of small wetlands (prairie potholes) were created as the glaciers receded. The small wetlands were highly productive and helped sustain the historic migratory bird populations.

Climate

The climate in Big Stone and Lac qui Parle Counties is temperate and is characterized by warm-to-hot summers and cold winters. Average annual precipitation is 24.08 inches, with about 63 percent falling during the growing season. The annual average snow fall is approximately 40 inches. Summer temperatures average 81.6 ºF with occasional highs above 100 ºF (maximum recorded temperature of 108 ºF). Daylight winter temperatures average 20 ºF with occasional lows below -30 ºF (minimum recorded temperature of -36 ºF). Winds average about 12 miles per hour but have been noted greater than 40 miles per hour in any month of the year. The growing season varies annually from 110 days to 140 days. The first killing frosts occur in late September to mid-October, and the soils usually freeze in late November.

Winter on the Refuge

Climate Change

The increase of carbon dioxide and other greenhouse gasses in the earth's atmosphere resulting from the burning of fossil fuels has been linked to the gradual rise in surface temperature, commonly referred to as global warming. In addition to rising air and water temperatures, there are a number of other effects associated with a changing global climate including intense heat waves; shrinking permafrost zones, winter snow cover, sea ice, and glaciers; ocean acidification; changing precipitation patterns and associated effects on water availability (drought, flooding); a general decrease in open water areas and soil moisture levels; increasing fire severity—intensity, extent, and frequency; migrating plant productivity and agricultural zones; habitat shifts at all scales from ecosystems and biomes to specific sites; dislocation of species as habitat ranges experience shifts, reductions, and/or expansions; increasing issues with plant and animal pathogens and pests—both exotic and endemic; and more.

Several examples of potential climate change impacts on wildlife have been identified. The following are just a few issues that may require further attention as climate change progresses (Green et al., 2000; Schneider and Root, 2002).

- Habitat available for coldwater fish such as trout and salmon in lakes and streams could be reduced.
- Forest distributions and compositions may change, with some species shifting their range northward, higher in altitude, or being replaced as other tree species move in to take their place.
- Ducks and other waterfowl could lose breeding habitat due to more severe and frequent drought events.
- Changes in the seasonality of life cycle stages such as migration and nesting could put some animals out of sync with the life cycles of their prey species.
- Herpetofauna may have trouble meeting the moisture conditions required for reproduction and respiration in their local habitats, and they may have difficulty dispersing through inhospitable environments.
- Animal and plant species, including invasive or pest species, shift their ranges north in latitude as winter climatic conditions become more moderate and the warm seasons lengthen.

The resiliency of natural systems is tied to biodiversity. The diversity of organisms may be one of our greatest weapons against climate change; each organism will react and respond differently (Scott et al., 2009). Biological communities will not shift or remain intact because of the variability in each organism's sensitivity to climate change, size, mobility, lifespan, and the availability of food, shelter, and other resources it requires (Karl, Melillo, and Peterson; 2009). In response, we must assess and provide for increased representation and redundancy across seasonal, geographic, and ecologic thresholds. Initial prioritization of action should be directed to those species for which climate change poses the greatest threat, namely those with limited distributions, highly specific ecological niches, and/or limited mobility. These include plants and animals that are highly temperature-sensitive or are confined to high altitudes or polar areas (Scott et al., 2009).

The U.S. Department of the Interior (DOI) issued Secretarial Order Number 3226 in January 2001 requiring all federal agencies with land management responsibilities within the DOI to consider potential climate change impacts as part of long-range planning efforts. This report was amended in January of 2009 to further expand and define bureau climate change, carbon sequestration, and energy conservation responsibilities.

In its strategic plan, *Rising to the Urgent Challenge: Strategic Plan for Responding to Accelerating Climate Change*, the U.S. Fish and Wildlife Service (FWS, Service) calls for bold and strategic action to address climate change through three broad, over-arching strategies: adaptation, mitigation, and engagement (FWS, 2010b). Despite considerable uncertainty regarding the magnitude, extent, and timing of changes, the Service vision includes measures to " . . . sustain diverse, distributed, and abundant populations of fish and wildlife through conservation of healthy habitats in a network of interconnected, ecologically functioning landscapes (p.5)." The plan also describes six principles deemed essential to achieving this vision: priority setting, partnership, best science, landscape conservation, technical capacity, and global approach. Climate change is a key consideration in the discussions and decisionmaking for the future management proposed in Big Stone NWR's Comprehensive Conservation Plan. Climate change is likely to have major impacts on larger river systems like the Missouri River through altered flow cycles, groundwater recharge within the watershed, water availability, land cover change, habitat availability, effects to infrastructure, and so forth.

Mitigation and Adaptation

According to the 2009 report, *Global Climate Change Impacts in the United States* there are two broad categories of responses to global climate change: mitigation and adaptation. Mitigation refers to actions taken before change occurs—efforts to reduce climate change as we move forward from the present and curb its effects before they increase in severity or reach critical thresholds. Adaptation measures can be applied both before (anticipatory) and after (reactive) climate changes have occurred and are actions aimed at avoiding or coping with harmful impacts and taking advantage of new opportunities presented by new climatic and environmental conditions (Karl, Melillo, and Peterson, 2009; FWS, 2009b).

There are many ways that refuges help mitigate the onset of climate change by increasing our ecological resiliency and reducing environmental stressors. Refuges will also play a critical role in adaptation strategies in the future. The table below (3-1) lists a number of examples in which refuges may contribute to climate change mitigation and adaptation.

Table 3-1: Refuge Contributions to Climate Change Mitigation and Adaptation

Challenge Associated with Climate Change	Refuge Mitigation/Adaptation Potential
Rising ambient air temperatures caused by increasing greenhouse gasses	Sequester carbon in vegetative biomass and serve as 'sinks' for greenhouse gasses. Move towards agency-wide carbon neutrality. Contribute to renewable energy development efforts.
Increased water temperatures from solar radiation	Manage for forest canopy adjacent to waterways.
Changing precipitation frequency and intensity, leading to flooding or drought	Provide floodplains as protection against surges and reservoirs to buffer periods of drought. Enhance wetland and bottomland habitats for groundwater recharge and to filter waterborne pollutants (fertilizers, pesticides, excessive sediment).
Disrupted ecological processes that sustain basic life support functions	Tailor refuge management to protect or, if necessary, restore essential ecological processes and services such as pollination, seed dispersal, soil formation and stabilization, primary production, photosynthesis, and air, water, and nutrient cycling.
Rising sea levels and increasing tropical storm intensities	Buffer coastal areas with natural cover-types to minimize socioeconomic losses as waters advance inland and storms pass from the oceans onto land.
Changes in wildfire frequency and intensity	Use controlled burn programs to reduce fuel loads on the refuge, and provide trained fire professionals to off-refuge areas in need.
Loss of species and their required habitats	Protect lands with a diversity of habitats for declining species and spearhead efforts to protect species of concern. Protect genetic diversity and serve as a source area for repopulation efforts.
Geographical shifts in biomes and species' ranges	Serve as large ecological hubs in a greater network of conservation lands allowing for species migration.
Altered species phenologies and interactions (competition, predations, parasitism, and disease)	Provide natural, minimally-altered settings for the evolutionary process and wildlife interaction.
Advancement of exotic invasives, pest species, pathogens, and contaminants	Manage to control and eradicate invasives on refuge lands, providing habitat for endemic species. Direct efforts to reduce species susceptibility to disease, pathogens, pests, and contaminants.
Limited scientific understanding of long-term climate change implications	Develop inventory and monitoring sites for ecological and climatic variables. Conduct directed research to address climate change topics. Continue to build scientific capacities and expertise in the agency. Foster collaboration among conservation science community.
General lack of knowledge and understanding regarding climate change	Increase climate change education, training, and outreach both within the agency, and to external audiences. Tailor environmental education and interpretation programs to climate change topics. Provide conservation support to partners and other interested parties. Collaborate and share information and resources both internally and externally.
Inadequate legal, regulatory, and policy framework to address climate change	Assist in the review and revision of environmental laws, regulations, policies, guidance, and protocols to increase incentives and eliminate barriers to conservation actions addressing climate change. Revise grant programs to direct funding to projects that address climate change.

A report, titled *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change*, was produced in 2001 by the National Assessment Synthesis Team (NAST), an advisory committee chartered under the Federal Advisory Committee Act to help the U.S. Global Change Research Program fulfill its mandate under the Global Change Research Act of 1990. The following excerpts and summaries are from the portion of the report that outlines issues faced by the eight-state Midwest Region.

Climate Trends of the Past Century
Over the 20th century, the northern portion of the Midwest, including the upper Great Lakes, has warmed by almost 4 ºF (2 ºC), while the southern portion, along the Ohio River Valley, has cooled by about 1 ºF (0.5 ºC). Annual precipitation has increased, up to 20 percent in some areas, with much of this coming from more heavy precipitation events (NAST, 2001).

