LONG RANGE ECOLOGICAL RESTORATION PLAN FOR THE LAKE OF THE WOODS USING WATERBIRD GUILDS AS INDICATOR SPECIES

by

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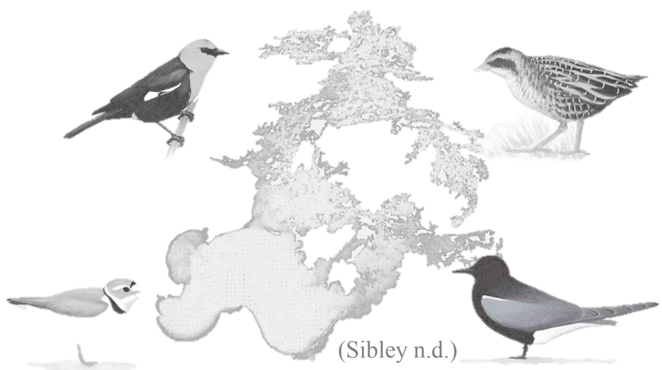

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LONG RANGE ECOLOGICAL RESTORATION PLAN FOR THE LAKE OF THE WOODS USING WATERBIRD GUILDS AS INDICATOR SPECIES

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An Undergraduate Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Honours Bachelor Environmental Management

FACULTY OF NATURAL RESOURCE MANAGEMENT

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ABSTRACT

Franchuk, S.M. 2020. Long Range Ecological Restoration Plan for the Lake of the Woods using Waterbird Guilds as Indicator Species. 79pp.

Key Words: black tern (*Chlidonias niger*), climate change, ecological restoration, Lake of the Woods, piping plover (*Charadrius melodus*), waterbirds, yellow-headed blackbird (*Xanthocephalus xanthocephalus*), yellow rail (*Coturnicops noveboracensis*),

This thesis explores a long-term ecological restoration plan for the Lake of the Woods area using waterbird guilds as indicator species to plan, adjust and minimize climatic affects in the future. In a time of rapid global climate change, it is important to develop conservation strategies that will adjust to critical habitats that are essential for the persistence of species with diverse and dispersed requirements. Lake of the Woods is a unique location as it is an inland island composed of a variety of ecosystems with rare and threatened species, including the piping plover (*Charadrius melodus*), black tern (*Chlidonias niger*), yellow rail (*Coturnicops noveboracensis*), and yellow-headed blackbird (*Xanthocephalus xanthocephalus*). In this paper, I briefly review historic data on Lake of the Woods and predicted population trends of indicator waterbird species to show evidence of how recent climate change has already affected populations. This will assist with the consideration of areas on Lake of the Woods that can be used to mitigate effects with ecological restoration.

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INTRODUCTION

The impact of climatic effects on the population of birds has been an important focus over the past half century (Crick 2004). Specifically, waterbirds as a guild are known for their long migrations, slow reproductive rate, and dependence on a variety of wetlands (Myers et al. 1987; Bart et al. 2007). Waterbirds, such as the piping plover, black tern, yellow-headed blackbird and yellow rail, are very responsive to climate change compared to other avian species and have shown changes in phenology and distribution (Jordan 2017). Migratory birds are of particular conservation concern as they are being affected by climate change due to the changes in temperatures, weather patterns, timing and extent of precipitation, and frequency and severity of extreme weather (Sutherland et al. 2012). These cause changes in behaviour, such as earlier breeding, altered timing of migration, changes in population sizes and changes in distributions (Crick 2004). This is a unique conservation challenge due to the waterbird population being influenced by geographically separated events during migration (Matrin et al. 2007).

The changing availability of migratory pathways such as wintering, stopover, and breeding locations relates to migratory shorebirds and the climatic effects they are facing now and, in the future (Sutherland et al. 2012). The loss of migratory locations can greatly affect whole populations that depend on these pathways during annual migrations (Sutherland et al. 2012). The lack of suitable habitats, migration corridors and landscape connectivity results in isolation, fragmentation and vulnerability for species trying to disperse and adapt to climate change (Society for Ecological Restoration International 2009).

The piping plover (*Charadrius melodus*), black tern (*Chlidonias niger surinamensis*), yellow rail (*Coturnicops noveboracensis*), and yellow-headed blackbird (*Xanthocephalus xanthocephalus*) birds were chosen as indicator species to assess climatic effects and assist with ecological restoration in Lake of the Woods. Indicator species can be used to monitor and predict environmental changes, and aid in the management solutions for climate change, fragmentation and habitat loss (Siddig et al. 2016). These indicator species are important as they reflect the conditions of the ecosystems where they are found. Each bird has been found at Lake of the Woods within their summer breeding ranges and they all require specific nesting habitats that depend on certain water levels. With these indicator species we can designate critical habitat, monitor ecosystem health, assess effects of climatic changes, and manage habitat restoration (Siddig et al. 2016).

Lake of the Woods is an important junction for distinct ecosystems and supports a diversity of flora and fauna species (Conway 1995). With over 14,500 islands it is mostly uninhabited and surrounded with majestic coniferous trees (Figure 1) (Lund 2002). Lake of the Woods Provincial Park was established in 1967 and is located near the borders of Ontario, Manitoba and Minnesota (Ontario Parks 2019). The 20675 hectare park lies within a transition zone of three diverse environments including northern, southern, and prairie (Ontario Parks 2019). In many of the inland island habitats, populations are faced with increasingly restricted ranges as species are pushed to their geographic limits to find appropriate feeding, breeding and nesting locations (Society for Ecological Restoration International 2009). In addition, indirect anthropogenic global climate change effects can be seen with prey availability, predation effects, land-use change, seasonal wetland conditions and the matching of the timing of arrival dates (Sutherland et al. 2012).

Figure 1. Lake of the Woods, Lake of the Woods County (Wright 1940)

Restoration ecology as defined by the Society of Ecological Restoration is the science of recovering degraded, damaged or destroyed ecosystems through the practice of active human intervention and management to re-establish structure and function (Society for Ecological Restoration International 2008a). Ecological restoration is an important tool to mitigate and slow the rate of human-caused climatic changes and impacts that can be seen at Lake of the Woods. By slowing the extinction rate of rare, threatened and endangered populations, their numbers can be gradually increased for the future (Society for Ecological Restoration International 2009). The lack of suitable habitats, migration corridors and landscape connectivity results in isolation, fragmentation and vulnerability for species trying to disperse and adapt to climate change. The chosen indicator species are vital to assess past and future climatic effects on wetland and shore habitat. They also play a large role with the planning and monitoring of Lake of the Woods Provincial Park and the intended long range ecological restoration plan.

OBJECTIVE

There are three objectives to this thesis. The first is to describe historic and recent climate change effects on Lake of the Woods, by using four bird species as indicators for this area with critical habitat information, population and distribution data from maps created by National Audubon Society using North American Breeding Bird Survey (BBS) and the Audubon Christmas Bird Count (CBC) information. The second is to use Climate Vulnerability Maps by the National Audubon Society to predict what the impacts of further climate change will be on these selected species. The third objective is to develop a long-range ecological restoration plan for this region using guidelines from case studies on large scale restoration, rare species management/biological conservation by The Society of Ecological Restoration International (SER), Lake Superior Binational Program and Great Lakes Restoration Plan.

LITERATURE REVIEW

BACKGROUND HISTORY ON LAKE OF THE WOODS

Lake of the Woods was carved into the Canadian Precambrian Shield by receding glaciers over 10,000 years ago (Lake of the Woods Township 2012). More specifically, it is a remnant of former glacial Lake Agassiz (Marsh 2018). Lake of the Woods is fed by the Rainy River from the south and drains to the Winnipeg River in the northwest (Marsh 2018). The second largest inland lake in Ontario (Lake of the Woods Township 2012), Lake of the Woods is host to a land of distinct ecosystems that supports a diversity of flora and fauna species (Conway 1995). Dating back to 7,000 BC, small bands of Palaeo Indians hunted prehistoric large game animals at Lake of the Woods and originally called the lake "minestic" or "Lake of the Islands" (Figure 2) that was later changed by French fur traders to "Lac du Bois" or Lake of the Woods (Lake of the Woods Township 2012). The Cree, Ojibwa and Sioux lived in the Lake of the Woods area before the lake became part of a main fur-trade route where voyageurs frequently lost their way among its 14,632 islands (Marsh 2018). As early as 1887, dams were built at the north outlets to the Winnipeg River that increased water levels by two metres. To this day, the establishment of dams have resulted in strictly controlled water levels in such a large complex system (LoW Paleolimnological Research n.d.). Lake of the Woods has over 104,000 km of shoreline making an ideal destination for anglers, hunters, birders and nature lovers alike who support the now well-established tourism industry (Lake of the Woods Township 2012). There are many birds, mammals and insects that are seasonal or permanent residents of Lake of the Woods that are not found elsewhere in Ontario and, in some cases, in the rest of Canada (LoW Paleolimnological Research n.d.).

Figure 2. Lake of the Woods, Canada (Linde 1930)

Historic Pressures on Waterbirds

Waterbirds are defined as *"a group of bird species strictly reliant on aquatic environments, at least in some stage of their life cycle"* (Jordan 2017). Besides the natural fluctuations in environmental conditions, organisms like waterbirds have to cope with conditions derived from human activities like over-hunting, extirpation, and rapid changes in climatic conditions (Jordan 2017). There is an extensive history of extirpation and extinction with wildlife species following the European travelers and settlers in

North America (Heffelfinger et al. 2013). Three distinct forces that commonly cause elevated extinction rates include: (1) habitat loss, (2) human exploitation and (3) effects of invasive species and diseases (Loehle & Eschenbach 2012). Historically, there was no real 'conservation ethic' as the future of wildlife resources were disregarded and market hunters drove wildlife to extinction (Heffelfinger et al. 2013). A more historical perspective is often needed when assessing the conservation status of a species. The maintenance of current abundance should also by recognised as an important conservation objective running in parallel with conservation efforts in order to save species in danger (O'Connell 2000). Evidence has shown that anthropogenic effects like climate change have become a major threat for biodiversity in the past decades (Jordan 2017). For example, the double-crested cormorant (Figure 3) has fluctuated in population numbers since the species was first reported breeding on Lake of the Woods in the 1700s. The birds have gone through human persecution due to perceived competition with fisheries, along with environmental contamination from DDT and PCBs, which severely reduced their numbers throughout North America (RE Grant & Associates n.d.). After DDT was banned, cormorant numbers began to rebound by the late 1907s and their populations have grown rapidly since; although, there are new laws being passed for culling the birds, as they can be detrimental to fish populations, island forest habitats and they may displace other waterbird species. While some organisms may not survive such changes, others have shown clear responses to changes in climatic conditions like altering the time of their phenological events, including flowering, migration and changing distribution (Jordan 2017). Today, hunters bring funds and advocacy to the table, and are known as the cornerstone of North American wildlife management (Heffelfinger et al. 2013). Most importantly, hunters remain the most effective logistical agents of actual population management. In preparing for the future it is vital to remember that *"we cannot continue to maintain wildlife unless its welfare is passionately defended and politically secured"* (Heffelfinger et al. 2013). The foreseen role of hunters in North American conservation will have to be comprised of a broader emphasis on the species that are not hunted. The future of conservation will have to increase attention given to general public needs so they can continue to reap the rewards of the conservation efforts made by hunters (Heffelfinger et al. 2013).

Figure 3. Photograph of Young cormorants in the nest, Cormorant Rock, Lake of the Woods (Sadler 1915)

The Migratory Bird Act

Components of integrated bird conservation have a long history (Andrew & Andres 2002). In North America, early European explorers pushed westward and converted many native forests, prairies and wetlands for agricultural and industrial use (Anderson et al. 2018). The once "remarkable abundance of wildlife" took on a large toll from the settlers. Birds were being commercially exploited for their meat and feathers, threatening the existence of many avian species. In the mid-1800s, outspoken naturalists, such as John James Audubon, John Burroughs and George Perkins Marsh, believed that wildlife, especially migratory birds, were rapidly declining from excessive exploitation and, thus, were in need of protection. President Theodore Roosevelt and George Bird Grinnel advocated together, generated public support and launched a campaign to end spring shooting and commercial market hunting of birds (Anderson et al. 2018). By 1912, Senator George Payne McLean and Congressman John Wingate Weeks sponsored broader federal migratory bird legislation which included non-game species. This legislation gained support from agricultural interests, bird watchers and sportsmen. A year later in 1913, the Mclean Act was passed by Congress, signed into law, and became known as the Migratory Bird Act (MBA) (Anderson et al. 2018). In 1916, the United States called for cooperative management of migratory birds across nations. Canada quickly passed the Migratory Bird Convention Act (MBCA) in 1917, and the United States Congress passed the Migratory Bird Treaty Act (MBTA) in 1918. These acts prohibited the taking or possession of all listed migratory birds (unless specifically allowed due to regulations or permits) and hunting of designated game species was limited too specified open seasons. The Migratory Bird Treaty (MBT) was built upon by conservationists to broaden bird protection along with other international agreements, such as Mexico in 1936, Japan in 1972 and the Soviet Union in 1976. In 1997, the United States and Canada amended their original MBT to allow for managed aboriginal hunting (traditional harvesting) of migratory birds in specific areas of Alaska and Canada (Anderson et al. 2018). Migratory birds are held in public trust throughout North America and overall responsibilities fall to the federal governments because of the 1916 MBT. The MBT played an important role of giving rise to the development of scientific foundations for management. The MBCA and MBTA are also used by environmentalists and government agencies as bases for conservation actions (Anderson et al. 2018). Currently, more than 1,000 bird species are protected under the MBTA (Franzen 2018). As an international treaty, it acknowledges the importance of birds and recognizes that bird populations transcend national boundaries. According to the Government of Canada (2017), the piping plover (Charadriidae) and yellow rail (Rallidae) are protected as Migratory Game Birds, whereas the black tern (Laridae) is protected as an Other Migratory Nongame Bird under the MBCA. The yellow-headed blackbird (Icteridae) is listed under Migratory Insectivorous Birds; however, blackbirds and specific others are excluded. The yellow-headed blackbird is listed under the Specially Protected Birds section by the Ontario Fish and Wildlife Conservation Act 1997 (Government of Canada 2017). In North America, bird conservation has a long history of success but the world has greatly altered since 1916 and new challenges are being faced. Challenges such as human population growth, and associated climatic changes and effects, can become existential threats to the migratory bird management system and to many natural resources (Anderson et al. 2018).