Climate Projections for the Next Century
During the 21st century, it is highly likely that temperatures will increase throughout the region, likely at a rate faster than that observed in the 20th century, with models projecting a warming trend of 5 to 10 °F (3 to 6 ºC) over 100 years. Precipitation is likely to continue its upward trend, with 10 to 30 percent increases across much of the region. Increases in the frequency and intensity of heavy precipitation events are likely to continue in the 21^{st} century. Despite the increase in precipitation, rising air temperatures and other meteorological factors are likely to lead to a substantial increase in evaporation, causing a soil moisture deficit, reduction in lake and river levels, and more drought-like conditions in many areas (NAST, 2001).

Midwest Region Key Issues

Water Resources
Water levels, supply, quality, and water-based transportation and recreation are all climate-sensitive issues affecting the Midwest Region. Despite the projected increase in precipitation, increased evaporation due to higher summer air temperatures is likely to lead to reduced water levels in the Great Lakes. Lower lake levels will cause reduced hydropower generation down-stream, with reductions of up to 15 percent by 2050. The projected increase in demand for water across the region while there is a simultaneous decrease in net flows is of particular concern. For smaller lakes and rivers, reduced flows are likely to make water quality issues more acute. In addition, the projected increase in very heavy precipitation events will likely lead to an increase in flash flooding and, thus, worsen agricultural and other non-point source pollution as more frequent heavy rains wash pollutants into rivers and lakes. Lower water levels are likely to make water-based transportation more difficult, with increases in navigation costs from 5 to 40 percent. Some of this increase may be offset as reduced ice cover extends the navigation season and the geography of navigable waters changes. Reduced water levels may also decrease shoreline damage resulting from high lake levels by 40 to 80 percent.

Adaptations: A reduction in lake and river levels would require adaptations such as re-engineering of ship docks and locks for transportation and recreation. If flows decrease while demand increases, commissions focusing water issues will become even more important in the future. Improved forecasting of extreme precipitation events could help reduce some related impacts.

Agriculture
Agriculture is of vital importance to this region, the nation, and the world. Agricultural systems have exhibited a capacity to adapt to moderate differences in growing season climate, and it is

likely that agriculture will be able to continue to adapt. With an increase in the length of the growing season, double cropping—the practice of planting a second crop in a single year after the first is harvested—is likely to become more prevalent. The fertilization effects of CO_2 are likely to enhance plant growth and contribute to generally higher yields. The largest increases are projected to occur in the northern areas of the region, where crop yields are currently limited by the length of the cold season and correspondingly short annual growing period. However, yields are not likely to increase in all parts of the region. Consumers may pay lower prices due to increased yields, while producers are likely to suffer reduced profits because of declining prices. Increased use of pesticides and herbicides are very likely to be required, presenting additional challenges.

Adaptations: Plant breeding programs can use climate prediction models to direct research to breeding new varieties for new growing conditions. Farmers can then choose varieties better suited to the expected climate. It is likely that plant breeders will need to use all tools available in adapting to climate change including genetic engineering. Modifying planting and harvest dates, changing planting densities, and using integrated pest management, conservation tillage, and new farm technologies are additional options. There may be opportunities to shift or expand the area where certain crops are grown if climate conditions become more favorable. Weather conditions during the growing season are the primary factor in year-to-year differences in corn and soybean yields. Droughts and floods result in large yield reductions. Severe droughts like the drought of 1988 cause yield reductions of over 30 percent. Reliable seasonal forecasts would help farmers adjust their practices from year-to-year to respond to such events.

Changes in Semi-natural and Natural Ecosystems

Forests: Different United States forest types are expected to expand (oak-hickory), contract (maple-beech-birch), or disappear altogether (spruce-fir) (Ryan et al., 2008). The Upper Midwest has a unique combination of soil and climate conditions that favor the growth of conifer forests. Higher temperatures and increased evaporation will likely reduce boreal forest acreage and make current forestlands more susceptible to pests and diseases. It is likely that the southern transition zone of the boreal forest will be susceptible to expansion of temperate forests, not to mention increased competition from other land use pressures. However, warmer weather (coupled with beneficial effects of increased CO_2 on vegetation), are likely to lead to an increase in tree growth rates on marginal forestlands that are currently temperature-limited. Most climate models indicate that higher air temperatures will cause greater evaporation and hence, reduce soil moisture, a situation conducive to forest fires. Increased temperatures and longer growing seasons may also speed up decomposition rates and nutrient cycling, depending on water availability. As the 21st century progresses, there will be an increased likelihood and intensity of environmental stress on both deciduous and coniferous trees, making them susceptible to disease, pest infestation, and ultimately, mortality.

Water Habitats: As lake water temperatures increase, major changes in freshwater ecosystems will very likely occur. For example, a shift may occur from coldwater fish species such as trout, to warmer water species such as bass and catfish. Warmer water is also likely to create an environment more susceptible to invasive, non-native species. Runoff of excess nutrients (such as nitrogen and phosphorus from fertilizer) into lakes and rivers is likely to increase due to an increase in heavy precipitation events. This, coupled with warmer lake temperatures, is likely to stimulate the growth of algae, depleting dissolved oxygen content in the water to the detriment of other living organisms. Reduced lake levels will likely impact the current distribution of wetlands. There is a chance that some wetlands could migrate gradually over time, but they would disappear in areas where their migration is limited by the topography or anthropogenic land change. Changes in bird populations and other native wildlife have already been linked to increasing temperatures, and more changes are likely in the future.

Outdoor Recreation
The climate change impacts on environmental systems will have direct consequences to humans. In the context of Service management responsibilities, this may result in effects on appropriate and compatible Refuge uses. Popular winter activities such as cross-country skiing, snow-shoeing, and ice fishing may have shorter seasons and have the potential to be compromised by thinner ice and reduced snow cover. However, opportunities for warm-season activities can be expected to see an equal and opposite changes. Not only may warm-weather recreation seasons lengthen, but changing life cycles and distributions of wildlife may alter opportunities for hunting, wildlife viewing, and photography. Changes in activities not only affect Refuge management, but the local and regional economy.

Soils

The highly fertile soils in western Minnesota are a result of glacial till, glacial windblown sediment, and centuries of decomposed, deep rooted, tallgrass prairie plants. These soils were created over the past 10,000 years as the minerals in the glacial sediment were broken down. Ten thousand years' worth of root activity, frost, fire, burrowing, and acid leaching from leaf litter have all played a role in forming the soils in the Minnesota River watershed.

The various soil types have characteristic properties that determine their potential and limitations for specific land uses. Most of the Refuge soils are loams formed from calcareous glacial drift. Although some soils are clayey and sandy and gravelly, these are localized and account for only a small percentage of the Refuge soils.

Soils in the upland ridgelines range from loam to sandy and gravelly loam; these soils are well-to-excessively drained. Loam soil characteristics vary greatly in the upland plateaus ranging from well drained to poorly drained. This soil diversity exemplifies the "Prairie Pothole Region" with thousands of temporary and seasonal wetlands that are interspersed throughout the prairie.

Soil diversity is also prevalent in the river bottoms. The most prevalent features in the river bottoms are the granite outcroppings. Most of the floodplain soils are rich fertile loams and are moderate-to-well drained. The wetland soils are primarily silt and clay loams, which are poorly drained soils. However, there are gravel and sand lenses inter-laced throughout these soils. Thirty-seven soil series have been identified on the Refuge.

Hydrology and Water Quality

The Refuge receives drainage from multiple river systems including: the Minnesota River, the Little Minnesota River (into Big Stone Lake), the Whetstone River and Yellow Bank River originating from South Dakota, and Stony Run Creek. The combined drainage area covers a total of 1,356 square miles. Most of these water bodies are listed as impaired by the Environmental Protection Agency (EPA) for water quality impairments, including bacteria, dissolved oxygen, turbidity, and mercury. Land use practices within the Refuge's watershed, as well as stream alterations and dam construction both within and beyond the Refuge boundary strongly influence hydrology and water quality within the Refuge. The following description is focused on the drainage from Big Stone Lake and Whetstone River.

The origins of Refuge hydrology—like area's geological formations—go back to the end of the last ice age, more than 9,000 years ago, when the River Warren began draining Lake Agassiz, an immense body of meltwater produced by the retreating ice sheet. The force and volume of the Glacial River Warren carved a wide, flat valley that today is known as the Minnesota River Valley. After the retreat of the glaciers, Glacial Lake Agassiz and Glacial River Warren ceased to exist and the Minnesota River watershed was formed. With less drainage area and a greatly reduced source of water, the Minnesota River has historically occupied a portion of the valley floor in the form of meandering braided channels. Hydrology and water distribution was dictated by runoff induced streamflow, which likely ranged from shallow flows across much of the valley during flood events to a single meandering channel during dry periods. This variation in hydrology helped to drive morphological processes, such as scour and fill, which in turn resulted in channel formation and abandonment.


Streamflow on the Refuge

Areas just upstream and downstream of the Refuge were the sites of tributary confluences with the Minnesota River where sediment deposition and scour would have created alluvial fans and ever-dynamic channel morphology. Snowmelt-driven flood events in the spring months typically produced the highest flows, which pushed water levels over banks, filling abandoned channels and low lying areas of the valley. These riverine processes resulted in a wide riparian corridor comprised of a myriad of habitats, including bottomland woodlands, wetlands, and wet prairies. Vegetation within these habitats was dependent upon topography (depth of water) and frequency of inundation (duration). Flooding recharged wetlands and oxbow lakes providing important spring habitat for migrating waterbirds and spawning areas for fish species, while dry periods helped to sustain prairie habitats and species within the valley.

Today the river and many of its processes have been altered. Minnesota River streamflow entering what is now the Refuge has been regulated by the Big Stone Lake Dam since 1937, while all streamflow exiting the Refuge has been regulated by the U.S. Army Corp of Engineers (USACE) Highway 75 Dam at the downstream end of the Refuge since 1974. Refuge staff works with the USACE to meet Refuge management objectives, but flood control remains the purpose of the dam and the highest priority for the USACE. During high flows much of the Refuge is inundated for extended periods, often for weeks at a time. The purpose of the Big Stone Lake Dam is to regulate the level of Big Stone Lake within a relatively narrow range of water levels to meet the recreational, industrial, and residential water use needs of the local area. These strict requirements result in maximum discharge from the dam during wet periods to prevent flooding along the lake and a near shutdown of the dam during dry periods to ensure adequate water levels for the above uses. The Upper Minnesota River Watershed District, which operates the Big Stone Lake Dam, is obligated to maintain a minimum flow rate of 5 cubic feet per second (cfs) if there is sufficient water within the lake. In combination, the two dams strongly influence water delivery, storage, and movement within the Refuge, altering many of the river's natural cycles, processes, and historical interaction with valley habitats. Hydrographs of streamflow entering the Refuge display sharp fluctuations, as well as prolonged periods of low and high streamflow, which may negatively impact species dependent upon gradual variations and inconsistency in water levels.

Water impoundment on the Refuge reduces velocity, sediment transport and distribution, and dynamic channel morphology; and it increases the depth and duration of inundated areas under many streamflow scenarios. Additionally, land use changes within the watershed that converted forest and prairie to agriculture, increased surface runoff, erosion, and contaminant concentrations in the Minnesota River and many of its tributaries. Three tributary streams (South Fork Whetstone River, Yellow Bank River, and Stony Run Creek) entering the Minnesota River on or upstream of the Refuge, along with the Minnesota River itself, have been listed as an impaired water by the Minnesota Pollution Control Agency (MPCA), South Dakota Department of Environment and Natural Resources, and the EPA because of high levels of mercury, turbidity, and bacteria.

Historically the Minnesota River occupied numerous channels within the river corridor. Since construction of the Big Stone Dam in 1937, streamflow immediately downstream has been confined to a single ditched channel under most flow conditions. Due to water shortages and a desire to regulate levels on Big Stone Lake more intensively, the Whetstone River was diverted into the outlet of the lake, just upstream of the dam. The sediment-laden waters of the Whetstone River accelerated silt deposition in the lower end of Big Stone Lake. To alleviate this problem the USACE conducted an investigation that verified several flood-related problems on Big Stone Lake and in the immediate vicinity. The Big Stone Lake-Whetstone River Project of Minnesota and South Dakota was authorized under the Flood Control Act of 1965 (Public Law 89-298). The project was designed to improve conditions on Big Stone Lake by severing inflows from the Whetstone River and redirecting those flows into the Minnesota River; provide flood control benefits to lands downstream on the Minnesota River; create a siltation barrier downstream; and provide a major national wildlife refuge for migratory birds and other wildlife. The Highway 75 Dam was completed in 1974, and the USACE transferred the project lands to the Service in 1975 creating Big Stone NWR. Refuge lands serve as the siltation barrier for downstream flows.

The Minnesota River was straightened and widened (ditched) from Big Stone Lake to the Refuge to facilitate downstream flows. As part of these efforts, a series of structures were installed at the present day Refuge boundary and approximately 1.2 miles upstream with the intended purpose of deflecting low flows up to 400 cfs into the historic channel of the Minnesota River. During highwater events the excess flows would overtop the weir and flow through Pool 10 into West Pool on the Refuge via a diversion channel that extends the ditch system onto the Refuge. Due to sedimentation and design limitations these structures have failed to operate as intended, and all but the highest of flows are confined to the diversion channel.

These hydrologic alterations resulted in the segregation of over 6 miles of the historic Minnesota River channel, 4.5 miles of which is now part of the Refuge, due to a lack of streamflow and a degradation of riverine habitats. Dynamic riverine processes that once balanced streamflow, sediment transport, and erosion were replaced with the linear and static conditions typical of a ditch system. The loss of these processes likely impacted downstream habitats dependent upon the variability of the Minnesota River. However the most significant impact to the hydrology and habitats to this portion of the Minnesota River occurred with the construction of the Highway 75 Dam in 1974. The large flood retention dam, along with smaller scale impediments to flow such as levees, roads, and water control structures impounded large portions of the Minnesota River reducing flow velocity, while increasing water depth, duration, and extent under most conditions.

The diversion channel system intended to expedite flows downstream of Big Stone Dam now empties into the impounded waters resulting from Refuge water control and the Highway 75 Dam. These areas are depositional zones that are prone to sediment and contaminant accumulation. Other impacts associated with the failure of these structures are the continuous delivery of flow into West Pool and the direct transport pathway for water quality contaminants to enter the wetland, most noticeable of which is an apparent high concentration of sediments. Sedimentation within wetlands increases turbidity, decreases native plant and invertebrate growth, increases the production of undesirable or invasive plant species (such as hybrid cattail), and decreases wetland volume. In addition to sedimentation, other water quality contaminants, such as high concentrations of nutrients and heavy metals, are suspected to be impacting one or more wetlands on the Refuge. The Minnesota River, upstream of the Refuge, was listed by the MPCA in 2010 as impaired due to mercury contamination.

Within this framework, the Refuge manages several smaller impoundments that are strongly influenced by streamflow into the Refuge and the path water takes through the Refuge. Numerous dikes, levees, and roads exist on the Refuge, many of which that have been constructed perpendicular to the river corridor with the purpose of water impoundment.

Biological Environment

Wetlands

There are about 4,500 acres of wetlands within the Refuge, mostly within the floodplain of the Minnesota River (figure 3-2). Typically, floodplain wetlands are strongly influenced by both seasonal and annual wet and dry cycles coupled to streamflow, in this case the Minnesota River and its tributaries. In natural systems the interplay of these long- and short-term wet/dry cycles in turn affects the amount and types of vegetation within the wetlands. The construction of dams along the Minnesota River as well as land use changes within the watershed altered numerous factors including: water delivery and storage within the floodplain; frequency, duration and extent of inundation; water chemistry; and composition of wetland vegetation.

Within the Refuge, several dikes with water control structures allow water level manipulations on about 3,500 acres of wetlands. Varying water levels helps produce optimum conditions for the growth of aquatic invertebrates and vegetation used as food and cover by migrating birds in the spring and fall. Throughout the rest of the year, wetlands serve as production and maintenance habitat for waterfowl, other migratory birds, and resident wildlife. In addition to water level management, prescribed fire is used as a disturbance agent within a number of Refuge wetlands to set back vegetative succession. The ability to meet Refuge objectives related to wetlands is strongly influenced by water management of Big Stone Lake Dam and the Highway 75 Dam as well as water movement patterns across the Refuge. The impoundments (managed wetlands) average two to five feet in depth and are identified as West Pool, East Pool, and Pools 3, 4, 4a, 5, and 6.

The two main impoundments, West Pool and East Pool, total 3,200 acres. The two pools, once interconnected, are now separated by a dike and water control structure built in 2007 to allow water management of each pool independently. West Pool is about 1,400 acres; much of it covered by a dense stand of cattail and willow with some moist soil plants along the backwater edges. East Pool contains 1,800 acres of open water and emergent marsh over a gravel and boulder substrate that, when exposed, provides high quality feeding habitat for shorebirds.

Available open water within each pool is used as roosting habitat by migrating waterfowl and waterbirds.

The other five impoundments are much smaller in size and collectively encompass approximately 285 acres of primarily emergent marsh habitats. They were constructed in 1988–89 with funding provided by Ducks Unlimited for the purpose of increasing the amount of available nesting, brood-rearing, and foraging habitat for waterfowl. Pools 3, 4, 4a, 5, and 6 are located within the Minnesota River floodplain and are greatly influenced by the water levels and conditions of the river. Most of the water that fills these impoundments occurs from rainfall. All of these impoundments have stoplog water control structures located within their dikes that have been strategically located in a manner that connects them to the Minnesota River, Yellow Bank River, or East Pool. Water levels are increased within these impoundments primarily by backflow through these structures during highwater events. The impoundments are drained by releasing water into the rivers or West and East Pools. This system does not provide consistency or precision in managing the water levels within these pools. Supplemental water can be added to Pools 3 and 4 by pumping water out of the Yellow Bank and Minnesota Rivers.