BREEDING LOCATION AND BIRD STATUS

Waterbirds are a diverse assemblage of wetland and open-water species often categorizes by their social approaches to nesting, feeding and roosting (Soulliere et al. 2007). Like most wildlife populations, waterbird trends largely reflect the abundance of quality habitat and breeding habitat quality, which is often related to water levels, precipitation and recent climatic conditions. Many waterbird species receive only limited survey coverage, and regional population estimates have not been generated from current monitoring data. Populations of many waterbird species are poorly understood, and the population data that is available is often imperfect (Niemuth 2005). The North American Waterbird Conservation Plan (NAWCP) was created to provide a continental perspective on the status and conservation efforts for waterbirds in North America. The plan is the product of an independent partnership of individuals and institutions having interest and responsibility for waterbird and their habitat conservation. It covers 210 species in 23 families, including the interests of 29 nations in North America, Central America and surround pelagic zones. Although, NAWCP only addresses colonial and semi-colonial waterbirds, the solitary breeders are to be eventually addressed in the second version of NAWCP (Niemuth 2005).

Piping Plover

The piping plover (*Charadrius melodus*) is a small migratory shorebird (Figure 4) with a widespread and scattered breeding distribution in North America; it overwinters in the southern United States, Mexico and on some Caribbean Islands (Kirk 2013). There are three distinct breeding locations including the northern Great Plains, the Great Lakes region and the Atlantic coast (Manitoba Conservation n.d.). The main focus is the northern Great Plain breeding population which occurs from central Alberta to Lake of the Woods in northwestern Ontario, and south to northern Oklahoma (Manitoba Conservation n.d.; Alberta Conservation Association 2002).

The piping plover is listed as a provincially endangered bird in Ontario, Manitoba, Saskatchewan, and Alberta (Alberta Conservation Association 2002; Kirk 2013). In addition, the Manitoba Conservation Data centre listed the piping plover as provincially rare, and the Association for Biodiversity Information states that it is globally uncommon. According to the U.S. Fish & Wildlife Service (2012), the northern Great Plains populations of piping plovers are listed as threatened in Minnesota.

Figure 4. Piping plover (*Charadrius melodus*) (Cafuoco 2016)

The Ontario Lake of the Woods subpopulation nests in similar habitats to the Ontario Great Lakes subpopulation, which includes river and cobble beaches, freshwater dune formations and islands or peninsulas of inland lakes around late April or May (Kirk

2013; U.S. Fish and Wildlife Service 2012). Furthermore, this suggests that Lake of the Woods may have represented a route of interchange between the Northern Great Plains and the Great Lakes piping plover populations (U.S. Fish and Wildlife Service 2015). Breeding sites are commonly found adjacent to hypersaline water bodies and areas rich in mineral salts (Alberta Conservation Association 2002). The piping plover uses a shallow bowl-like nest created in sand or gravel that can be affected by periodic high-water events that can limit the availability of critical nesting sites (Alberta Conservation Association 2002).

Black Tern

The Black tern (*Chlidonias niger surinamensis*) is a semi-colonial marsh-nesting bird (see Figure 5) that can also be found in freshwater wetlands, wet meadows and ponds throughout their summer breeding range (Hughes 2001; Burke 2012). This

Figure 5. Adult Black Tern, breeding plumage (Reed, n.d)

species represents the waterbird group that uses semi-permanent deep water emergent marsh, and can serve as a surrogate for Foster's tern, common moorhen and the American coot (Soulliere et al. 2007). Their breeding range exists across the northern United States and Canada, whereas in the winter they migrate to Central America and northern South America in search for marine-coastal habitats (Hughes 2001; Peterjohn & Sauer 1997; Burke 2012).

The black tern is listed as a species of special concern in Ontario, and can be found in scattered locations across the province, including small concentrations in Lake of the Woods (Burke 2012). In other sources, it is considered Vulnerable in Ontario, Manitoba and Quebec. In Ontario, the black tern has been recommended for listing as Threatened (Austen & Cadman 1994; Shuford 1999). It has an existing management plan and landscape model for the Prairie Pothole Region.

The largest populations are concentrated in zones of highly productive wetlands, particularly in the prairies of Alberta, Saskatchewan, Manitoba, North Dakota, South Dakota, and Minnesota (Shuford 1999). The black tern as been chosen as one of Audubon Minnesota's state Target Conservation Species and to represent Minnesota's Prairie Parkland Region (Pfannmuller 2014). The North American population of black terns is estimated between 100,000 and 500,000 birds (Burke 2012). There is a rough estimate of 2,873 to 14,996 black tern breeding pairs in Ontario which appears to be the only estimate in Canada suspected of having thousands of breeding black terns (Austen & Cadman 1994; Shuford 1999). Although black terns have a widespread distribution in Minnesota, they have been declining an average of 5.8% per year over the last 46 years, adding to an approximate total of 94% lost in the state population (Pfannmuller 2014).

Yellow-headed Blackbird

The yellow-headed blackbird is a conspicuous breeding bird in deep-water and emergent wetlands throughout nonforested regions of western North America (Twedt & Crawford 1995). Their distribution is centered on the prairie potholes of the northern Great Plains. Flocks will migrate to the southern United States and Mexico for overwintering. They are large-bodied (Figure 6), highly social and polgynous species that nest on grouped territories. Nests are typically placed in marshes, firmly lashed to standing vegetation such as cattails, bulrushes and reeds that are growing in water up to three feet above the water's surface (Audubon Minnesota 2014). The range of the yellow-headed blackbird is limited by the availability of emergent wetland habitat.

Figure 6. Yellow-headed Blackbird (*xanthocephalus xanthoecephalus*) (Sullivan 2012)

The yellow-headed blackbird is the only chosen species in this paper that is not listed as a species at risk in Ontario, as they are considered abundant and secure throughout most of their range. However, they are declining in some eastern parts of their range due to their sensitivity to drought, loss of wetland habitat, and pesticides where they forage (National Audubon Society n.d.). For example, in 2004 the population estimate for the United States and Canada was 23 million and in 2012 it had declined significantly to 11 million (Audubon Minnesota 2014). Minnesota has selected the yellow-headed blackbird as one of their 26 Target Conservation Species for *Blueprint for Minnesota Bird Conservation*, and one of the eight species selected to represent Minnesota's Prairie Hardwood Transition Region. It is considered one of four of the highest level priority out of the eight selected species that are given a conservation management plan. Given the blackbird's overall decline, simply maintaining the current population is not a sufficient conservation goal (Audubon Minnesota 2014). Therefore, the conservation objective is to implement conservation actions that increase yellow-headed blackbird populations in Minnesota an average of 2.5% per year over 30 years, overall doubling Minnesota's yellow-headed blackbird population from its current estimate.

Lake of the Woods has many freshwater islands that are important habitat for many colonial nesting birds, including the yellow-headed blackbird (Nature Conservancy of Canada 2020). They are restricted to western North America, only stretching as far east as the Great Lakes. They are primarily a prairie-nesting species but have nested in Ontario and in the Rainy River District since at least 1961 (Elliot & Tozer 1989). The yellow-headed blackbird has also been recorded using breeding areas around Tern Island in the Lake of the Woods (Maxson & Haws 1992). Marsh drainage has reduced or eliminated some breeding populations, as several isolated populations have been reported throughout Michigan and Ontario (Twedt & Crawford 1995).

Yellow Rail

The yellow rail is widely distributed in the United States and Canada, primarily east of the Rocky Mountains. Little is known about their migratory behaviour; some are known to migrate in groups during the night. Their breeding range and presence is quite local, generally in fresh and brackish-water marshes, particularly the higher and drier margins (Leston & Bookhout 2015). The yellow rail represents species that are dependent on wet meadow with open water (Figure 7). It has unique meadow habitat needs that can be associated with other birds such as the American bittern, Le Conte's sparrow and sedge wren (Soulliere et al. 2007). In Ontario, the yellow rail occurs predominantly in three areas; (1) southern and eastern Ontario, (2) in the Rainy River area on the Ontario-Minnesota border and (3) along the coasts of James and Hudson bays (Leston & Bookhout 2015). Yellow rails are widespread in Minnesota's northwest, although no-one has searched the small portion of Ontario located on the west side of Lake of the Woods. The species has been found (within 5 km of Ontario) at Indian Bay, Manitoba that is only accessible by the Manitoba side (COSEWIC 2009). In Canada where 90% of the yellow rails global breeding range occurs, it is listed as a species of Special Concern by the Committee on the Status of Endangered Wildlife in Canada, provincially in Ontario and federally in the Species At Risk Act (Leston & Bookhout 2015). Populations in the northern United States are relatively small and appear to be declining. The yellow rail also has concern status in each of the six US states in which it is known to breed : Threatened in Michigan and Special Concern in Minnesota (COSEWIC 2009).

Figure 7. Yellow Rail (Coturnicops noveboracenis) (Brunoni 1997)

Yellow rails, like most wetland birds, are highly dispersive which is likely an adaptation to their locally ephemeral habitat. The global population size is unknown: however, the most authoritative estimate suggests in Canada there are 10,000 to 25,000 immature individuals, and approximately 10,000 to 12,000 mature individuals (COSEWIC 2009). In both Canada and the United States, the yellow rail is presumed to have declined historically based on habitat trends rather than the number of individuals found. Together, habitat loss and degradation are undoubtedly the main threat to this species on both its breeding and wintering grounds.

CRITICAL HABITAT

According to the Species At Risk Act, critical habitat is defined as “the habitat that is necessary for the survival or recovery of a listed wildlife species” (Environment Canada 2009a). Although critical habitat is vital for a species survival, it does not always encompass or represent the species entire current habitat or probable future habitat (U.S. Fish and Wildlife Service 2015). Recovery plans are not limited to the areas designated as critical habitat because habitat concerns can be applied to the entire range of the species. The term “essential habitat” is often referred to as it is collectively all of the area that is essential to species at risk throughout their breeding, migration and wintering grounds (U.S. Fish and Wildlife Service 2015). Critical habitat designation conserves habitats by being effective year-round with required specific components that must be identified in the location over time, although it may not always occur every year (Department of the Interior 2002). For example, an area that may be temporarily masked by snow, ice or other features is still considered to be critical habitat because it contains the primary constituent elements (Department of the Interior 2002). Critical habitat designations can be subsequently reviewed if there is additional information in the future, as well as a formal proposal and public comments prior to any changes or additions to areas of critical habitat. *“Critical habitat receives protection under section 7 of the Endangered Species Act through the prohibition against destruction or adverse modification of critical habitat with regard to actions carried out, funded, or authorized by a Federal agency”* (Department of the Interior 2002). Conferences are required with the Service on Federal actions that may result in a proposed critical habitat becoming destroyed or adversely modified.

<u>Piping Plover</u>

The identification of critical habitat for the piping plover in Canada is based on site occupancy and suitable habitat criteria described in *Action Plan for the Piping Plover* (*Charadris melodus circumcinctus*) *in Ontario* by Environment Canada (2013). Each criterion is based on multiple year occupancy of sites and confirmed breeding of the piping plover (Environment Canada 2013). Occupancy criterion recognises sites based on reliable sources where confirmed nesting was observed in a minimum of one year and where the site has proof of breeding pairs being present in multiple years (aka species fidelity) (Environment Canada 2013). Suitable habitat of the piping plover is identified using the Ecological Land Classification (ELC) for Ontario. The ELC classifies critical habitats by vegetation, hydrology and topography which ultimately provides a standardized approach to the explanation and delineation of ecosystem boundaries. Open Beach/Bar (BBO) and Open Sand Dune (SDO) are the two ELC Community Series designations that have been documented as habitat attributes from sites currently occupied and historically occupied by piping plovers in Ontario (Environment Canada 2013).

Minimum requirements for identifying critical habitat in Manitoba and Ontario includes: (1) an average number of greater than or equal to two adults plovers over all surveys, or 5% of the province's recovery goal in any one year during the window, (2) a minimum of three surveys per site during the breeding season that are each carried out on a different year, (3) a floating window of at least 15 years, which is based on three international censuses occurring every five years, starting in 1991 to determine wetland, lake and or riverbed status (Environment Canada 2006). The Prairie Canada population recovery goal is a minimum of 1,626 adult piping Plover, or 813 pairs during each of the three consecutive international censuses (Environment Canada, 2006). The minimum provincial targets of adults for Lake of the Woods (Ontario) is 6, whereas Alberta is 300; Saskatchewan 1,200; and Manitoba 120 (Environment Canada 2006).

Critical habitat for the piping plover has been identified in four sites in Ontario: Windy Point on Lake of the Woods, Wasaga Beach Provincial Park on Georgian Bay, and both Sauble and Oliphant Beach on Lake Huron (Environment Canada 2013). The piping plover site on Lake of the Woods (Prairie Canada Population) is more susceptible to broad-scale alterations to habitat because of its remote nature and limited human interactions. Alterations can include hydroelectric dam construction that can result in water level fluctuations, destruction or changing of critical habitat availability and flooding nests (Environment Canada 2013). Other broad-scale changes include wetland/watershed management changes or residential development that can result in loss of critical habitat, availability and suitability (Environment Canada 1991). The socio-economic effects associated with implementing an action plan for the benefit of the piping plover Prairie Canada Population includes the alteration of water level management and fluctuations conducted by the Lake of the Woods Control Board (LWCB) (Environment Canada 2013). The LWCB manages the existing patter of water levels that are relied on by stakeholders such as cottagers, residents, tourism, local industry and hydro-electric power generation. Other costs for an action plan would be associated with transportation to the remote locations for surveys, staff time, and material for building predator enclosures (Environment Canada 2013).

On 11 September 2002, 19 critical habitat units were designated for the Northern Great Plains piping plover population, containing approximately 183,422 acres of prairie alkali wetlands, the surrounding shoreline (sparsely vegetated), river channels and associated sandbars, reservoirs, inland lakes, peninsulas, islands and 1,207.5 river miles (U.S. Fish and Wildlife Service 2015). These areas provide the piping plover with habitat for primary courtship, nesting, foraging, sheltering, brood-rearing and dispersal (U.S. Fish and Wildlife Service 2015).

Critical habitat designation in Minnesota has been limited to three sites on Lake of the Woods where piping plovers have been observed nesting in more than one year (Department of the Interior 2002). The northern Great Plain population of piping plovers has 19 critical habitat units in the United States of America containing one or more of the primary constituent elements previously described. In Minnesota, Lake of the Woods falls under unit MN-1 which includes Rocky Point, Pine, and Curry Island and Morris Point (Department of the Interior 2002). Unit MN-1 represents the most eastern portion of the northern Great Plains population of breeding piping plovers and may be a vital relationship between the northern Great Plains and the Great Lakes breeding populations; moreover, it is the only remaining breeding site for piping plovers in Minnesota. This critical habitat unit has sparsely vegetated windswept islands, peninsulas, sandy points or spits that interface with Lake of the Woods, and it includes approximately 253.2 acres (95.1 hectares) of this unique habitat in total (Department of the Interior 2002). Approximately 100.4 acres (40.6 hectares) are designated within Rocky Point Wildlife Management Area, which consists of 697 acres or 282.3 hectares that is public ownership, managed by the Minnesota Department of Natural Resources. Approximately 134.8 acres (54.5 hectares) are designated within the Pine and Curry

Island Scientific and Natural area that is also public ownership and managed by the Minnesota Department of Natural Resources (Department of the Interior 2002). This area includes 112.6 acres (45.6 hectares) of a sandy barrier island known as Pine and Curry Island, and 22.2 acres (8.9 hectares) of an adjacent peninsula known as Morris Point that is situated at the Rainy River mouth on Lake of the Woods (Department of the Interior 2002).