There are also approximately 270 temporary and/or seasonally flooded depressions totaling approximately 260 acres. Most of these are shallow sedge meadow basins or depressions ranging from 0.1 to 1.5 acres in size. Some depressions stay wet into the growing season while others are only temporarily wet. The presence of these temporary wetlands promotes waterfowl production by providing greater area for the establishment of territories by breeding pairs. Substantial emergent and submergent vegetation occur in wetlands on the Refuge. Other water features on the Refuge include three abandoned quarry ponds. No active management occurs with them.

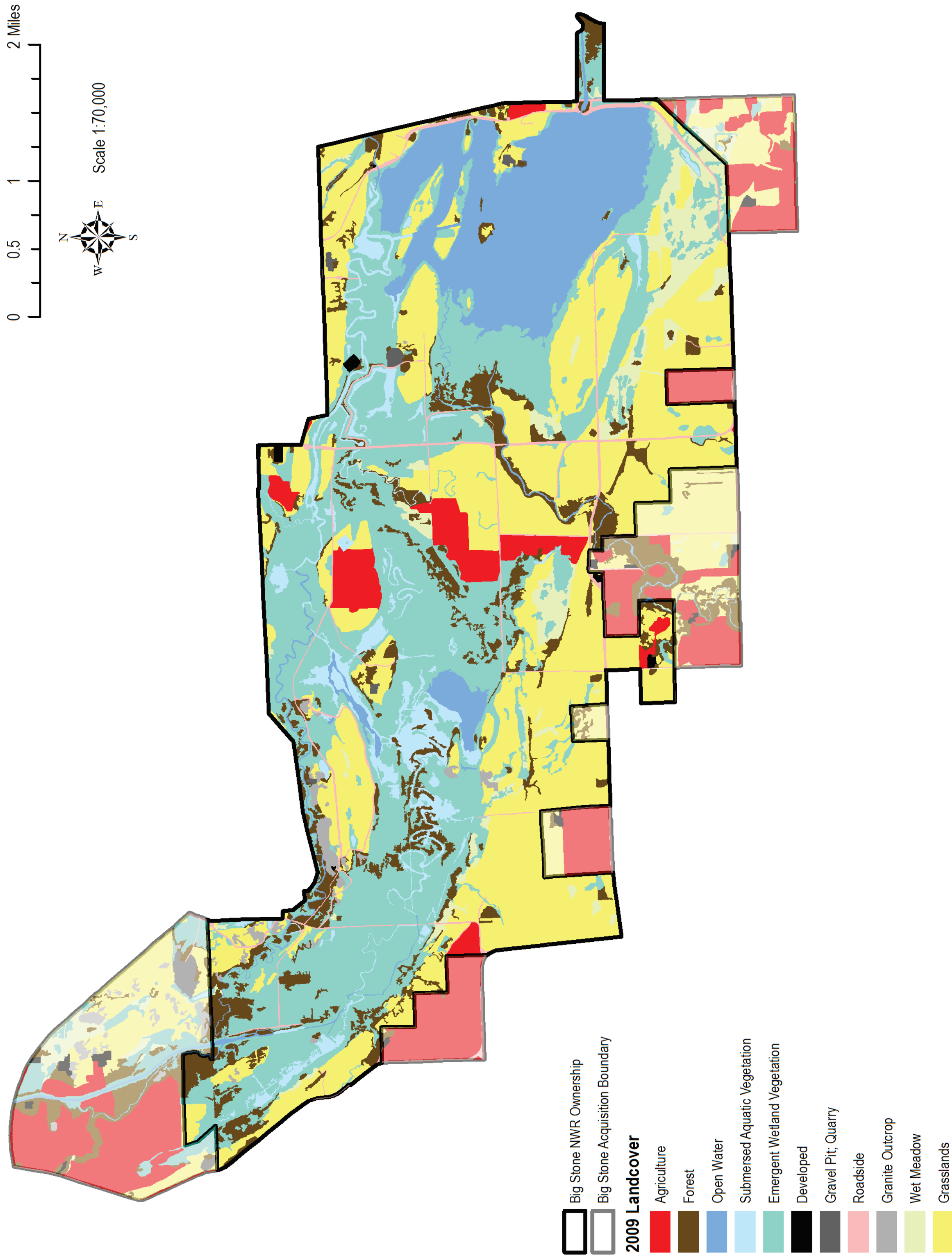
Grasslands

Based on soil conditions and floristic composition, the 5,500 acres of Refuge grasslands are categorized as wet meadow, remnant prairie, restored and partially restored grasslands, and areas dominated by non-native grasses (figure 3-2). Historically, fire and grazing influenced the structure, function, and composition of prairie. Currently, the Refuge relies on prescribed burning, haying, chemicals, and more recently grazing to manage Refuge grasslands. Many unwanted species are encroaching on Refuge grasslands, notably: Kentucky bluegrass, smooth brome, Canada thistle, leafy spurge, sweet clover, and reed canarygrass.

Wet Meadow

Wet meadows occur on poorly drained soils and are treeless areas dominated by broadleaved herbaceous plants including sedges and grasses. There are about 1,000 acres of wet meadow habitat across the Refuge that serves as a transition from wetlands to grass-dominated upland habitats (figure 3-2). Areas dominated by sedges and prairie cordgrass are still intact in some areas of the Refuge, but most of the wet meadows have been invaded by reed canarygrass.

Figure 3-2: Current Land Cover, Big Stone NWR



Remnant Prairie

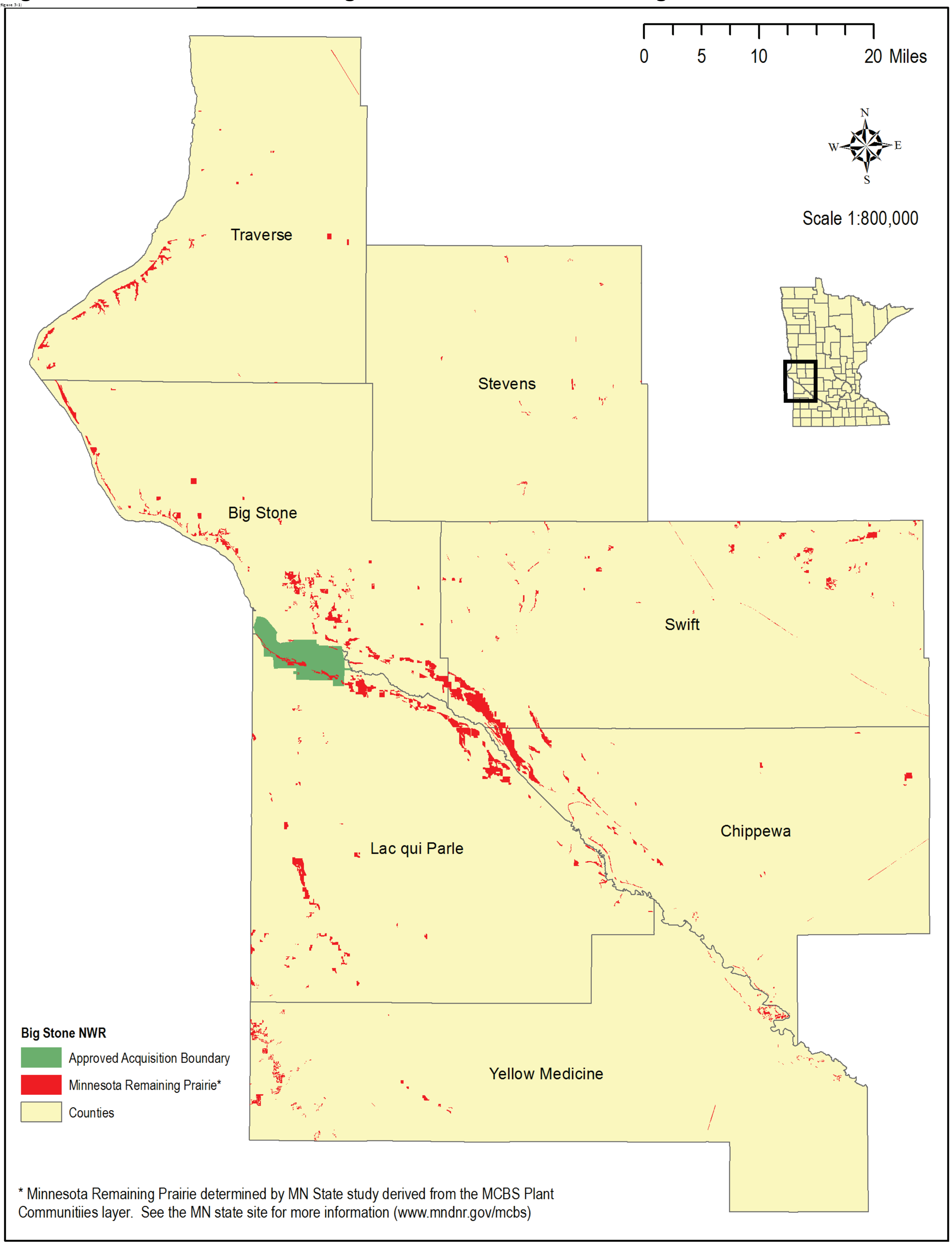
Sites dominated by native grasses and with untilled intact soils are considered remnants of the once expansive tallgrass prairie. About 1,700 acres of these remnants are within the Refuge (figure 3-3). Remnant prairie sites were intact prior to establishing the Refuge and were primarily used as pastureland. Remnant prairie is dominated by short- to mid-height, native prairie grasses with scattered clumps and pockets of tallgrass species and a suite of forbs. The wide range of species found with remnant prairie makes it the most floristically and structurally diverse Refuge grasslands.