The primary constituent elements on inland lakes in Minnesota Lake of the Woods include sparsely vegetated, windswept sandy to gravelly islands, beaches, peninsulas and the interface with the water body (Department of the Interior 2002). For feeding sites, adult piping plovers prefer shoreline or beach pool edges with wet sand over open beach with dry sand. Piping plovers favour sand points or spits in large lakes with the rare combination of windswept islands and peninsulas with a lack of adjacent tree cover. It should be considered that the time spent foraging at these sites can be influenced by changing habitat conditions and prey availability (Department of the Interior 2002).

The evaluation of recovery efforts for the Prairie population is important to review for more insight into critical habitat. The securement of breeding habitats is one of the approaches used for piping plover conservation and ranks as the key component for recovery (Goossen et al. 2002). Other techniques, such as predator exclosures and habitat management, have been applied to indirectly protect plovers from predators. Information gained from monitoring populations, such as through international censuses, that used to assess trends and status of the piping plover is critical for recovery and planning (Goossen et al. 2002). In addition, other important factors like communication and public awareness, supported research, population dynamics, reproductive success, adult and juvenile survival are all areas that need to be studied and learned to benefit the conservation efforts for the piping plover Prairie population (Goossen et al. 2002).

Key Habitat Values

The habitat of the piping plover is represented on beach between the high water mark and the water's edge of a lake, wetland, sandbar or river. Below is a list of key habitat attributes of the piping plover (Environment Canada 2009b) that would be useful for mapping or classifying habitat requirements and restoration techniques.

- Beach width greater than 10 m
- Shoreline length greater than 0.4 km
- Patches of gravel or sand/gravel
- Sandbars
- Distance to tree line from normal high-water mark greater than 50 m
- Beach with less than 50% vegetation cover
- Access to wet, sandy shoreline or seeps, small streams or interdunal wetlands for feeding
- Alkali deposits present somewhere on beach (for alkali lakes/wetlands)
- Adjacent upland vegetation from where insect drift occurs and
- Key ecological processes that create, maintain or affect habitat such as weather including precipitation and drought, wind, groundwater, salinization, water fluctuations, vegetation encroachment or succession, fire and herbivory

Black Tern

Black tern critical habitat is not identified, although they require freshwater marshes, wetlands and emergent vegetation for breeding habitat (Kudell-Ekstrum & Rinaldi 2004). Black terns can create their nests on floating substrates, detached root masses, floating wood or boards, and matted marsh vegetation like cattails. Large preserved wetlands can attract black terns and encourage adults to move and adjust to areas with suitable water depths (Kudell-Ekstrum & Rinaldi 2004). Research shows that the breeding habitat requirements of the black tern varied in response to structure of the wetland landscape, and they prefer wetlands surrounded by grasslands that are greater than 50% tilled for agriculture (Shuford 1999). Black terns prefer small wetland area (6.5 ha) in high wetland density landscapes with a combination of both small and large wetlands (Shuford 1999: Naugle 2004).

There seems to be a lack of information on a wide variety of black tern biology that needs research including the foraging range and habitat use at breeding sites, comparative studies across habitats and regions and evaluating factors affecting re-nesting after nest failure (Kudell-Ekstrum & Rinaldi 2004). Breeding Bird Surveys appears to be the only monitoring and research program for black terns (Peterjohn & Sauer 1997; Shuford 1999). Establishing a black tern survey that can yield population and habitat data across the species entire range would be beneficial as current population data such as the Breeding Bird Survey (BBS) is commonly insufficient and lacking in many regions (Naugle 2004; Heath et al. 2009). Priorities for future research on black terns include increasing knowledge on wetland management for both breeding and migration range would greatly improve our understanding on population and habitat information for waterbird populations and ecology. Future research should focus on chick and adult survival rates to evaluate breeding success and limitations on nest success (Heath et al. 2009).

According to Shuford (1999), the recovery of black tern populations, improvement of habitat conditions and nesting success will consist of both management efforts and policy initiatives. The conservation priorities for the black tern are a combination of four steps: (1) refining monitoring techniques to improve detection of population trends and the determine the causes of changes, (2) stemming the tide of wetland loss from a landscape perspective by creating partnerships to protect and restore wetlands, (3) habitat managing for black terns based on current knowledge and leading research to identify limiting factors, and evaluate additional management techniques and, lastly, (4) educating the public about the importance and value of wetlands and possible effects of their actions on black tern (Shuford 1999).

Key Habitat Values

Black terns inhabit limestone (or igneous rock based) rich freshwater marshes with emergent vegetation along lakes, rivers or inland locations during their breeding season (Naugle 2004; Burke 2012). The black tern can exploit newly available habitat; although, they are sensitive to habitat loss and change (Burke 2012). They may also breed sparsely in open fens across the boreal, and in marshy lakes where nests are placed on structures such as collapsed muskrat houses and driftwood. Nest placements are likely to be within, or at the edge of, a low density of emergent vegetation close to open water (Burke 2012). Black terns have a high variability of habitat requirements, although specific information about the characteristics of these sites are unknown and lacking. There are no current critical habitat requirements for the black tern; although, there is a detailed list of ideal habitat listed below according to Burke (2012).

- Wetlands 1.6 to 5 ha, and in excess of 20 ha for nesting
- Smaller wetlands less than 6.5 ha in high-density wetland landscapes composed of large greater than 15.4 ha wetlands
- Roughly equivalent proportion (50:50) of open water interspersed with irregular patches of dense emergent vegetation, also referred to as hemi-marsh
- Vegetation comprised of cattail (*Typha* spp.) and bulrush (*Cyperaceae* spp.) and rushes (*Juncus* spp.), sedges (*Carex* spp.), bur-reed (*Sparganium* spp.), spikerushes (*Eleocharis* spp.), pickerelweed (*Pontederia* spp.), smartweeds (*Polygonum* spp.), Reed-canary Grass (*Phalaris arundinacea*), arrowhead (*Sagittaria* spp.), spadderdock (*Nuphar* spp.), water lilies (*Nymphaea* spp.), Wild Rice (*Zizania aquatica*) and other plants
- Disturbances to marshes such as water level fluctuations, Muskrat activity, drought, winter ice damage and fire can maintain habitat of the black tern but will eventually be rejected because of a lack of open water
- Vegetation height at nesting sites is usually less than 0.25 to 0.5 m, and greater than 1.0 m by the time eggs hatch (Heath et al. 2009)
- Nests are typically located within 6 m of open water but can be up to 25.3 m away
- Water depth tends to be 0.5 to 1.2 m where nests are floating among emergent vegetation (James 1985)

Yellow-headed Blackbird

Lake of the Woods Waters Conservation Reserve is provincially significant for its estuarine and lacustrine wetlands, fish nursery and spawning habitat, and most importantly, nesting habitat for imperiled black terns and yellow-headed blackbirds (Ontario Ministry of Natural Resources 2006). It is a significant habitat for these waterbirds and other species at risk, and its regional importance as a migratory stopover. A lack of basic species biology information is a major impediment to the conservation and restoration efforts to the yellow-headed blackbird (Ward et al. 2000). The need for critical habitat information is crucial as urban development continues and undefined yellow-headed blackbird essential habitat may disappear in the future. The yellow-headed blackbird is a species of the marshes of desert and grassland areas of western North America; it is restricted to marshes during nesting season (Burt 1970). Burt (1970) determined that 77% of all yellow-headed blackbird nests were found within 20 feet of open water. The yellow-headed blackbird normally nests over water in emergent vegetation but it has also been recorded nesting in flooded willows in central marsh areas (Burt 1970). The yellow-headed blackbird generally requires a shallow aquatic habitat with emergent vegetation in the littoral zone, as well as a water depth preference of 1-5 feet (Illinois Natural History Survey n.d.). Yellow-headed blackbirds can move between wetlands up to 40 km apart, likely due to poor habitat conditions and a need for quality nesting success (Ward et al. 2000). They are quite specific in habitat choice and therefore have low adaptability (Weller & Spatcher 1965). The presence of damselflies and dragonflies can have a significant effect on populations of yellow-headed blackbirds as it is the main diet of the young. This information may prove to be a valuable tool in the management of this species.

Key Habitat Values

Yellow-headed Blackbirds are a large-bodied blackbird that are polygynous, highly social, and nest in grouped territories (Twedt & Crawford 1995). As large flocks they often use uplands for foraging and prairie wetlands for roosting. Deep-water with emergent vegetation is important for nest construction, likely in cattails (*Typha* spp.), bulrushes (*Scirpus* spp.), or reeds (*Phragmites* spp.) (Twedt & Crawford 1995).

- Emergent freshwater marsh, good quality hemi-marshes
- 50:50 ratio of open water to emergent vegetation (Audubon Minnesota 2014)
- Inhabits prairie wetlands and forest edges on larger lakes in mixed-wood boreal forest (Twedt & Crawford 1995)
- 35 – 77% of emergent vegetation coverage within a territory (Audubon Minnesota 2014)
- Nest in outer edges of marshes over standing water 20-90 cm deep (James 1985)
- Territories may be as small as 0.03 ha in semicolonial situations (James 1985)
- Identify and maintain deep-water wetlands greater than 20 ha (or 50 acres) in size (Audubon Minnesota 2014)
- Deep-water with stable water levels (Audubon Minnesota 2014)

Yellow Rail

Yellow rails nest in wet marshy areas that consist of short vegetation (sedges, *Carex* spp.) with an overlying dry mat of dead vegetation that they will use as a roof for their nests (COSEWIC 2009). They require specific breeding habitat in terms of water levels and vegetation mats. In the spring, yellow rails will arrive at breeding sites where the water levels may surpass 50 cm (COSEWIC 2009). The water levels must subside below 15 cm by the time nesting begins and avoid flooding out the mats of dead vegetation. These water levels variation factors have been proven to closely track the annual variation in presence and or abundance of yellow rails at several sites (COSEWIC 2009). Rail species are known as highly dispersive birds, likely an adaptation to these local ephemeral water conditions as mentioned above. The yellow rail is one of several waterbird species that serves as an indicator of the health of fens and wet prairies, which can often be overlooked in conservation practices as it is not considered a “typical” wetland (COSEWIC 2009).

Lake of the Woods is one of few places in Minnesota and Ontario where yellow rails have been confirmed consistently using breeding sites (Alvo & Robert 1999; Audubon 2019). Rainy Lake to Lake of the Woods consists of many freshwater islands, sandy beaches and marshes that provide habitat for birds like the yellow rail (Nature Conservancy of Canada 2020). The Rainy River population is contiguous with the northern and northwestern Minnesota population that is adjacent to the Rainy River area (Alvo & Robert 1999). Yellow rails were known to prefer habitat in northern Lake of the Woods County in Minnesota. Rough estimates suggest 115-125 pairs in total for Central

Ontario and Rainy River region in the 1990s, with 4-6 identified summer locations (Alvo & Robert 1999). It is important to note that there is significant evidence proving continuous habitat decline for the yellow rail. In the past, yellow rails in the Rainy River region have lost numerous small (3-4 hectare habitat) sites due to wetland drainage. The yellow rail is one of the least understood North American birds due to its secretive behaviour. It is particularly valued by birders because of its rarity (Alvo & Robert 1999), as they are seldom seen without special effort and are mostly detected by their call; a repeated pattern of two, then three clicks: *tic–tic, tic–tic–tic* (COSEWIC 2009).

Overall, there appears to be no identification of specific critical habitat requirements for the yellow rail and it has not been covered in recovery strategies. The yellow rail could benefit from night surveys designed to monitor population sizes in order to improve conservation efforts with a better understanding of its habitat suitability and related variables (Martin 2012).

Key Habitat Values

The yellow rail prefers shallow standing water habitats with monotypic stands of sedges and or grasses (James 1985). They prefer the higher drier margins of fresh and brackish water marshes with dense, fairly low herbaceous vegetation with little standing water (Alvo & Robert 1999). The yellow rail is a secretive bird that is extremely difficult to observe (Leston & Bookhout 2015). Habitat selection might be influenced primarily by plant physiognomy and maximum water levels; the following list comprises key habitat values derived from Alvo & Robert (1999).

- Little to no standing water, 0-12 cm
- Breeding sites can vary from 0.5 ha, several 2 – 3 ha sites, and greater than 10 ha
- Marshes dominated by sedges, true grasses, and rushes, particularly by fine-stemmed emergents of the genera *Carex, Spartina, Juncus, Calamagrostis, Scirpus, Eleocharis,* and *Hierochloe*

THREATS TO WATERBIRDS AND WETLANDS

Predictions suggest that during the next 100 years even greater changes will occur and put increasing pressure on waterbirds, wetlands and biodiversity. For global wetlands, it has been estimated that over 50% of inland sites have been lost since 1900 (O'Connell 2000). The main cause of wetland loss is conversion into agricultural systems. There are three common themes that describe issues for the conservation community in relate to the loss and degradation of wetlands and their biodiversity: (1) a lack of quantitative data for wetland loss or degradation from most regions of the world, (2) a continued loss of wetlands and in some areas an accelerating loss, (3) a need for greater capacity to develop sustainable strategies to halt wetland losses while incorporating the needs of local people (O'Connell 2000). A range of human activities pose potential threats to wetlands and their biodiversity (Table 1). The loss and degradation of wetlands has had major effects on waterbirds that utilise these systems for all or part of their life cycle. This threat, habitat loss or degradation, affects 84% of IUCN Red list anseriform species, followed by unsustainable hunting (64%) and the effects of introduced species (31%) (O'Connell 2000).

Table 1. Human activities and associated potential threats to wetlands and their biodiversity (O'Connel 2000)

Human Activities		Associated Potential Threats				
		WA	WR	WQ	UE	AS
Water use	Abstraction	*	*			
	Diversion	*	*			*
	Channelisation	*	*			
	Impoundment	*	*	*		*
	Flood Defences	*	*			
Agriculture fisheries & forestry	Reclamation	*	*		*	
	Drainage	*	*			
	Abstraction	*	*			
	Diversion	*	*			
	Channelisation	*	*			
	Toxic chemicals			*		
	Organic inputs			*		
	Nutrient inputs			*		
	Atmospheric deposition			*		
	Use of non-native species			*		*
	Harvest of natural resources				*	
	Coastal defences	*	*			
Industry	Reclamation	*	*			
	Atmospheric deposition			*		
	Chemical deposition			*		
	Disturbance	*				
	Coastal defences	*	*			
Urbanisation	Reclamation	*	*		*	
	Atmospheric deposition			*		
	Abstraction	*	*			
	Nutrient inputs			*		
	Effluent inputs			*		
	Chemical deposition			*		
	Waste	*	*	*		
	Disturbance	*				
	Non-native species			*		*
	Coastal defences	*	*			
Mining	Reclamation	*	*		*	
	Drainage	*	*			
	Chemical deposition			*		
Recreation	Water sports	*		*		
	Hunting			*	*	*
Others	Peat removal	*	*	*	*	
	Aquaculture	*		*		*

WA = changes in wetland area; WR = changes in water regime; WQ = changes in water quali
unsustainable exploitation; AS = introduction of alien species.

The impacts of climate change presents a great challenge of balancing current species conservation needs while predicting and planning for unknown responses in the future (Langham et al. 2015). Human-induced climate change is progressively recognized as a central driver of biological process and patterns. Climatic changes have historically shown to have caused shifts of species geographic ranges, and it is predicted that there will be even greater redistributions of species with future climate change (Langham et al. 2015). Recent climatic change data from 1980-2015 has shown that climate warming has significantly reduced the amount of water and has shifted the seasonality of water into wetlands, as well as notable changes in waterbird species composition over time (Haig et al. 2019). It is critical to include climate sensitivity into current conservation planning in order to create adaptive management plans that will accommodate changes like the shrinking and shifting of species geographic ranges (Langham et al. 2015).

In several bird species, habitat changes permit a measure of habitat preference and adaptability (Weller & Spatcherm1965). More specifically in marsh habitats, short-term fluctuations and conditions appear more common as a result of rainfall changes and subsequent water level changes. Hemi-marsh conditions are ideal for most whereas dry and wet open stages are the least productive for marsh birds. Marsh bird populations are characterized by pioneering ability, mobility and adaptation to different habitat conditions (Weller & Spatcher 1965). *"Understanding changes in environmental conditions at multiple spatial and temporal scales is essential for regional habitat conservation planning and for evaluating the status of hemispheric migratory* *pathways"* (Haig et al. 2019). A variety of marsh sizes and types in an area is vital for the preservation of marsh bird diversity (Weller & Spatcher 1965).

Bird populations are being both positively and negatively affected by climate change; changes in temperatures and weather patterns, timing and extent of precipitation and frequency and severity of extreme weather (Sutherland et al. 2012). Anthropogenic global climate change indirect effects can be seen with prey availability, predation effects, land-use change, seasonal wetland conditions and the matching of the timing of arrival dates (Sutherland et al. 2012).

Canada's boreal forest houses the world's largest concentrations of surface water (Casey-Lefkowitz et al. 2011). When looking at the important wetlands and waterways in Canada, there are three critical habitat areas; the Hudson Bay and James Bay Lowlands, the Peace-Athabasca Delta, and the Lake Superior Watershed. Unfortunately, these waterways and wetlands are under increasing pressure causing increased habitat loss for bird populations across Canada, due to the impact of industry and current and future impact of global warming that is altering the integrity of North Americas wetlands and valuable waterway resources (Casey-Lefkowitz et al. 2011).

Climate change models are predicting much warmer and drier summers for the boreal forest region (Casey-Lefkowitz et al. 2011) including Lake of the Woods. In addition, there will be more fires and more desiccation of wetlands that are critical to many North American wildlife species. Climate change models are ultimately predicting that these changes, as well as current industrial activity will pose threats for these important breeding sites and the inhabitants of the wetlands (Casey-Lefkowitz et al. 2011). MNRF professionals in Kenora have many responsibilities related to the current climate change issues including detecting exploitation, studying the effect of changing water levels and acidification and watching for shoreline development and invasive species (Lund 2002). It is important to note that in 1989 there were three metre water fluctuations that resulted in numerous small islands and rocky outcrops turning into nothing but submerged reefs (Conway 1995). Record high water in 2011 proved loons to have difficulty constructing nests on waters edge presumably effecting their population (Lund 2002).

Given the nature of complex climatic effects it has been proven difficult to predict the response of these interactions on species, although changes to date are beyond the expected natural variability (Sutherland et al. 2012; Jordan 2017). An increase in temperature is one of the main features of climate change. The boreal zone including Lake of the Woods, as well as the Arctic are anticipated to experience the fastest changes in relation to climate warming. Specifically, these two regions are used by many waterbird species as main breeding grounds, including the piping plover, black tern, yellow-headed blackbird and yellow rail. Any variation in temperature change can have a profound impact on birds. Waterbirds will be specifically impacted as most of them are migratory species that are more vulnerable to the asynchrony of these changes (Jordan 2017). More analyses of current data is needed to assess future climate change impacts on bird populations (Sutherland et al. 2012).

WHY MONITOR WATERBIRDS

Monitoring serves two primary functions, (1) providing data needed to inform management decisions based on resource status and (2) the analysing of monitoring data can help identify the causes of demographic changes and provide improved basis for future habitat management decision-making (Soulliere et al. 2007). Many waterbirds are considered keystone species that have crucial ecological roles in functioning ecosystems, as well as a high economic and societal importance (Jordan 2017). Waterbirds are one of the most visible and diverse components of wetland and lake ecosystems. They are effective sentinels for both acute environmental insults (chemicals, oil spills, diseases) and long-term changes in the environment (wetland degradation, loss of fish stocks and climate change) (Watts 2013). The status of waterbirds is also of recreational and aesthetic interest to the public, as a general interest to society and a driver of local economies. Moreover, waterbirds provide other ecosystem services that are beneficial and enhance people's welfare and daily life, including: bird-watching, ecotourism or enhancement of recreational areas (Jordan 2017).

There are three broad classes of rationales or needs for local conservation monitoring including: (1) regulatory mandates, (2) contributions to range wide population objectives and (3) informing local management (Watts 2013). This typically applies to species with a high conservation priority, and or species with nuisance or hunting status. Monitoring may be a legal requirement for many species that have formal legal protection under federal or state/provincial statue. Information from monitoring is often essential for local planning and management, and typically supplies the metric of success for adaptive management programs (Watts 2013).

As one of the best-studied groups in the world, birds offer an opportunity to model climate change responses for a taxon at wide geographic ranges and spatial resolution (Langham et al 2015). Birds are reasonable indicators and proxy for the implications of climate changes for all wildlife in north America as they are so widespread and cover a variety of habitats (Langham et al. 2015). Canada's boreal forest wetlands and waterways are critical habitat for waterbird species as it serves as prime breeding habitat (Casey-Lefkowitz et al. 2011). Waterbirds can be defined as a wide range group of distantly related species from loons to gulls (Casey-Lefkowitz et al. 2011). Waterbirds are considered indicators of wetland health and biodiversity and their abundance and diversity are often used as criteria to identify and quality important or protected (wetland) areas (Jordan 2017). Waterbirds have become a 'flagship community' for leveraging wetland conservation management strategies, more specifically for the habitats under rapid environmental change (Ramírez et al. 2018). A flagship species can be defined as a high profile interesting species that has important ecological roles with cultural associations. It is based of a concept that by raising the profile of a particular species, it will increase public awareness for conservation and protection of the species' habitat (Schlagloth et al. 2018). There are a number of key attributes associated with effective (wildlife) bio-indicators. For example, they should be quantitative, simplifying, user driven, policy relevant, scientifically credible, responsive to changes, easily understood, realistic to collect, and susceptible to analysis (Gregory, et al. 2003). As stated by Ramírez et al (2018),*"…waterbird communities, which are composed of species with different ecological needs and conservation requirements, are extremely sensitive to changes in the availability of suitable and heterogeneous wetland habitats".* There are three different approaches to generate an indicator species. The first approach is to measure diversity through time, where species loss or gain can be used to assess biodiversity trends (Gregory et al. 2003). Secondly, to determine the passage of species through categories of conservation which is best for one's interest in rare or endangered species. Lastly, the third approach would be to use a mean index of change taken across the species which would overall fulfil several criteria for a wildlife indicator (Gregory et al. 2003).

In a large-scale situation, the response of species to climate change can be a poleward expansion or altering geographic ranges in search for more ideal habitats (Society for Ecological Restoration Inernational 2009). Environmental changes are now accelerating quickly, and individual species or whole species assemblages are now threatened with extinction without the possibility to avoid population declines by adapting, expanding range or migrating elsewhere (Society for Ecological Restoration Inernational 2009). The changing availability of migratory pathways such as wintering, stopover, and breeding locations relates to migratory shorebirds and the climatic effects they are facing now and, in the future (Sutherland et al. 2012). The loss of migratory locations can greatly affect whole populations that depend on these pathways during annual migrations. Although bird have the ability to successfully shift migratory behaviour, the lack of alternate available locations would also have to be considered for these birds to exploit (Sutherland et al. 2012). Migratory waterbirds (waterfowl, shorebirds, wading birds) are undergoing significant population declines due to large-scale climate-induced habitat changes in degraded North American migratory stopover sites (Haig et al. 2019).

ECOLOGICAL RESTORATION

Natural systems themselves can alter with time by external forces such has flooding, drought, fire, exotic species, global climate change and more (Society for

Ecological Restoration International 2008a). A checklist can be helpful for assessing the viability and chances for a successful ecological restoration project. The checklist includes, (1) Timing and levels of funding, (2) Setting and meeting interim and final goals, (3) Nature and status of the federal-state partnership, (4) Quality of the science and its integration in decision making, (5) Conflict management and resolution, (6) Building and maintaining public awareness and support (Society for Ecological Restoration International 2008a). Regulations and incentives should be applied for commercial fishermen (Society for Ecological Restoration International 2008a), shoreline residents, and others who's work may impact or be impacted by Lake of the Woods. An ecological analysis of Lake of the Woods Provincial Park is needed to determine issues and develop solutions. An ecosystem-wide approach recognized the complex interactions of Chesapeake Bay and it would also be beneficial to apply it to a large-scale freshwater lake like Lake of the Woods. Forests and wetlands adjacent to waterways is critical to the entire body of water's ability to sustain its living resources.*"Land can be protected permanently with a perpetual conservation, and open space easement or fee ownership controlled by a federal, state, local government, or non-profit organization"* (Society for Ecological Restoration International 2008a). Local community programs can work with municipalities to employ practices along with the coordination and cooperation of all levels of government to achieve long term goals (Society for Ecological Restoration International 2008a).

For Lake of the Woods, a program should be created to carry out a large in-depth study of the environmental health, report the findings and indorse ways to improve the management of biotic and abiotic aspects (Society for Ecological Restoration International 2008a). According to past successful restoration project at Chesapeake

Bay, the most critical elements in the overall protection and restoration include 6 goals; (1) Water quality protection and restoration, (2) living resource protection and restoration, (3) vital habitat protection and restoration, (4) sound land use, and lastly (5) stewardship and community engagement (Society for Ecological Restoration International, 2008a). The long-term protection of the natural landscapes like open water, marshes, wetlands, streams and forests support living resource abundance and provide key food and vital habitat for Lake of the Woods Provincial Park.

MATERIALS AND METHODS

For materials I will be using a variety of texts including publications by the Society for Ecological Restoration International, Lake Superior Binational Program and Great Lakes Restoration to assist with the planning of a long term, full recovery and large-scale restoration project. I will also be using models like Climate Vulnerability maps created by the National Audubon Society to prove how the piping plover, black tern, yellow-headed black bird and yellow rail ranges will shift, expand and contract under increased global temperatures. I will be discussing how Audubon created the following maps, along with the information they used including Bird Data, Climate Data, Emissions Scenario and Climate Change Models and Uncertainty.

AUDUBON: CREATING THE MAPS

The National Audubon Society has completed a continental analysis of how North America's birds may respond to future climate change (National Audubon Society 2014). The created maps look similar to the species range maps, but they differ in significant ways. The following maps indicate climatic suitability for a species or group of species rather than just showing the geographic limits of a species distribution. They used extensive citizen science data and detailed climate layers and developed models to characterize the relationship between species distribution and climate. Computer modeling was used to relate historical bird observations from the Audubon Christmas Bird Count (CBC) and the North American Breeding Bird Survey (BBS) to a suite of climate variables. The models were then used to forecast species distributions to future time periods based on climate estimates (described by the Intergovernmental Panel on Climate Change (IPCC)). Three topics of general interest for broad-scale bird conservation were addressed: (1) the impact of climate change on bird diversity in the US and Canada, (2) identification of areas that are expected to remain important to birds under the present and future climate and (3) in-depth analyses of potential climate change impacts on 314 species.

Audubon's Conservation Science team has generated three data products: (1) Climate Sensitivity Lists, (2) Individual Species Modeled Climatic Suitability and (3) Climate Prioritizations as shown below on pages 56-60. Audubon scientists built a climate profile of each bird species across a spectrum of temperature, precipitation, and seasonality variables. The created models describe the relationship between bird occurrences and the climate space that favours each species. The results estimate climatic suitability in summer and winter for each bird species for every 10 x 10 km grid cell across North America (National Audubon Society 2014). The value of each grid is a probability of occurrence based on climatic suitability of the species. The strength of the colour represents the probability values. This data is available as animated illustrations on the Audubon's website. The prioritizations highlight areas likely to offer suitable climates for single species or multiple species currently and into the future. This data can also be used to strengthen the justification for projects already in process and to identify new areas that are in need of conservation attention (National Audubon Society 2014).

Bird Data

Bird distribution was obtained from Audubon Christmas Count (CBC) and the North American Breeding Bird Survey (BBS). The CBC is a long-standing National Audubon Society program with more then 100 years (since 1900) of citizen science involvement. The CBC is an early-winter bird census across the U.S, Canada and other countries in the Western Hemisphere that go out over 24-hour periods to count birds with thousands of volunteers. CBC surveys are conducted within 24.1 km diameter circles for one 24 h period during a two-week interval that is centered on December 25. (National Audubon Society 2014). The BBS is a long-term and large-scale international avian monitoring program that began in 1966 in order to track the status and trends of bird populations in North America. It was initiated for the purpose of monitoring bird populations in the summer months. The USGS Patuxent Wildlife Research Center, the Canadian Wildlife Service and the National Wildlife Research Center jointly coordinate the BBS program. The survey routes are 24.5 miles long with stops at 0.5-mile intervals, where 3-minute point count and records of birds seen or heard are conducted at each stop. For these map analyses, data for the fist 30 stops (~24 km) were used to balance efforts between CBC and BBS. In reference to climate sensitivity, species were classified based on projected impacts of climate change on their current and future range. For example, Audubon classified species as climate endangered, climate threatened, data deficient or climate stable (National Audubon Society 2014).