Remnant prairie is dominated by short- to mid-height, native prairie grasses with scattered clumps and pockets of tallgrass species and a suite of forbs such as yellow coneflower (*Ratibida columnifera)*, purple coneflower (*Echinacea angustifolia)*, beardtongues (*Penstemon spp.)*, false gromwell (*Onosmodium molle)*, purple prairie clover (*Dalea purpureum)*, wild bergamot (*Monarda fistulosa)*, blazing star (*Liatris spp.)*, and leadplant (*Amorpha canescens)*. The native cool season grasses include Junegrass (*Koeleria pyramidata)*, needle and thread (*Stipa comata*, porcupine grass (*Stipa spartea),* and western wheatgrass (*Elytrigia smithii)*. The warm season grass component consists of side oats grama (*Bouteloua curtipendula)*, little bluestem (*Schizachyrium scoparium)*, switchgrass (*Panicum virgatum)*, indiangrass (*Sorgahstrum nutans)*, big bluestem (*Andropogon gerardii)*, prairie sandreed (*Calamovilfa longifolia)*, prairie and tall dropseed (*Sporobolus heterolepis*, *Sporobolus asper*, respectively), plains muhly grass (*Muhlenbergia cuspidata)*, and blue grama (*Bouteloua gracilis)*. Many unwanted species are encroaching on Refuge grasslands. Kentucky bluegrass, smooth brome, Canada thistle, leafy spurge, and reed canarygrass are the primary exotic species. The wide range of species found with remnant prairie makes it the most floristically and structurally diverse Refuge grasslands.

Restored Grasslands

Restored grasslands, presently about 500 acres, are located on sites that at one time were prairie, but that had been converted to agriculture or some other cover type. Although they lack the intact soils of the remnant prairies, restored grasslands include many of the native grasses and forbs found in the remnants. Up to 11 cool and warm season grass species and 40 forb species exist in these grasslands. Dominant grass and forbs species include big bluestem, little bluestem, switchgrass, Canada wildrye (*Elymus canadensis)*, sideoats grama, prairie and tall dropseed, yellow and purple coneflowers, purple prairie clover, thimbleweed (*Anemone cylindrical)*, blazing star, and goldenrods (*Solidago spp).*

Figure 3-3: Remnant Prairie in Big Stone NWR and Surrounding Minnesota Counties



Partially Restored Grasslands

Partially restored grasslands are an intermediate stage dominated by grasses but that lack many or all of the forbs found in fully restored grasslands. These grasslands are dominated with tall (up to six feet) warm season native grasses including big bluestem, Indian grass, switchgrass, and Canada wildrye. The lack of forbs makes these areas less floristically and structurally diverse than either restored grasslands or remnant prairie. At present there are about 1,300 acres of partially restored grasslands on the Refuge.

Non-native Grasslands

There are about 800 acres dominated by non-native grasses. Much of this persists from plantings of non-native grasses done in the 1970s to increase the amount of dense nesting cover available for waterfowl. About 500 acres of this grassland type were planted with non-indigenous Nebraska origin cultivars. Species include big bluestem, Indian grass, and switchgrass. These grasses produce significant amounts of biomass but are infertile. Some fields were planted to non-native Dense Nesting Cover and include species such as alfalfa (*Medicago sativa)*, red clover (*Trifolium pretense)*, orchard grass (*Dactylis glomerata)*, intermediate wheatgrass (*Thinopyrum intermedium)*, and smooth brome. These areas are the least floristically and structurally diverse of Refuge grasslands.

Cropland

Presently, there is about 280 acres of cropland on the Refuge; it is the first stage in grassland restoration. Farming future grassland sites for three to four consecutive years helps prepare a favorable seed bed. Corn and soybeans are the primary crops. The amount and location of cropland changes as sites ready for restoration are planted with native grasses and additional restoration sites are planted to crops.

Granite Outcrops

The most unique habitat on the Refuge is the lichen-covered granite outcrops. The Refuge has approximately 100 acres of granite outcrop habitat, which contains shallow fragile soils that can be easily disturbed. Several of the granite outcrops have become covered with trees and shrubs and have an open grass understory. Some native tree and shrub species like oak exist on the outcrops; however, most of the trees are exotic species. The only population of ball cactus in the State of Minnesota is located on the outcrops that lie in the upper portion of the Minnesota River Valley. Approximately 2,000 ball cacti exist on Refuge outcrops. The cacti are monitored by Refuge staff. The primary threat for this species is from human poachers that collect the cacti, typically for use in home landscaping. Several other interesting species include brittle cactus (*Opuntia fragilis)*, mudworts, ferns, fameflower (*Talinum parviflorum)*, and mousetail (*Myosurus minimus)*. Most of the native vegetation found on the outcrops is reflective of shortgrass prairie and is rich in forb diversity.

Forests and Shrubs

Approximately 1,050 acres of forest-shrub habitat exist on the Refuge (figure 3-2). Riparian woodlands concentrated along the Minnesota River and Yellow Bank River corridors account for about 660 acres. Much of this area is not formally managed although some areas have been included in past prescribed burns. Seasonal and at times prolonged flooding hamper the growth of understory vegetation including young trees. The remainder of the forest and shrub habitat is scattered trees and lowland shrubs found in the prairie coulees, old farmstead sites, wetlands, and grasslands. Primary bottomland and upland forest-tree species include plains cottonwood (*Populus deltoids)*, elm (*Ulmus spp.)*, silver maple *(Acer saccharinum)*, green ash (*Fraxinus pennsylvanica)*, willow *(Salix spp.)*, boxelder (*Acer negundo)*, and oak (*Quercus spp.)*. Tree invasion is a major threat to remnant prairie and grasslands on the Refuge.

Birds

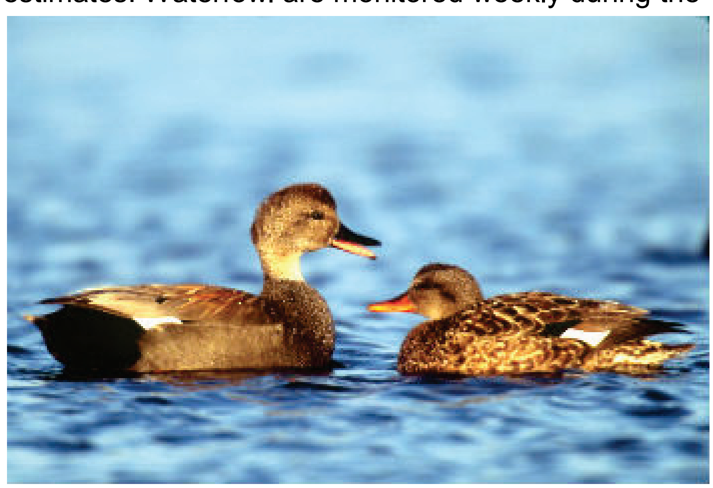
More than 250 species of birds have been recorded at the Refuge. The full range of passerine and other birds common to the Plains states are found on the Refuge at some time during the year. The Refuge serves as an important migration stopover. Refuge habitats are managed for the benefit of migratory bird species. Upland and wet meadow habitats are managed to provide nesting and brood rearing cover for waterfowl, some shorebird species, and grassland-dependent passerine species. Wetlands are managed through drawdowns, fire treatments, and disking (site dependent) to create quality habitat for waterfowl, marshbirds, shorebirds, wetland dependent passerines, and raptors. The only active management for tree nesting raptor species occurs with bald eagle nest tree protection.

In 2007, Audubon Minnesota designated the Upper Minnesota River Valley from Montevideo, MN to Big Stone Lake as an Important Birding Area (IBA) under the name Lac qui Parle – Big Stone IBA. The entire Refuge is included in this designated area.

Waterfowl and Waterbirds

Forty-six species of waterfowl and waterbirds use the Refuge for migration and/or nesting. During the spring and fall migrations waterfowl numbers have peaked at 75,000 ducks and 84,000 geese (2006). The Refuge provides habitat for more than 7 percent of the eastern prairie population of Canada Geese during fall migration. It also provides habitat for large numbers of Mallards during fall migration. Because the Refuge is positioned between the Mississippi flyway and Central flyway, it hosts western and eastern bird species.

Breeding waterfowl pair counts are conducted every spring on the Refuge. The pair count data is used to generate waterfowl production estimates. Waterfowl are monitored weekly during the spring and fall migrations. Over 20 species of ducks, geese, and swans are surveyed to evaluate migration progress and population estimates. The fall migration data are provided to the Minnesota DNR to be incorporated into their state-wide migration reports. Dominant species include Canada Geese, Mallards, Blue-winged Teal, Gadwall, Green-winged Teal, Lesser Scaup, and Ring-necked Ducks.



Gadwall pair; photo by John Jave

Marshbird and other waterbird species are monitored during the spring and fall migration periods at the same time as waterfowl. Refuge staff conducts weekly surveys during these timeframes and records presence/absence and numbers of birds by species. Although there is much variation and many missing species in these counts due to the secretive nature of many of these birds, documentation of species occurrence is still considered important. Throughout the summer months the waterbird species are monitored by casual observations. The most frequently observed waterbird species include American White Pelican, Great Egret, Great Blue Heron, Double-crested Cormorant, American Coot, Pied-billed and Western Grebes, Black-crowned Night-heron, Sora, Virginia Rail, and American Bittern.

Shorebirds

Shorebirds are very common during the migration periods in the spring and fall. Forty-six species of rails, plovers, sandpipers, terns, and gulls have been documented on the Refuge. Sandpipers, terns, and gulls are the most prominent during the migration periods. Although rare in most parts of the State, Black Terns nest on the Refuge and are easily observed during the summer. Based on the availability of highly qualified volunteer birders, weekly shorebird migration monitoring is done during spring and fall migration periods. Woodcock are not surveyed on the Refuge but are present around the wetland complex and occasionally observed.

Landbirds

Twenty-three species of raptors use the Refuge. Of those, seven species of owls and seven hawk species have been documented at the Refuge. Red-tailed Hawk, Swainson’s Hawk, Northern Harrier, American Kestrel, Great-horned Owl, and Eastern Screech-owl are some of the more common species seen on the Refuge. Four Bald Eagle nests are located on the Refuge. Two Bald Eagle pairs nest on the Refuge and are commonly observed from February through November each year. Peregrine and Prairie Falcons are occasionally observed during fall migration. Raptor species are monitored weekly in the spring and fall while conducting the waterfowl migration surveys. Species and numbers of birds are recorded. Bald Eagle nests are monitored during the breeding season to evaluate eaglet production.

Approximately 50 species of passerines have been documented from point count surveys on the Refuge. Point count surveys were conducted on the Refuge from 1994–1999, 2001, and 2007. The point count transects were focused on the remnant native prairie portions of the Refuge and designed to evaluate songbird species presence and abundance.

Several species of non-migratory birds are found at the Refuge. Ring-necked Pheasants, though an introduced species, have a stable population. Gray Partridge can be observed during the winter months. Eastern Wild Turkeys were reintroduced to the Refuge in 1995. The population has been slowly growing since then, and turkey sightings are now common on the Refuge. The Greater Prairie-Chicken was reintroduced into west-central Minnesota in 1999–2005. A total of 58 prairie-chickens have been released on the Refuge. Most of the birds settled off the Refuge; however, prairie-chickens are occasionally observed. Sharp-tailed Grouse were documented on the Refuge during the winter of 2006. During the spring of 2007 a Sharp-tailed Grouse lek was located in the Lee Habitat Unit on the south side of the Refuge. See appendix C for a complete Refuge bird list.

Fish and Other Aquatic Species

Refuge marshes are natural spawning areas for northern pike and European carp. Ruby Red Quarry is a spawning area for bass, crappie, and bluegill. Catfish, bullhead, northern pike, walleye, white bass, and carp are the predominant river species. The Minnesota River is a common travel lane for numerous species that originate in Big Stone Lake. A fishery survey conducted shortly after the Refuge was established documented 36 species of fish in Refuge waters. Test nettings have shown that a viable fishery exists on the Refuge in the major wetlands and river systems. It appears that water level fluctuations through management manipulations have been instrumental in controlling rough fish populations such as European carp.

Currently, there is no active management of fish or other aquatic species on the Refuge. The Minnesota DNR Fisheries personnel and Service Fisheries Biologists conduct formal surveys approximately every four years to assess the current fish populations. These surveys are usually done in the Minnesota River and East Pool using electrofishing, hoop netting, and gill netting techniques. The Refuge annually coordinates with the Minnesota DNR to stock fish in the Ice-Block pond also known as the "Fishing Pond." Fish are stocked in preparation for "Youth Fishing Day" a special event held each May. See appendix C for a complete fish list for the Refuge.

Fifteen species of freshwater mussels have been identified on the Refuge. Surveys in 1999 revealed the most common species to be the fat mucket. Most of the species exist in the wetlands and rivers on the Refuge. However, three of the species—Wabash pig-toe, pink papershell, and creek heel-splitter—were found only in the Yellow Bank River. See appendix C for a complete list of mollusks documented on the Refuge.

Butterflies

Butterfly surveys conducted in 1988, 1999, and 2000 documented a total of 46 species. See appendix C for a complete list of butterflies documented on the Refuge.

Threatened and Endangered Species

Threatened and Endangered Flora

No federally threatened and endangered plant species have been found on the Refuge. The state endangered ball cactus (*Escobaria vivipara*) exists on the Refuge. Approximately, 2,000 cacti are in the population and doing well. Mud plantain (*Heteranthera limosa*) is a state threatened species. Species of special concern for the State include brittle cactus (*Opuntia fragilis*), disk waterhyssop (*Bacopa rotundifolia*), and water mudwort (*Limosella aquatica*). Threestamen waterwort (*Elatine triandra*) is not currently listed but has been proposed for state threatened status. All of these species exist on and are confined to the granite outcrops. Management actions around the granite outcrops have focused on minimizing negative impacts to all of these species. The greatest threat to these species on the Refuge is the encroachment of woody species on the outcrops. Efforts have been made to remove the woody vegetation.

Threatened and Endangered Fauna

The Dakota skipper butterfly is a candidate species for federal listing. Candidate species are plants and animals for which the Service has sufficient information on their biological status and threats to propose them as endangered or threatened under the Endangered Species Act of 1973 but for which development of a listing regulation is precluded by other higher priority listing activities. The Dakota skipper was identified during butterfly surveys in 1988, 1999, and 2000. It was found in one remnant native prairie habitat unit on the northwest end of the Refuge. Two state species of concern have been found on the Refuge during the surveys: the poweshiek skipperling and regal fritillary. A 2009 butterfly survey found no occurrences of Dakota skipper or poweshiek skipperling and one occurrence of regal fritilliary.

Management actions in the remnant prairie have focused on minimizing negative impacts to prairie-obligate butterfly species. The Dakota skipper butterfly is the species of greatest concern for management. Prescribed burns are used to treat skipper habitat. A number of mitigation measures are used to reduce adverse impacts to butterfly populations. The poweshiek skipperling and regal fritillary are managed under the Dakota skipper management guidelines.

Invasive and Nuisance Species

Exotic and invasive plant species pose one of the greatest threats to the maintenance and restoration of the diverse habitats found on the Refuge. They threaten biological diversity by causing population declines of native species and by altering key ecosystem processes such as hydrology, nitrogen fixation, and fire regimes. Left unchecked, these plants have come to dominate areas on some habitat units and have reduced the value of the land as wildlife habitat.

The primary invasive exotic species include smooth brome, Kentucky bluegrass, reed canarygrass, Canada thistle, and leafy spurge. Fire is currently used to set back the cool season exotic grasses. Late spring burns during the bolt stage of growth on Kentucky bluegrass and smooth brome injure the grasses and delay seed head development. Setting back these species at the right time benefits the native warm season grasses and forbs. Occasionally, areas dominated by these species are hayed to prevent seed maturation. Reed canarygrass is another exotic cool season grass that is associated with wetlands. Currently the only means of controlling this species is to flood the plants for an extended period of time.

The encroachment of invasive woody species, namely trees, also has negative impacts on the prairie landscape. Very few trees were present prior to European settlement. As settlers homesteaded the area, they planted trees around their houses and created shelterbelts. Shelterbelts dotted the landscape. Over time the trees gradually spread throughout the prairie. Most of the species were not native to this area. Granite outcrops have shallow fragile soils and were too dry to support trees. However, over time boxelder and exotic elm trees became established and have continued to invade the outcrops. They threaten the endemic shortgrass plant species on the outcrops by shading them out.

European carp is the primary pest species invading and degrading Refuge wetlands. Carp retard the growth of aquatic vegetation by consuming it and by causing turbidity in the water, which reduces photosynthetic efficiency, an essential component of wetland food chains. Pools are occasionally drawn down to provide waterfowl and shorebird habitat, an action that temporarily reduces carp abundance. Once water levels within Refuge wetlands are restored, carp numbers are restocked from the population in the adjoining Minnesota River. No other active management occurs for this species.