Climate Data

Climate data was obtained from the Canadian Forest Service (CFS) website for the mid-point of each CBC circle and to the start-point of each BBS route. Bird data and climate data was matched on an annual basis assuming that climate variables from the year leading up to each survey would best inform an understanding of occurrence data. Climate data for the year prior to a CBC survey event includes monthly climate data from that winter's survey since each CBC survey data is considered as of January 1st following December counts. Therefore, climate parameter also include indices of minimum and maximum monthly temperatures, precipitations and mean variables. Bioclimatic models, also known as species distribution model, were also formulated using a modeling algorithm to describe relationships between geographically coincident environmental variables and bird occurrence data. This statistical model was used to characterize relationships between species presence and absence based on CBC or BBS data. This resulted in predictive distribution maps that describe geographic areas that are suggested to be climatically suitable for the bird species. CBC and BBS data was used to separate bioclimatic models for winter and summer seasons. There was sufficient data to construct models for 543 species of wintering birds that represents 90% of the species from 1950-2010 with at least one count in a CBC circle (National Audubon Society 2014). Earlier time periods were also used to assess the predicative ability of the models. By validating models using CBC data from different time periods, it reduced the sample sizes depending on information available.

Emissions Scenario

The emissions scenario predicts a future trajectory for greenhouse gas emissions in the 21st century. There are three future emissions scenarios, each informed by multiple general circulation models. Scientists agree that immediate action should be taken to hold warming at 1.5°C or increasingly fire consequences will follow. If nothing is done, 1.5°C is imminent, 2°C can happen as soon as 2050 and 3°C by 2080 (National Audubon Society n.d.). These scenarios reflect assumptions about the pace and distribution of global economic development based off the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report (AR4). To deal with uncertainty, analyses are based on possible emission scenarios and General Circulation Models (GCMs) for North America (National Audubon Society 2014).

Climate Change Models and Uncertainty

All developed models that consist of predictions about the future entail uncertainty. Sources of uncertainty include the previously discussed emissions scenarios and variation across future time periods including 2020s, 2050s, 2080s (National Audubon Society 2014). The best hope for making sound conservation decisions is to account for uncertainty. The three major sources of uncertainty to consider when forecasting species response to climate change are: (1) future climate uncertainty, (2) modeling uncertainty, and (3) biological uncertainty. Biological uncertainty is captured in the prioritization by treating future climatically suitable range as (1) opportunity, (2) risk and (3) ignoring it. These correspond to the biological responses: “track and move”, “suffer in place”, and “adapt in place”. In addition, the three prioritizations are built for each season including summer and winter, which are combined by taking the maximum score for any grid cell across all prioritizations and rescaling the result between 0 and 1.

Climate Vulnerability Maps

The following Climate Vulnerability Maps (National Audubon Society 2014) (Figures 8-23) were used to demonstrate the changes that the piping plover (PIPL), black tern (BKTN), yellow-headed black bird (YHBK) and yellow rail (YERA) ranges will go through under increased global temperatures. The species overall vulnerability status (Stable, Moderate and or High) is shown in relation to how much of their range is lost, maintained or gained. The Lake of the Woods area is outlined with a black square to highlight changes made in that region through different warming scenarios.

Piping Plover: Climate Vulnerability Maps (National Audubon Society n.d.)

Range gained · Improving · Slightly improving · Stable · Slightly worsening · Worsening · Range lost · Range maintained

(Sibley n.d.)

Figure 8. PIPL Warming Scenario: Current

Overall species vulnerability status:

Stable

100% range maintained

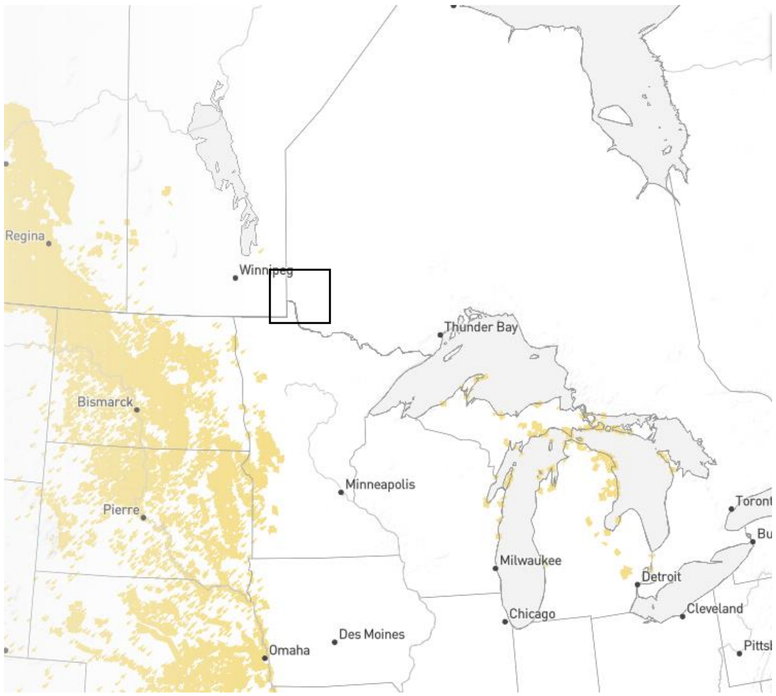


Figure 9. PIPL Warming Scenario: +1.5℃

Overall species vulnerability status:

Moderate

38% range gained

38% range maintained

62% range lost

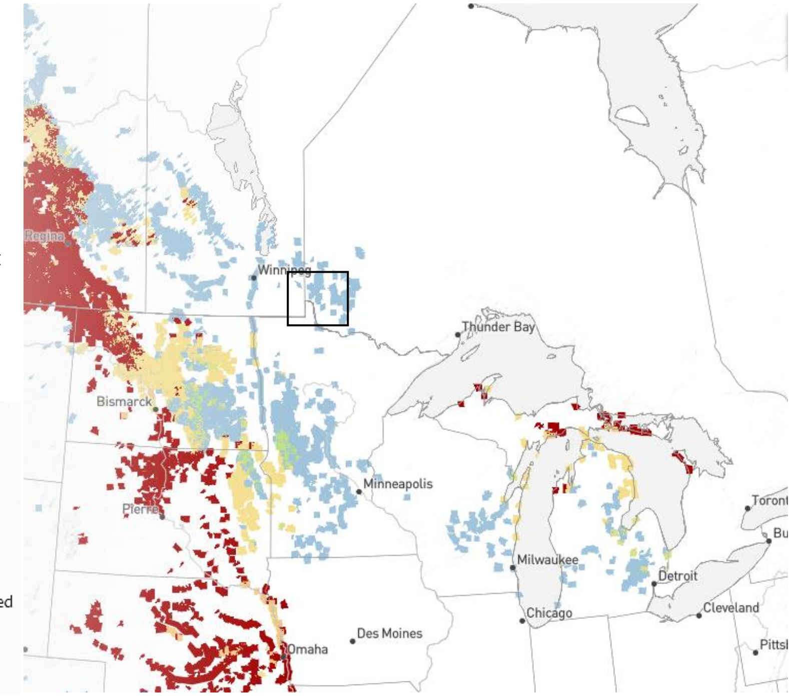


Figure 11. PIPL Warming Scenario +2.0℃

Overall species vulnerability status:

Moderate

39% range gained

26% range maintained

74% range lost

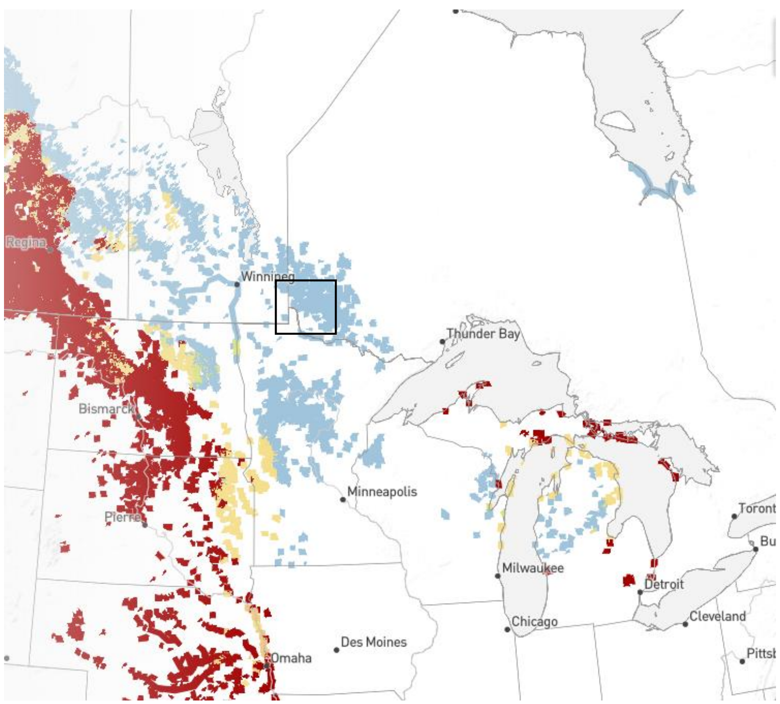


Figure 10. PIPL Warming Scenario +3.0℃

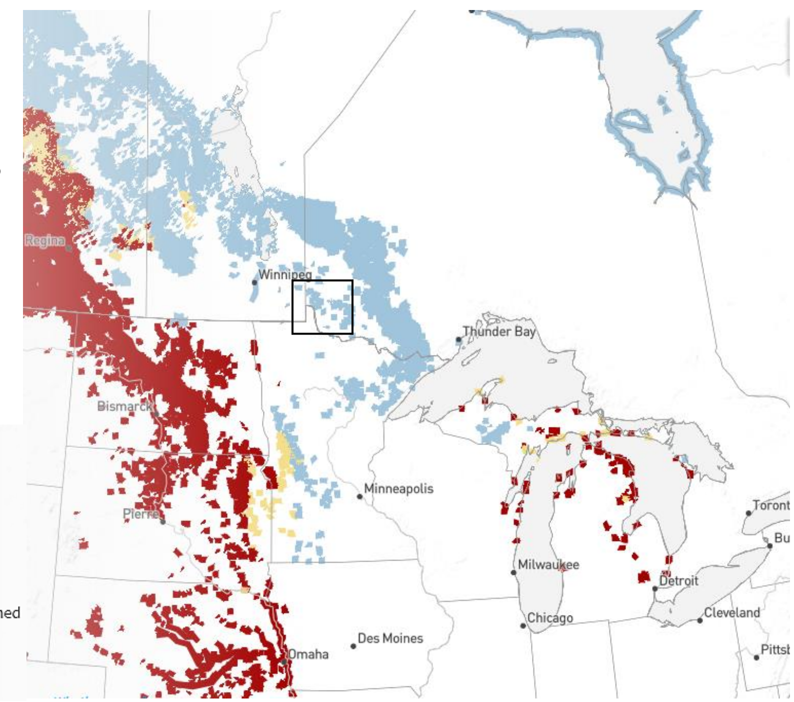
Overall species vulnerability status:

High

59% range gained

13% range maintained

87% range lost



Black Tern: Climate Vulnerability Maps (National Audubon Society n.d.)

(Sibley n.d.)

Range gained · Improving · Slightly improving · Stable · Slightly worsening · Worsening · Range lost · Range maintained