On occasion, beaver dams obstruct waterflow through water control structures. Beaver have also constructed lodges beside Refuge interior dike roads, which can jeopardize dike integrity. Beaver are removed under these circumstances by a trapping permit and the dams and lodges removed by Refuge staff. Muskrat can become a pest species when it burrows into the impoundment dikes. The burrows jeopardize dike integrity. Muskrats are trapped as a part of the Refuge's trapping program.

Mammals

Muskrat

A variety of mammal species inhabit the Refuge. White-tailed deer, coyotes, rabbits, squirrels, and chipmunks are the most visible mammals of the Refuge's 45 species. Beaver, muskrat, mink, and raccoon are observable along river corridors and cattail marshes. The prairie supports the greatest wildlife diversity, and less observable but common species include: shrews, moles, weasels, ground squirrels, pocket gopher, mice, and voles. River otters were reintroduced to the Refuge in 1981, and a viable population continues to thrive today. Refuge grasslands and marshes are important for all of these species for forage and cover. See appendix C for a complete list of mammals documented on the Refuge.

Amphibians and Reptiles

Seventeen species of amphibians and reptiles have been documented on the Refuge. The most commonly observed species are western painted turtle, western plains garter snake, bull snake, and northern leopard frog. Five-lined skinks are occasionally seen on the granite outcrops, and western spiny softshell and snapping turtles can be observed along the banks of the Minnesota River and Yellow Bank River. See appendix C for a complete list of amphibians and reptiles documented on the Refuge.

Socioeconomic Environment

Socioeconomic Setting

Big Stone NWR is located in Big Stone and Lac qui Parle Counties, Minnesota. Other nearby Minnesota counties are Chippewa, Stevens, Swift, Traverse, and Yellow Medicine. Each of the seven counties within this region decreased in population from 2000 to 2009. During this same time the population of the State of Minnesota grew. On average, the area's population has a lower median household income and less high school and college education than the State's population.

Population

The 2009 estimated total population of the seven counties was 58,574. Compared to 2000 estimates, the population decreased 9.6 percent while the State's population increased 7 percent. Traverse County decreased the most at minus 13.6 percent, and Stevens County the least at minus 4.2 percent. Table 3-2 compares the racial composition of the seven-county area with that of Minnesota as a whole. In Minnesota, 8.5 percent of people five years and older speak a language other than English at home; in the seven-county area the figure is 4.3 percent (U.S. Census Bureau, 2010).

Table 3-2: Percentage of Population by Race for Seven-county Area and Minnesota (2009)

Race	Seven-County Area	Minnesota
White persons	95.3	88.60
Black persons	1.0	4.70
American Indian and Alaska Native persons	1.6	1.30
Asian persons	0.8	3.80
Native Hawaiian and Other Pacific Islander	0.5	0.10
Persons of Hispanic or Latino origin	2.5	4.30
Persons reporting two or more races	1.0	1.60

Employment

In the period from 2005 to 2009, the educational services, health care, and social assistance industry was the largest economic and employment sector in the seven-county area, accounting for 27.1 percent of employment. Agriculture, forestry, fishing and hunting, and mining accounted for about 12 percent of the jobs across the area. Retail trade, manufacturing, and construction were also important economic sectors (U.S. Census Bureau, undated).

Income and Education

Average per-capita income in the seven-county area was $22,809 in 2009; in Minnesota it was $29,431. The median household income of the seven-county area was $42,581 in 2009; in the State it was $57,007 (U.S. Census Bureau, undated).

In the seven-county area, 16.1 percent of persons over 25 years of age hold a bachelor's degree or higher. The comparable figure in the State is 31.2 percent. This discrepancy is typical of the difference between largely rural areas like these seven counties and entire state populations, which include large numbers of more urban residents who are professionals and have higher educational attainment on average (U.S. Census Bureau, undated).

Demand and Supply for Wildlife-Dependent Recreation

In order to estimate the potential market for visitors to the Refuge, we looked at 2007 consumer behavior data within approximately 30- and 60-mile drives of the Refuge. The data were organized by ZIP Code™ areas. The 30-mile area extended beyond the communities of Ortonville and Appleton, MN and Milbank, SD. The 60-mile area included Montevideo, Benson, and Morris, MN and Watertown, SD. The consumer behavior data that we used in the analysis are derived from Mediamark Research, Inc. data. The company collects and analyzes data on consumer demographics, product and brand usage, and exposure to all forms of advertising media. The consumer behavior data were projected by Tetrad Computer Applications, Inc. to new populations using Mosaic data. Mosaic is a methodology that classifies neighborhoods into segments based on their demographic and socioeconomic composition. The basic assumption in the analysis is that people in demographically similar neighborhoods will tend to have similar consumption, ownership, and lifestyle preferences. Because of the assumptions made in the analysis, the data should be considered as relative indicators of potential not actual participation.

We looked at potential participants in birdwatching, fishing, and hunting with shotgun. In order to estimate the general environmental orientation of the population, we also looked at the number of people who might contribute to an environmental organization. The consumer behavior data apply to persons more than 18 years old. Table 3-3 displays the consumer behavior numbers for two distances to the Refuge. The projections represent the maximum audience that we might expect to make a trip to the Refuge for approximate drives of half-hour (30 miles), and 1 hour (60 miles). Actual visitors will be fewer, because the estimate is a maximum, and we expect less than that will travel to the Refuge.

Table 3-3: Maximum Adult Audiences Within 30 and 60 Miles of Big Stone NWR for Activities and Environmental Contributions

Activities	Population within 30 miles	Population within 60 miles
Birdwatching	5,986	19,196
Hunting	6,856	20,661
Fishing	13,019	41,119
Contribute to Environmental Organization	1,743	6,060

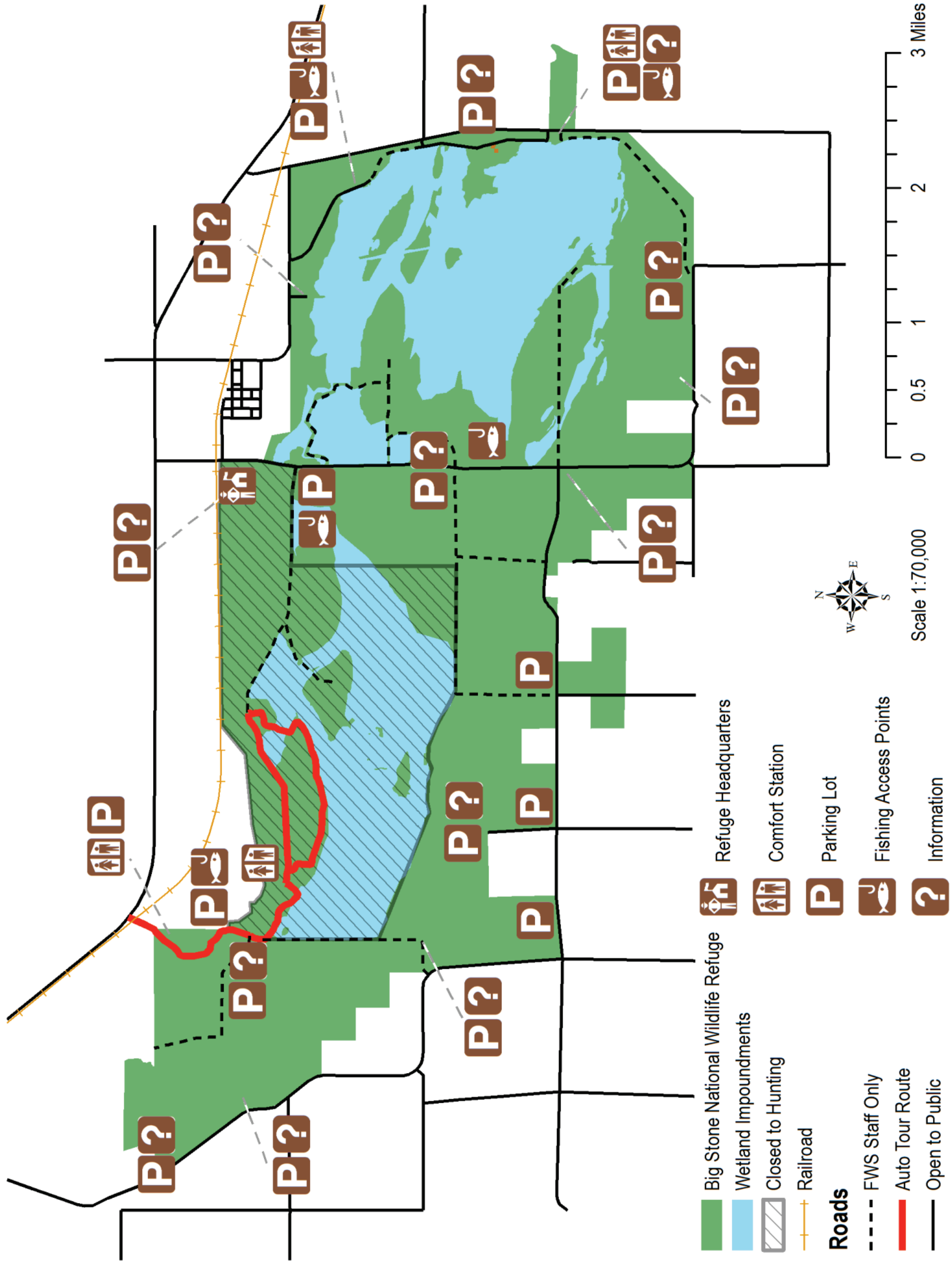
Wildlife-Dependent Recreation

Hunting

The Refuge maintains hunting programs for small, upland, and big game species in accordance with state seasons and regulations. No special permits are needed to participate in any of the hunting seasons other than what may be required by the State, such as a turkey permit. Currently, species that can be hunted include rabbits, squirrels, fox, raccoon, skunk, Ring-necked Pheasant, Gray Partridge, turkey, and deer. Deer hunting is permitted during archery, shotgun, and muzzleloader seasons. No migratory game bird hunting is allowed on the Refuge.