Figure 11. BKTN Warming Scenario: Current

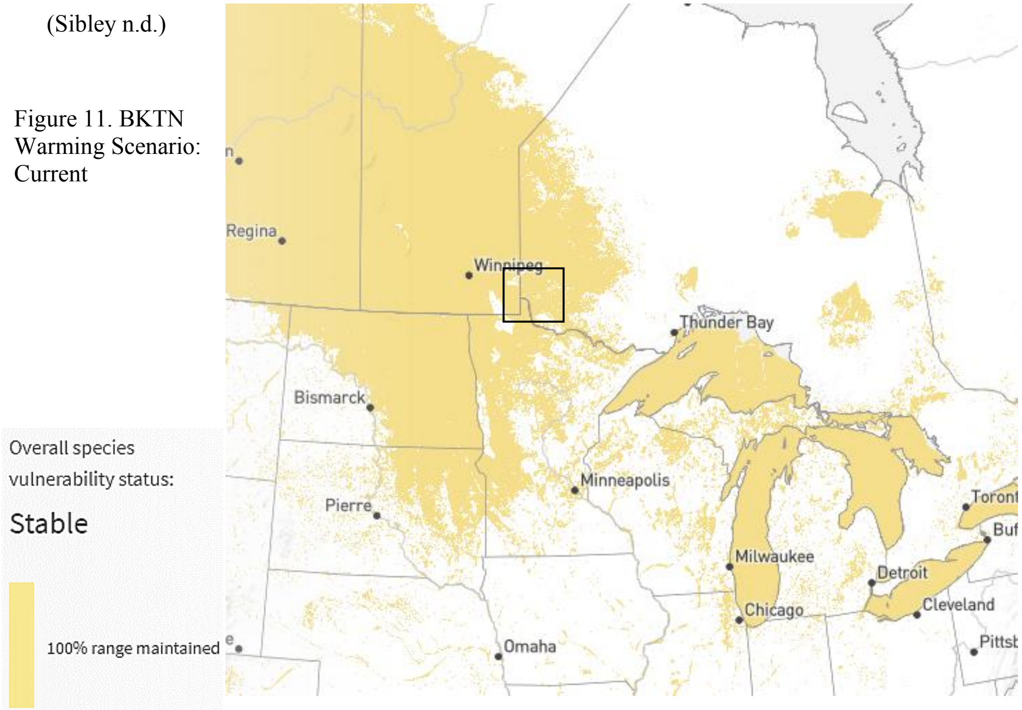


Figure 12. BKTN Warming Scenario: +1.5°C

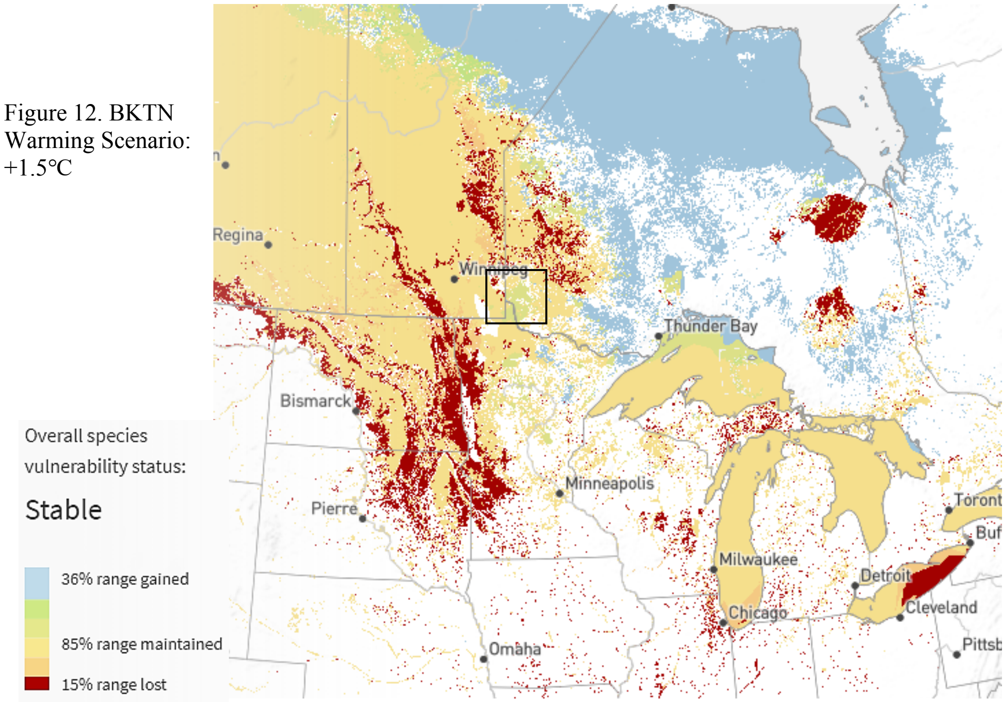


Figure 13. BKTN Warming Scenario: +2.0°C

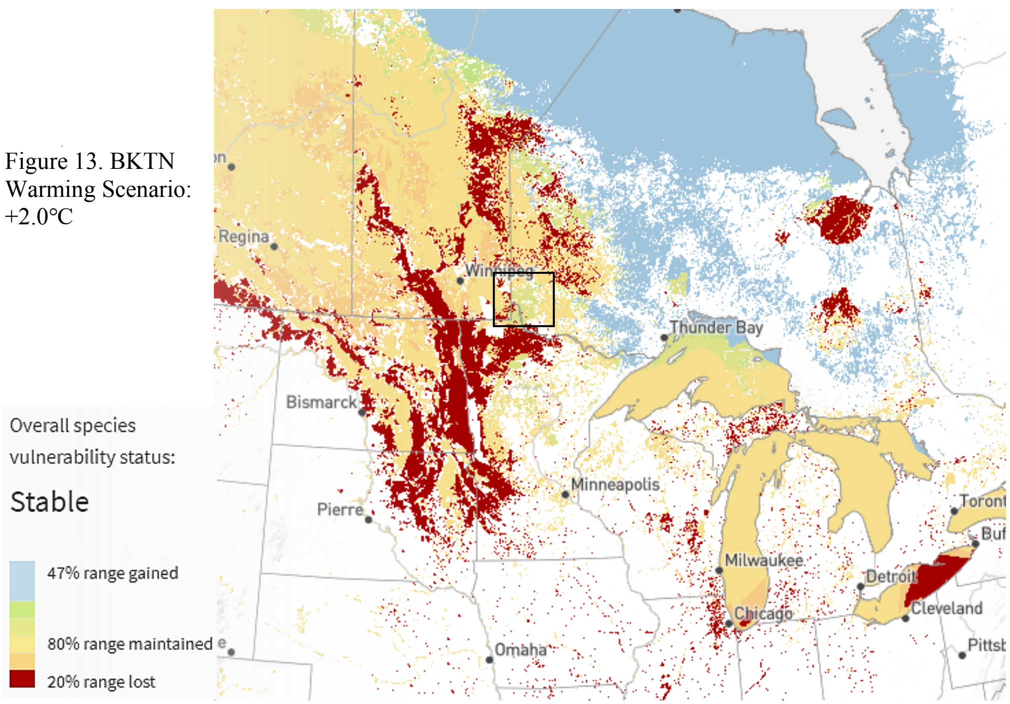
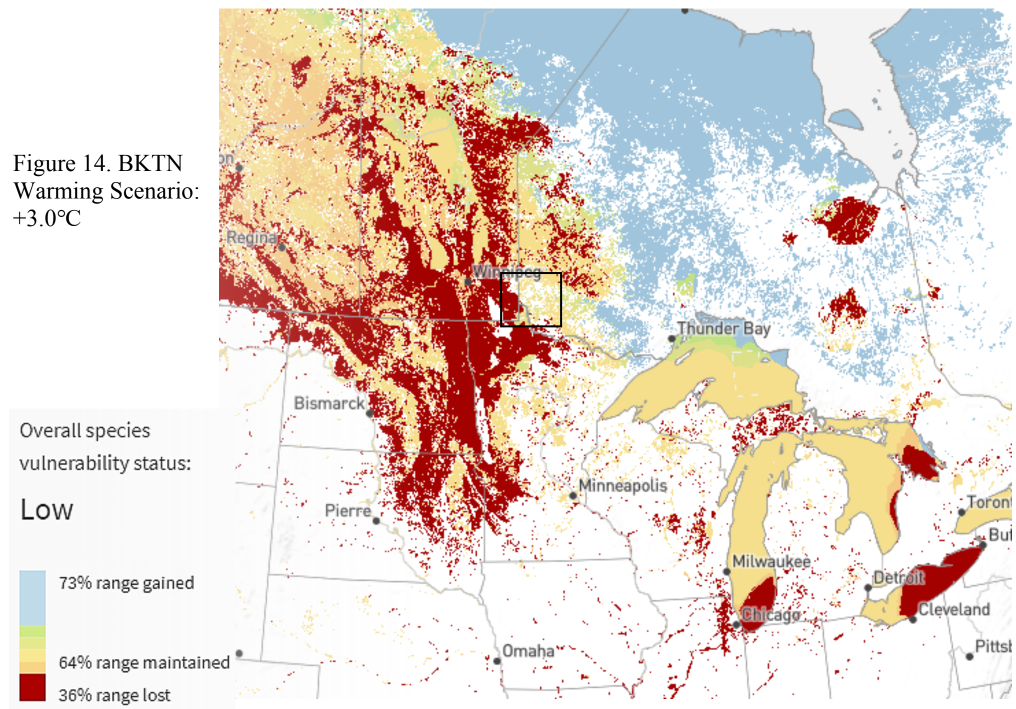


Figure 14. BKTN Warming Scenario: +3.0°C



Yellow-headed Blackbird: Climate Vulnerability Maps (National Audubon Society n.d.)

(Sibley n.d.)

Range gained · Improving · Slightly improving · Stable · Slightly worsening · Worsening · Range lost · Range maintained

Figure 15 YHBK Warming Scenario: Current

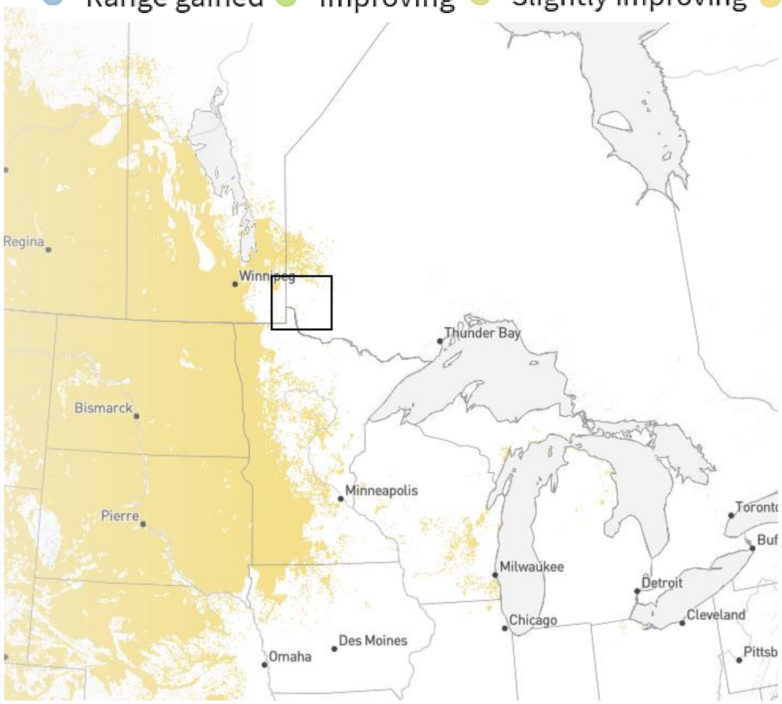


Figure 16. YHBK Warming Scenario: +1.5°C

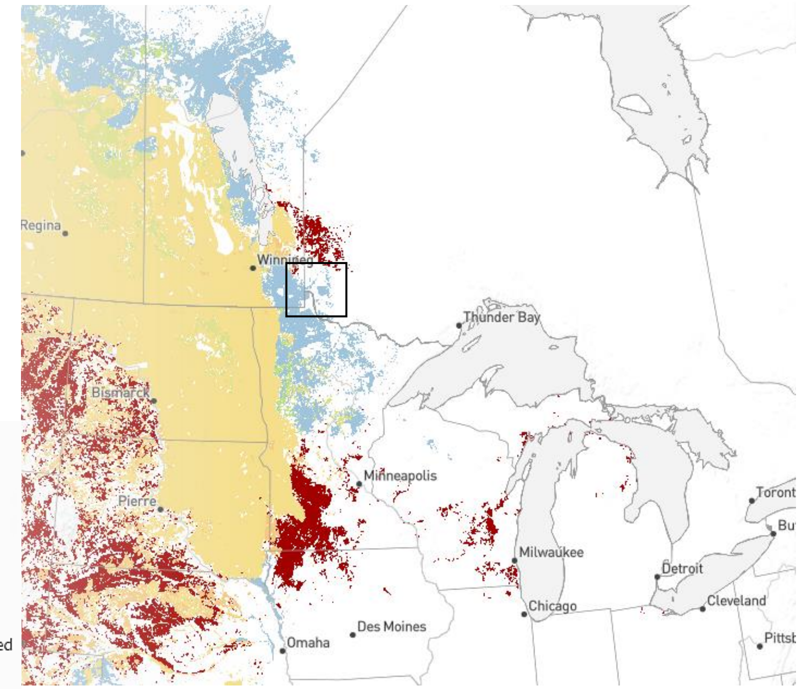


Figure 18. YHBK Warming Scenario: +2.0°C

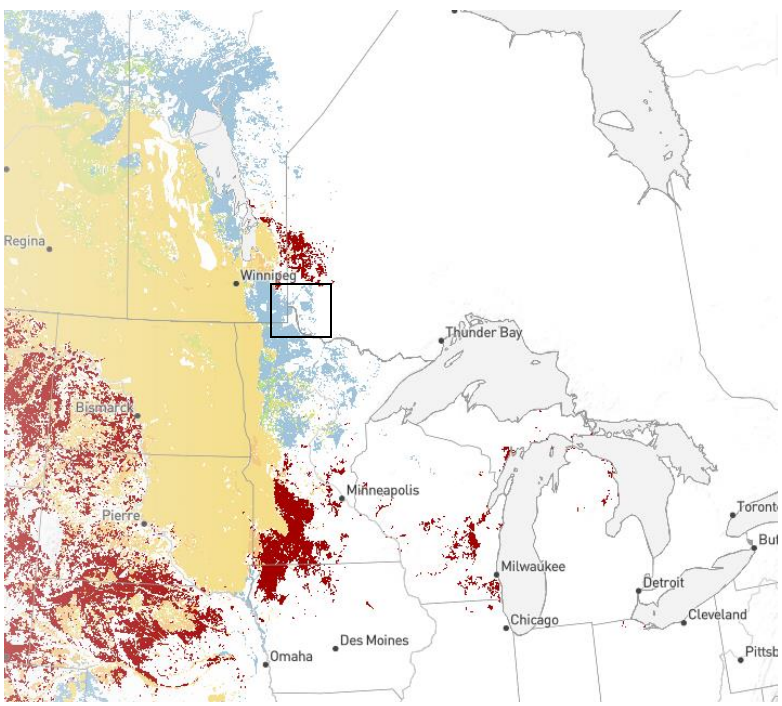
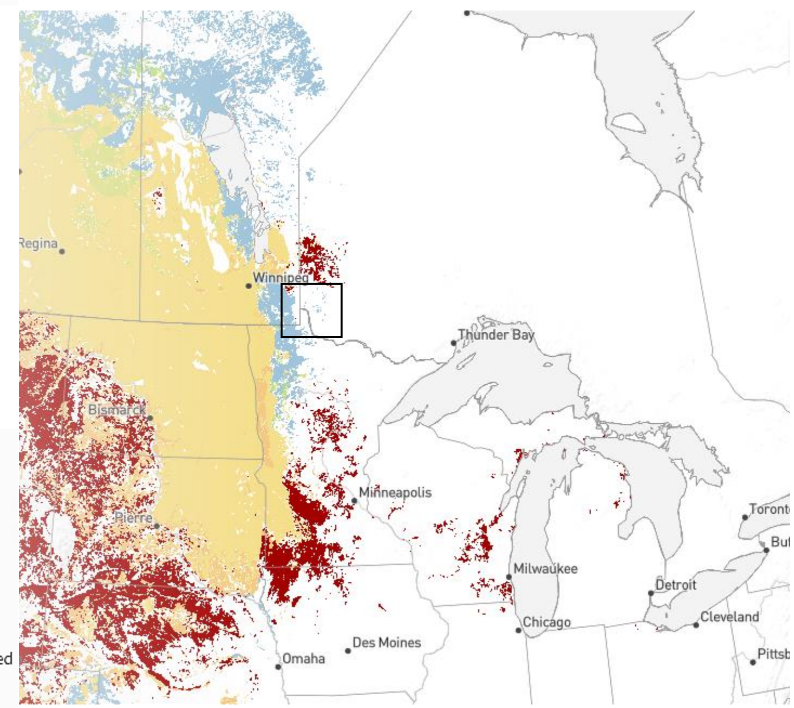


Figure 17. YHBK Warming Scenario: +3.0°C

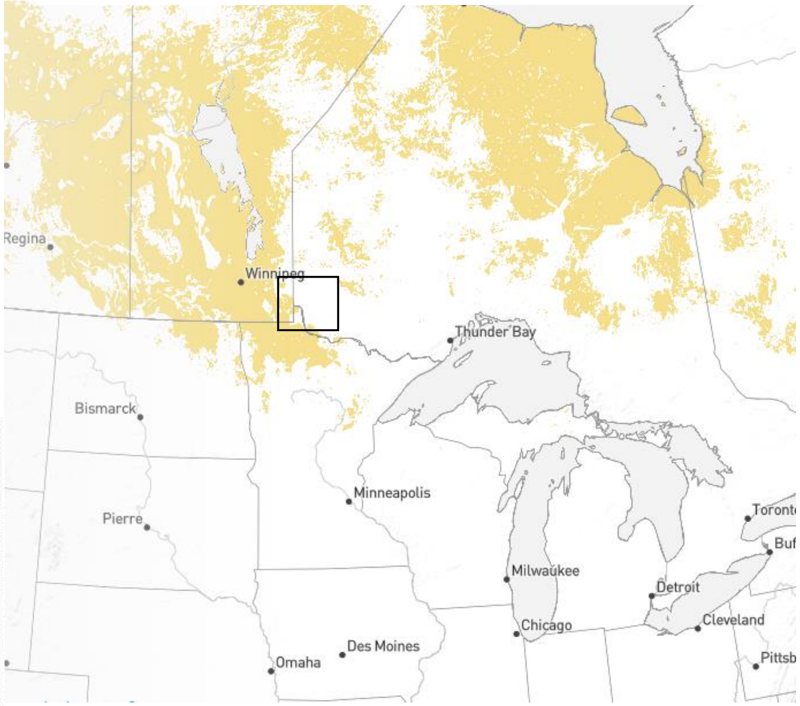


(Sibley n.d.)