The Refuge maintains a zone, approximately 2,850 acres, where all hunting is prohibited (figure 3-4). The zone is not closed to other uses, such as hiking and wildlife observation. In the past the zone was temporarily opened to deer hunting. This was done for deer herd management purposes and may be applied again in the future if excessive deer numbers cause depredation problems outside the Refuge and no other viable alternative exists.

Figure 3-4: Current Visitor Services Facilities Big Stone NWR



Fishing

The entire Refuge is open to fishing wherever foot access is possible (figure 3-4). Boating is limited to the natural channel of the Minnesota River. The quarries, once popular local fishing sites, are currently closed to public access due to safety issues.

Game fish such as walleye, northern pike, largemouth bass, white bass, drum, perch, crappie, catfish, sunfish, and bullheads are all abundant and sought throughout the year by local fishermen. The Minnesota River and Yellow Bank River are both fished frequently during the open water seasons. Ice fishing also occurs on the Refuge, but access, quality of fishing, and available water usually limit it to East Pool.

Wildlife Observation and Photography

Wildlife observation activities account for a majority of the visitation that occurs on the Refuge each year. Four developed facilities enhance this use: the Auto Tour Route, Granite Outcrop Hiking Trail, Highway 75 Dam Drive, and Minnesota River Headwaters Trail (figure 3-4).

The Auto Tour Route is a 5-mile paved roadway that winds through an interior portion of the Refuge. Visitors can view wildlife and plant life associated with riparian woodlands, native and restored prairie grasslands, granite outcrops, and prairie floodplain-associated pothole wetlands and managed wetlands. White-tailed deer as well as a variety of waterfowl and waterbirds are commonly seen. Associated with the Auto Tour Route is a hiking trail that winds along the granite outcrops offering visitors a close up experience with outcrop plant and animal life as well as a scenic view of the Minnesota River corridor.

The Highway 75 Dam Drive is a 1-mile paved road found on top of the Highway 75 Dam. This drive offers a view of East Pool, flood control facilities, and the remains of a historic granite quarry operation. Seasonally, visitors can view large concentrations of migrating waterfowl from this site. The Minnesota River Headwaters Trail links the foot of Big Stone Lake in Ortonville to the Auto Tour Route. The Refuge portion of this multi-use trail is 1.3 miles and unpaved. It offers a trip through riparian woodland and floodplain wetland habitats.

Wildlife observation and photography

Interpretation

The Auto Tour Route and Granite Outcrop Trail include interpretation of the Refuge's habitats, wildlife, management, and unique features. The renovated Refuge headquarters also will include an expanded area of interpretive displays.

Environmental Education

There are no facilities specifically designed for environmental education purposes nor are there any staff dedicated to full-time outreach or environmental education activities. Refuge personnel provide tours on request and occasionally assist teachers onsite with outdoor classroom activities. Various Refuge locations are available for independent environmental education programs and projects.

Other Recreation

Canoeing and Kayaking

Approximately 11.5 miles of the Minnesota River wind through the Refuge. A portion of this river is accessible to canoes and kayaks and offers a scenic river experience. There is a developed boat ramp located near the Refuge headquarters that provides access. The upper portion of the river is inaccessible due to the extensive log jams, while the mid and lower portions provide good canoeing and kayaking conditions during times when river flows are higher.

Administrative Facilities

The administrative facilities are located approximately one-half mile west of Odessa, MN on Big Stone County Highway 19. The compound consists of the Refuge office and attached shop; two large pole shed buildings used for equipment storage; and a pole shed used for seed cleaning purposes. Several smaller storage buildings are also on the compound grounds. The office portion of the building was added on to the existing shop building in 1997. The office/maintenance shop building is currently going through an energy retrofit to install a geothermal heating/cooling system. Other renovations planned as part of this project include a new roof, new windows, an enlarged visitor contact area and multipurpose room, the redesign/realignment of current office space, and the redesign of the visitor and staff parking areas. The existing shop area will be incorporated into the design and become part of the staff office space. A new shop building will be constructed as part of this energy retrofit project.

Volunteers

Volunteers have always been an important part of the Refuge workforce. Individuals, more than organized groups, have come forward to offer their time and services for Refuge needs. Projects where volunteers have been involved include: wildlife surveys, monitoring, wildlife research projects, seed collecting, assisting with public events, and even routine maintenance duties.

Archeological and Cultural Values

Much of what is known about the prehistoric human occupations or visitations of the Refuge and surrounding area is drawn from a 1987 cultural resources survey report (Roetzel et al., 1987). Human activity is documented in the present day Minnesota River Valley in Western Minnesota to at least 9,000 years ago. Early peoples, called “Paleoindians” by archaeologists, were highly mobile and followed the migratory habits of the big game animals present at the end of the last ice age, such as mammoths and ancient bison. This cultural group is largely known by the large, chipped stone spearpoints used to kill and butcher these animals. One such spearpoint, identified as an Agate Basin type, was recovered in nearby Clay County, and chalcedony knives and fluted projectiles were recovered from the Browns Valley burial site in Traverse County. Although Paleoindians did occur in the area, the low amount of recovered artifacts suggests the population density was low. To date, no evidence of Paleoindian sites have been found within the Refuge boundary.

As the climate became closer to today's range, the ice age big game animals became extinct and, as such, humans adapted and became less mobile and used a much broader range of plant and animals resources. These people, called "Archaic" by archaeologists, were foragers that while still somewhat nomadic, returned year after year to favorite hunting and gathering spots. As such, they left behind a wide range of stone tools including smaller spearpoints and plant grinding implements. The archaeological sites for this time period are more numerous suggesting the human population began to increase and expand. A broken spearpoint, likely from this time period, was found on the Refuge.

By around 2,000 years ago, the introduction of new technologies from the east such as clay pottery and the bow and arrow set off a change in the subsistence and social structure of the people in the area. These peoples, called "Plains Woodland" by archaeologists, settled down in year-around residences in small villages exploiting local resources. Pottery has been found in and around the Refuge which suggests occupations by or contact with other Post-Archaic peoples such as Mississippian, Plains Village, Cambria, and Oneota. To date, no evidence of Plains Woodland sites have been found within the Refuge boundary.

Cultural Resource Management

Cultural resources (archaeological sites, historic structures, and Native American traditional cultural properties) are important parts of the nation's heritage. The Service strives to preserve evidence of these human occupations, which can provide valuable information regarding not only human interactions with each other, but also with the natural environment. Protection of cultural resources is accomplished in conjunction with the Service's mandate to protect fish, wildlife, and plant resources.

The Service is charged with the responsibility, under Section 106 of the National Historic Preservation Act of 1966, of identifying historic properties (cultural resources that are potentially eligible for listing on the National Register of Historic Places) that may be affected by our actions. The Service is also required to coordinate these actions with the State Historic Preservation Office, Native American tribal governments, local governments, and other interested parties. Cultural resource management in the Service is the responsibility of the Regional Director and is not delegated for the Section 106 process when historic properties could be affected by Service undertakings, for issuing archaeological permits, and for Indian tribal involvement.

The Archaeological Resources Protection Act of 1979 (ARPA) Section 14 requires plans to survey lands and a schedule for surveying lands with "the most scientifically valuable archaeological resources." This Act also affords protection to all archeological and historic sites more than 100 years old (not just sites meeting the criteria for the National Register) on federal land, and requires archeological investigations on federal land be performed in the public interest by qualified persons.

The Regional Historic Preservation Officer (RHPO) advises the Regional Director about procedures, compliance, and implementation of these and other cultural resource laws. The actual determinations relating to cultural resources are to be made by the RHPO for undertakings on Service fee title lands and for undertakings funded in whole or in part under the direct or indirect jurisdiction of the Service, including those carried out by or on behalf of the Service, those carried out with federal financial assistance, and those requiring a federal permit, license, or approval.

The responsibility of the Refuge Manager is to identify undertakings that could affect cultural resources and coordinate the subsequent review process as early as possible with the RHPO and state, tribal, and local officials. Also, the Refuge Manager assists the RHPO by protecting archeological sites and historic properties on Service managed and administered lands, by monitoring archaeological investigations by contractors and permittees, and by reporting ARPA violations.