Yellow Rail: Climate Vulnerability Maps (National Audubon Society n.d.)

Range gained · Improving · Slightly improving · Stable · Slightly worsening · Worsening · Range lost · Range maintained

Figure 20. YERA Warming Scenario: Current

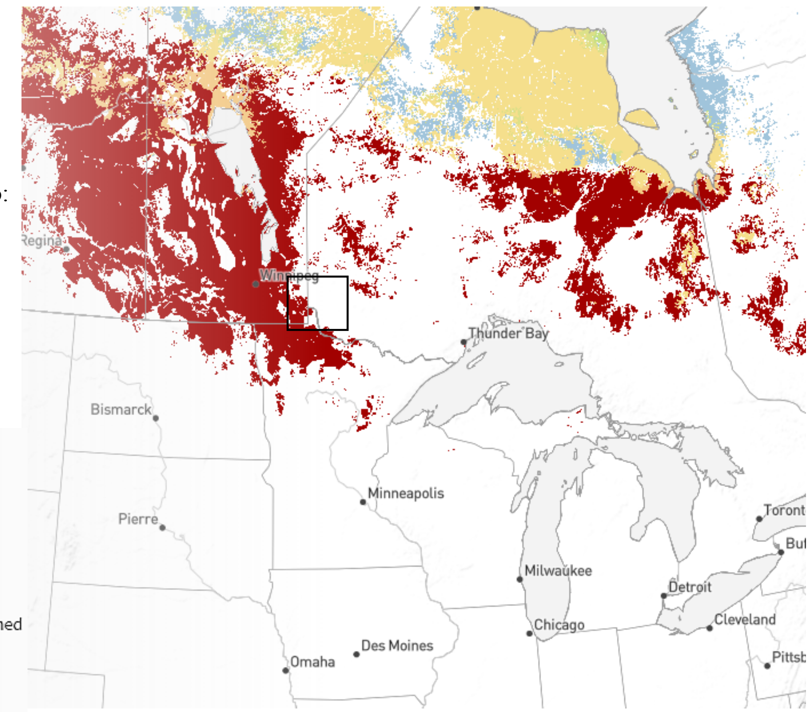


Overall species vulnerability status:

Stable

100% range maintained

Figure 19. YERA Warming Scenario: +1.5°C

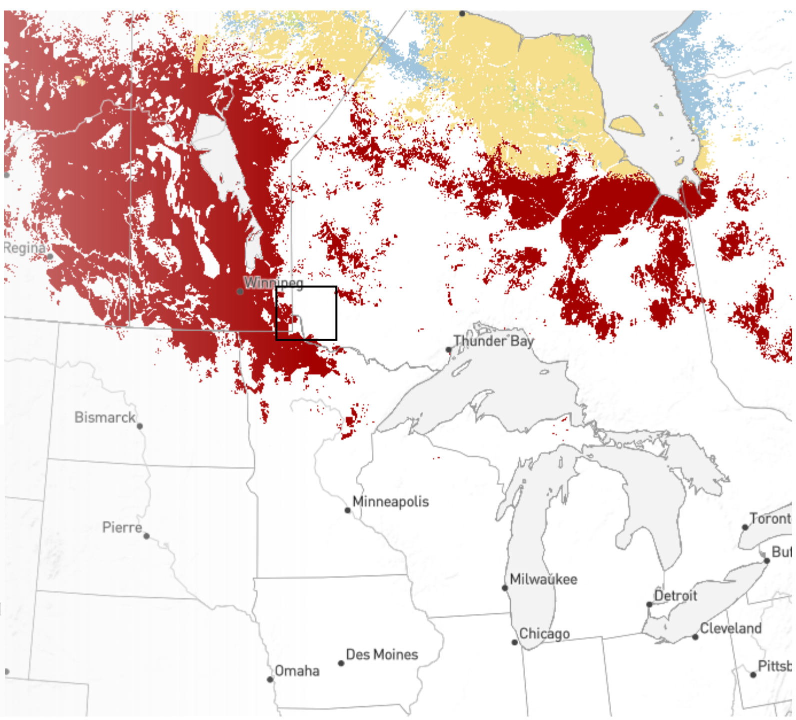


Overall species vulnerability status:

High

18% range gained
44% range maintained
56% range lost

Figure 21. YERA Warming Scenario: +2.0°C

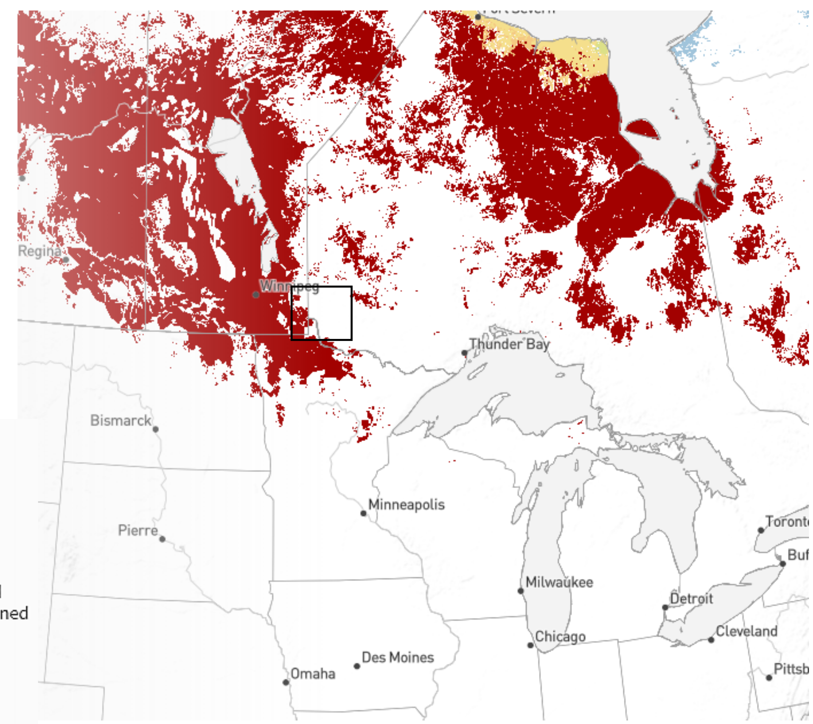


Overall species vulnerability status:

High

17% range gained
28% range maintained
72% range lost

Figure 22. YERA Warming Scenario: +3.0°C



Overall species vulnerability status:

High

17% range gained
5% range maintained
96% range lost

DISCUSSION

CLIMATE CHANGE & WATERBIRD DISTRIBUTIONS

Waterbirds may reduce their migration distance and spend the winter in newly available wintering grounds closer to the breeding sites (short-stopping). This is a direct result of the increase in temperature during winter months which can create new ice-free wetlands further north (Jordan 2017). The possibility of new wintering sites may result in a shift northwards of wintering ranges. However, waterbirds can adjust their migration to current weather conditions and move further southwest along the flyway during harsh winters or unexpected cold-spells (Jordan 2017). This spectacle has risen concerns about the effectiveness of the current network of protected areas. These protected areas are “static entities” that may fail to protect species like waterbirds as they alter their distributions in response to climate change.

Piping Plover

According to the Climate Vulnerability Maps (Figure 8-11), the piping plover will be gaining range within the Lake of the Woods area throughout each warming scenario. This is important information as restoration plans can be put into place to preserve breeding habitat for the piping plover, and mitigation measures for other areas that are predicted to lose range. Data on the piping plovers critical habitat can be used and implemented to preserve specific stopover and summer habitat. In the most extreme warming scenario of +3.0°C (Figure 11), the piping plover will be at a high vulnerability status because 87% of its range will be lost. However, a significant 59% of its range will be gained and 13% of its range will be maintained.

Black Tern

According to the Climate Vulnerability Maps (Figure 12-15), the black tern will be maintaining and losing range throughout the Lake of the Woods area in each warming scenario. With this predicted scenario, restoration plans can be implemented further north in areas with better wetlands and marshes to support this species in the future. In the most extreme warming scenario of +3.0°C (Figure 15), the black tern will be at a low vulnerability status because 73% of its range will be gained. Although, attention must be brought to the Lake of the Woods area which falls under 64% of its range being maintained and 36% of its range lost.

Yellow-headed Blackbird

According to the Climate Vulnerability Maps (Figure 16-19), the yellow-headed blackbird will be overall gaining range within the Lake of the Woods area with each warming scenario. This is vital data and can be used to optimize critical habitat for the yellow-headed blackbird in the future, and provided suitable breeding grounds in freshwater wetlands like Lake of the Woods. In the most extreme warming scenario of +3.0°C (Figure 19), the yellow-headed blackbird will be at a low vulnerability status because 78% of its range will be maintained and a significant 40% of its range will be gained. However, 23% of its range will be lost throughout important areas around the Great Lakes region and Lake Winnipeg area.

Yellow Rail

According to the Climate Vulnerability Maps (Figure 20-23), the yellow rail will be completely losing its range throughout the Lake of the Woods area in each warming scenario. With this predicted scenario, restoration plans can be implemented further north in the Hudson Bay area and places with suitable marshes to support this species in the future. In the most extreme warming scenario of +3.0°C (Figure 23), the yellow rail will be at a high vulnerability status because 96% of its range will be lost. In addition, only 5% of its range will be maintained and a small 17% will be gained far north of its current distribution.

RESTORATION PLANNING

A long-range restoration plan for Lake of the Woods Provincial Park is necessary to plan when considering the climatic effects impacting natural systems worldwide. A restoration plan will accelerate efforts to protect and restore hundreds of thousands of shorelines, freshwater inland lake habitat and island ecosystems. Hypothetically, undertaking a restoration plan at Lake of the Woods to protect existing natural resources and wildlife would be less costly then restoring a degraded area and resources (Great Lakes Restoration 2019). A restoration plan can be implemented similar to the Great Lakes Restoration Initiative (GLRI) Action Plan by Great Lakes Restoration (2019) by following 5 principles; (1) Accountability and Reporting, (2) Communication and Outreach, (3) Partnerships and Engagement, (4) Project Sustainability and (5) Science-Based Adaptive Management. In this case, part of this restoration plan will be based off the same two Focus Areas; Focus Area: Habitats and Species and Focus Area: Foundations for Future Restoration Actions (Great Lakes Restoration 2019).

Habitats and Species

The first objective of this focus area is to *"Protect and restore communities of native aquatic and terrestrial species"* (Great Lakes Restoration 2019) important to Lake of the Woods. This can be achieved by identifying critical habitats that support important wildlife species and indicators and take action to restore, protect, enhance, and or provide connectivity for these habitats. For example, the Great Lakes Restoration (2019) projects; "Bringing Back the Great Lakes Piping Plover" and "Coastal Wetlands Protection" are two past accomplishments that can also incorporated as future goals for Lake of the Woods. Examples of other projects that can be achieved include; restoring riparian habitat corridors and riverine wetlands associated with significant fish barriers, further connecting high-quality terrestrial and aquatic habitat area and reducing impacts of human activities such as trash, litter and debris in the waters.

The second objective of this focus area is to *"Conduct comprehensive science programs and projects"* (Great Lakes Restoration 2019). This can be achieved by assessing the overall health of the Lake of the Woods ecosystems and identifying the most significant remaining problems. In addition, cross-cutting science priorities should be identified and projects should be implemented to address those priorities. For example. Water quality and health can be tested near shorelines and far offshore to retrieve samples and sediments.

<u>Foundations for Future Restoration Actions</u>

The first objective of this focus area is to *"educate the next generation about the (Lake of the Woods) ecosystem"* (Great Lakes Restoration 2019). This can be achieved by supporting experience based learning opportunities for the youth and public to promote Lake of the Woods stewardship. For example, the youth can be impacted through education and stewardship projects and support stewardship, promote conservation, and expose and prepare under-represented youth for higher education opportunities in the field of natural resource management (Great Lakes Restoration 2019). Furthermore, educational activities can encourage opportunities to incorporate traditional ecological knowledge and cross-cultural learning.

Key Restoration Strategies

The Lake Superior Binational Program (2015) outlined key strategies of the Lake Superior Biodiversity Conservation Strategy that can be referred to for a potential restoration plan in Lake of the Woods (Lake Superior Binational Program 2015). These key strategies include:

Table 2. Key Restoration Strategies for Lake of the Woods (Lake Superior Binational Program 2015)

1. Restore and protect a system of representative, high-quality habitats
2. Manage plants and animals in a manner that ensures diverse, health and self-sustaining populations
3. Reduce the impact of existing aquatic invasive species and prevent the introduction of new ones
4. Adapt to climate change
5. Reduce the negative impacts of dams and barriers by increasing connectivity and natural hydrology between the lake and tributaries
6. Address other existing and emerging threats that may impact important habitat or native plant and animal communities

Restoration Strategy 1

According to the Lake Superior Binational Program (2015) Lake Superior Biodiversity Conservation Strategy, this strategy addresses the protection and restoration of biodiversity targets. This will overall ensure priority areas are protected and restored that represent a full spectrum of habitats. Below is a list of sub-strategies identified by the Lake Superior Binational Program (2015) and altered to fit a suggested Lake of the Woods restoration plan.

Strategy 1: Restore and protect a system of representative, high-quality habitats

- Restore or protect wetlands, native riparian forests and coastal habitats such as rocky shorelines, beaches and dunes
- Where feasible, restore habitats that have been degraded and have lost some of their ecological capacity to support fish and wildlife communities.
- Use special land and water designations to protect important habitat on public property.
- Develop and put into place a policy that results in zero loss of wetland areas and function within the basin.
- Educated and engage people about restoring or protecting important habitat and related ecosystem services.
- Develop comprehensive and detailed inventories of important fish and wildlife habitats and assess impacts to these degraded areas.
- Develop and distribute information and/or indicators on ecosystem conditions, trends and stressors and important restoration or protection sites.
- Maintain and share data through existing and new mechanisms, as appropriate.

Restoration Strategy 2

According to the Lake Superior Binational Program (2015) Lake Superior Biodiversity Conservation Strategy, this strategy addresses the importance for ensuring that species of concern receive direct management. This will overall focus on the health of selected species populations and groups (biodiversity targets) including fishes, colonial nesting waterbirds and coastal species. Below is a list of sub-strategies identified by the Lake Superior Binational Program (2015) and altered to fit a suggested Lake of the Woods restoration plan.

Strategy 2: Manage plants and animals in a manner that ensures diverse, healthy and self sustaining populations

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- Use local native species, to the extent possible, in restoration projects and natural resource management, supported by the development or maintenance of lists of the native species, use standards, sources and seed zones
- Implement native fish and wildlife species restoration, protection or rehabilitation plans, as appropriate
- Manage the harvest of fish, wildlife and plants to ensure their health, long-term sustainability and balance in the ecosystem
- Manage over-abundant populations of species where there is strong evidence of sustained detrimental effects on habitats and / or species diversity
- Educate citizens about the importance and appropriate use of local native plants in restoration and landscaping projects
- Undertake comprehensive biological surveys in the watershed to identify species of conservation interest and remaining natural communities
- Catalogue Lake of the Woods genetic diversity
- Develop and distribute information and indicators on species conditions, trends stressors and potential rehabilitation locations

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Restoration Strategy 3

According to the Lake Superior Binational Program (2015) Lake Superior Biodiversity Conservation Strategy, this strategy addresses the management of existing aquatic invasive species and the prevention of new introductions. Below is a list of sub-strategies identified by the Lake Superior Binational Program (2015) and altered to fit a suggested Lake of the Woods restoration plan.

Strategy 3: Reduce the impact of existing aquatic invasive species and prevent the introduction of new ones

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- Establish first response control protocols in anticipation of newly discovered aquatic invasive species
- Undertake actions that greatly reduce the risk of aquatic invasive species being transferred between Lake of the Woods, Lake Winnipeg, Rainy Lake, Lake Superior and other inland waters
- Perform best management practices to prevent aquatic invasive species introduction during dredging operation, lock operations, construction and other maintenance activities
- Use regulations, policies and best management practices to reduce the risk of introduction of aquatic invasive species by all possible pathways, including boaters, travel guides, equipment and bait dealers, plant nurseries, airplane charter companies and those who recreate in the water
- Protect exposed or seasonally exposed wetland environments from off-road vehicular use that may be a vector for invasive plants
- Undertake outreach, education and enforcement and research on preventing and managing aquatic invasive species
- Maintain a list of aquatic invasive species likely to reach Lake of the Woods and identify ecosystems that may be vulnerable to this under changing environmental conditions

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Restoration Strategy 4

According to the Lake Superior Binational Program (2015) Lake Superior Biodiversity Conservation Strategy, this strategy addresses the protection and restoration actions that support ecosystem resilience and adaptation. Adapting to climate change is a complicated problem that consists of direct impacts that can also amplify other threats. Below is a list of sub-strategies identified by the Lake Superior Binational Program (2015) and altered to fit a suggested Lake of the Woods restoration plan.

Strategy 4: Adapt to climate change
• Review, revise and implement adaptation actions, conservation, restoration and management plans, guidelines and regulations as required in response to projected climate change impacts (increased water temperatures, water levels, droughts, storm events, etc.) • Improve the incorporation of climate change information into the communications, management, technical assistance, science, research and development programs of parks and protected areas in Lake of the Woods • Undertake climate change education and outreach activities, with a focus on disseminating materials and information available from domestic climate change programs • Monitor the effectiveness of the Lake of the Woods Control Board (LWCB) (controlled water levels) in responding to changing climate conditions with regard to protecting and preserving Lake of the Woods inland island and coastal ecosystems • Use parks or sentinel sites as long-term integrated monitoring sites for climate change (monitoring of species, and species at risk) • Continue to support and enhance scientific research designed to understand resilience of ecosystems to climate change and other cumulative effects • Make climate models, scenarios and impact information available and accessible to those making large and small scale natural resource management decisions, growth plan decisions and soci-economic analyses • Conduct climate change vulnerability assessments for forests, fisheries, priority habitats and species, and nearshore water quality

Restoration Strategy 5

According to the Lake Superior Binational Program (2015) Lake Superior Biodiversity Conservation Strategy, this strategy addresses that dams and other barriers as the highest threats to water health including limiting the recovery of several fish populations. This strategy will overall support increasing the amount of available spawning habitats while considering the benefits of barriers to limit the spread of invasive species. Below is a list of sub-strategies identified by the Lake Superior Binational Program (2015) and altered to fit a suggested Lake of the Woods restoration plan.

Strategy 5: Reduce the negative impacts of dam and barriers by increasing connectivity and natural hydrology between the lake and tributaries

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- On a watershed scale, assess and prioritize habitat connectivity opportunities with consideration of the benefits versus the costs
- Protect and restore connectivity where appropriate, by removing dams, upgrading stream/road crossing infrastructure or by other means
- Adopt flow standards to sustain key environmental processes, critical species habitat and ecosystem services
- Pursue, continue or enhance sustainable hydropower planning the adequately protects aquatic ecosystems, habitats and species

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Restoration Strategy 6

According to the Lake Superior Binational Program (2015) Lake Superior Biodiversity Conservation Strategy, this strategy supports necessary actions around other key issues, emerging threats and adaptive management needs. This strategy will overall consider new energy infrastructure, mining or pollution. Below is a list of sub-strategies identified by the Lake Superior Binational Program (2015) and altered to fit a suggested Lake of the Woods restoration plan.

Strategy 6: Address other existing and emerging threats that may impact important habitat or native plant and animal communities

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- Track and reduce atmospheric deposition of persistent, bioaccumulative, and toxic pollutants from in-basin sources through research, voluntary action, and enforcement of controls and regulations
- Eliminate contaminants at levels that are harmful to plants, fish and wildlife by reducing non-point source pollution resulting from flooding, transportation and other sources
- Use only certified sustainable forestry practices in the Lake of the Woods basin
- Track and implement control and/or eradication plans, where feasible for terrestrial invasive species at appropriate geographic scales
- Research or monitor potentially new or emerging threats to the biological integrity of Lake of the Woods

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Partnerships and Engagement

It is important to consider the long-range aspect of a 100-year long restoration plan and other factors that will be contributing to the implantation, success and continuation. Partners, agencies, educators, students, volunteers and the public will likely need to be involved to promote and encourage a healthy and sustainable ecosystem within Lake of the Woods. In the Great Lakes Restoration (2019) Action Plan III there are several partners mentioned including: The Center for Great Lakes Literacy (CGLL), The Great Lakes Bay Watershed Education and Training Program (B-WET) and the National Park Service. A restoration plan within Lake of the Woods should emphasize public/private partnerships in Ontario, Manitoba and Minnesota as well as to work with tribal governments and indigenous communities to support priorities that are consistent with Lake of the Woods restoration plan goals and objectives.

Table 3. 10 principles for establishing partnerships between conservation objectives and the basic needs of local people (O'Connell 2000)

1.	Provide benefits to local people
2.	Meet local needs
3.	Plan holistically
4.	Plan protected areas as a system
5.	Plan site management individually, with linkages to the system
6.	Define objectives for management
7.	Manage adaptively
8.	Foster scientific research
9.	Form networks of supporting institutions
10.	Build public support

Improving wildlife habitat in the Lake of the Woods region for waterbirds is the ultimate goal of this long range restoration plan. A restoration plan in intended to provide information and guidance that will support the long-term protection and restoration of Lake of the Wood's habitat and species. In order to achieve that, there will need to be coordination between partners at local, provincial, state and federal levels. Below is a list of potential partners that would have the knowledge, experience and or funding to assist with a restoration plan and related elements:

- Natural Resources Conservation Service
- The Aldo Leopold Foundation
- The Nature Conservancy
- U.S. Fish & Wildlife Service
- U.S. Forest Service
    - Northern Institute of Applied Climate Science
- U.S. Geological Survey
- U.S. National Park Service
- United States Environmental Protection Agency
- United States Department of Agriculture
    - Natural Resources Conservation Service
- Minnesota Department of Natural Resources
- Minnesota Department of Environmental Quality
- Minnesota Land Trust
- University of Minnesota Sea Grant Program
- Great Lakes Indian Fish and Wildlife Commission
- Environment Canada
- Fisheries and Oceans Canada
- National Oceanic and Atmospheric Administration
- Ontario Ministry of Natural Resources and Forestry
- Ontario Ministry of the Environment and Climate Change
- Parks Canada

RESEARCH NEEDS

There are six broad categories where research is needed to provide information for the conservation of waterbirds and wetlands while providing solutions to social and economic development: (1) Inventory, (2) Assessment, (3) Monitoring & surveillance, (4) Human problems & solutions, (5) Habitat creation and lastly (6) Evaluating conservation strategies (O'Connell 2000).

Inventory

Inventory can be defined as *"the collection or collation of core information for habitat and species management, and to inform the assessment, monitoring and surveillance"* (O'Connell 2000). Despite the clear need for inventories, they are still not available for most wetland types in most parts of the world. In some instances, where wetland inventories have been attempted, the major problems and information has not been collected to a common standard, and the quality of data has not been assessed. Despite recent Geographical Information Systems (GIS) technological advances, it is difficult and, in some cases, not possible to accurately assess the total global resource of wetlands and measure change over time. This situation must be remedied to acquire data to be accessed, visualised, queried, manipulated and eventually updated to a conservation 'framework' of assessment, monitoring and surveillance.

Assessment

Assessment involves two major themes: (1) identifying the status of abiotic components within wetlands and (2) assessing the nature, distribution, causes and consequences of different threats to wetlands and waterbirds (O'Connell 2000). Assessment can take place at different levels (species, communities, populations, ecosystems) and at multiple spatial scales (individual sites, regions, national, total global resource). Additional work is needed on how to assess the status and distribution of wetland habitats, and to assimilate these cost-effectively into inventories. Scientific methods will need to be developed for quantitatively assessing the relative impact and distribution of a variety of threats in connection with understanding whether the impact is on species distribution and diversity or on ecosystem function (O'Connell 2000). These types of assessment that can be stored by a GIS inventory will provide useful information on gaps in monitoring and surveillance activities.

Monitoring and surveillance

Monitoring and surveillance is fundamental in developing conservation strategies to project wetlands and waterbirds from threats. Monitoring can be defined as *"the collection of data in response to hypotheses about a particular species or habitat that has been derived from previous assessment activities"* (O'Connell 2000). Whereas surveillance is not hypothesis driven and involves the collection of time series data for species and sites. Together, they provide quantitative and qualitative information or data about natural resources. The biggest challenge in relation to threats will be to link the demographic and distributional changes from the analyses of species and habitat monitoring and surveillance data, to the anthropogenic changes in the environment. A system will need to be developed to allow assessment, monitoring and surveillance data to be inputted within a single, accessible and multi-functional wetland inventory. Overall, this will required collaborative input from different organisations to create an integrated conservation 'framework' to monitor threats to wetlands and waterbirds.

Human problems & solutions

Since the 1980s, conservation has changed to take a more social integrationist stance by researching the needs to people in relation to resource use and conservation action (O'Connell 2000). Much of the research in this area relates to the management of 'reserve' areas but can also be applicable to other areas. Understanding the needs of people in relation to wetland resources is important, although it is only the first part of a longer process. Projects that encourage joint solution oriented research between ecologists and social scientist are needed to gain the input of different useful insights from both disciplines. Research must be encouraged if the conservation community is legitimate about reducing and eliminating threats to wetlands and waterbirds in conjunction with the idea of sustainable development.

Habitat creation

Creating new areas of a particular habitat has recently received more attention by conservationists. Certain habitats are more amenable to creation projects than others, whereas wetlands present many challenges in this respect (O'Connell 2000). The long term results from wetland habitat creation are still being implemented and tested today. Habitat creation can be used as part of a ‘no net loss’ policy, where habitats are created to mitigate for loss. Although, this also requires further testing of the fundamental idea that the biodiversity of the created wetlands does actually replace the natural or relatively unimpaired sites (O'Connell 2000).

Evaluating conservation strategies

Activities that are undertaken by the conservation community are often articulated by common consent or experts in specific fields. On the other hand, the efficacy of conservation action and advice should still be evaluated periodically. For examples, Special Protection Areas (SPAs) cab be used for this type of research and testing by looking at species, communities and habitats before and after designation and at a variety of spatial scales. Monitoring and surveillance data and adequate to allow and further this research to provide significant information for the conservation process (O'Connell 2000).

CONCLUSION

Lake of the Woods plays a significant role in the life cycle of waterbird species and its relevant importance in contributing to estimates and monitoring of migratory summer season populations. It is characterized by the presence of numerous lakes, rivers, streams and wetlands that support a wide variety of waterbirds that utilize Lake of the Woods to regularly breed, overwinter, reside year-round or routinely migrate through the region. There are three key challenges arising from the current human-caused threats affecting waterbirds and wetlands (O'Connell 2000). Firstly, there is a need for more scientific methods in place to allow the input of assessment, monitoring and surveillance data into a framework that is centralised and accessible. Next, research is needed to permit the detection and measurement of environmental change and to understand the causes and consequences of that change. Lastly, information needs to be provided that is solution oriented, which can be assimilated into the social and economic agenda of a changing world. By identifying the broad critical habitat requirements for each priority species (piping plover, black tern, yellow-headed blackbird and yellow rail) within Lake of the Woods, it allows species to be grouped by shared habitat-based conservation issues and actions that may contribute to future estimates of shifting populations due to climate vulnerability and habitat loss. Waterbird conservation should be further researched and explored to maintain and restore populations to target levels. This can be achieved through strategic protection of lands by environmental non-government organizations, municipal and provincial land use plans, stewardship programs, effective forest management planning, strengthening of partnerships and overall ecological restoration actions. Implementation of a long range ecological restoration plan can be accomplished through a broad partnership of governments, industry and stakeholders, working together to pursue the common goal of biodiversity conservation in Lake of the Woods.

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