Coastal Wetlands of Manitoba's Great Lakes (Canada)

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3 authors, including:

Pascal Badiou
Ducks Unlimited Canada

L. Gordon Goldsborough
University of Manitoba

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Dale Wrubleski, Pascal Badiou, and Gordon Goldsborough

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Abstract

The province of Manitoba, Canada, contains three of the world's largest freshwater lakes; Lakes Winnipeg, Winnipegosis and Manitoba. A significant feature of these lakes are their extensive coastal wetlands. A GIS-inventory found the Manitoba Great Lakes have six times more wetlands per km of shoreline than the Laurentian Great Lakes. Lake Winnipeg has a coastal wetland area of 1,404 km^2, Lake Manitoba has 564 km^2, and Lake Winnipegosis has 742 km^2. Netley-Libau Marsh (222 km^2) on Lake Winnipeg, and Delta Marsh (185 km^2) on Lake Manitoba, are believed to be the largest freshwater coastal wetlands in North America. These wetlands provide many benefits to their adjoining lakes, and provide important wildlife and fisheries habitat. However, lake-level regulation, nonpoint source nutrient pollution and invasive species are significant threats to these coastal wetlands and the ecosystem benefits they provide.

D. Wrubleski (✉) · P. Badiou (✉)
Institute for Wetland and Waterfowl Research, Ducks Unlimited Canada, Stonewall, MB, Canada
e-mail: d_wrubleski@ducks.ca; p_badiou@ducks.ca

G. Goldsborough (✉)
Department of Biological Sciences, University of Manitoba, Winnipeg, MB, Canada
e-mail: Gordon.Goldsborough@umanitoba.ca

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Introduction

The province of Manitoba, Canada, located in central North America contains three of the world's largest freshwater lakes (by area). Lakes Winnipeg, Winnipegosis, and Manitoba are the remnants of glacial Lake Agassiz, which was the largest lake in North America during the last deglaciation (Mann et al. 1999). At any one time, Lake Agassiz covered at least 260,000 km^2 and had a volume of 22,700 km^3 (Leverington et al. 2000). However, over its 4,000-year history, Lake Agassiz covered an overall area of approximately 1 million km^2 (Teller and Clayton 1983).

Lake Winnipeg is the largest of the Manitoba Great Lakes at 23,750 km^2 and is the tenth largest freshwater lake in the world and sixth largest in Canada. Lake Winnipeg consists of a large, deeper north basin (mean depth 13.3 m) and a smaller, relatively shallow south basin (mean depth 9 m). Water levels on Lake Winnipeg are controlled by the Manitoba Hydro power utility, making Lake Winnipeg the third largest hydroelectric reservoir in the world (Environment Canada and Manitoba Water Stewardship 2011).

Lake Winnipegosis is the second largest of the Manitoba Great Lakes, covering an area of 5,375 km^2 with a mean depth of 3 m (Downing and Duarte 2009). Lake Winnipegosis is Canada's 11th largest lake and the 30th largest in the world. Its watershed spans 49,825 km^2. Lake Winnipegosis is the only Manitoba Great Lake whose water levels are not regulated.

Lake Manitoba is the smallest of the Manitoba Great Lakes. Like the other Manitoba Great Lakes, Lake Manitoba is very shallow with a mean depth of 5 m. At 4,625 km^2 it is Canada's 13th largest lake and the 33rd largest in the world. Lake Manitoba's watershed covers an area of approximately 79,000 km^2. However, when the Portage Diversion is in operation, which diverts flow from the Assiniboine River into Lake Manitoba, the watershed expands to cover 121,800 km^2 (Page 2011).

All three Manitoba Great Lakes are located within the Lake Winnipeg watershed. The Lake Winnipeg watershed spans nearly 1 million km^2, covering parts of Alberta, Saskatchewan, Manitoba, and Ontario in Canada and Montana, North Dakota, South Dakota, and Minnesota in the United States. The watershed is contained within the Nelson River drainage basin which flows into Hudson Bay. The northern and eastern portions of the Lake Winnipeg watershed lie mostly in the Canadian boreal forest and have vast expanses of peatlands. This is particularly the case for Lake Winnipegosis and the north basin on Lake Winnipeg. However, the dominant land cover in the Lake Winnipeg watershed is agricultural farmland which covers approximately 650,000 km^2.

Coastal Wetlands

Connection with waters of large lakes is a key feature that distinguishes coastal wetlands from other freshwater inland wetlands, and given the dynamic nature of large lakes, their coastal wetlands are also inherently dynamic (Keough et al. 1999). Most research on freshwater coastal wetlands has been conducted in the Laurentian Great Lakes where coastal wetlands have been defined as:

> . . . lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands must have one or more of the following three attributes: 1) at least periodically, the land supports predominantly hydrophytes; 2) the substrate is predominantly undrained hydric soil; and 3) the substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of the year. Wetlands may be considered to extend lake-ward to the water depth of 2 m, using the historic low and high water levels or the greatest extent of wetland vegetation. Hydrologic connections with one of the Great Lakes may extend upstream along rivers since exchanges caused by seiches [wind tides] and longer-period lake-level fluctuations influence riverine wetlands. Wetlands under substantial hydrologic influence from Great Lakes waters may be considered coastal wetlands. (Simon and Stewart 2006)

Freshwater coastal wetlands can be further separated into three specific hydrogeomorphic systems, lacustrine, riverine, and barrier-protected (Fig. 1), based on geomorphic position, dominant hydrologic source, and current hydrologic connectivity to the lake (Albert et al. 2005). In brief, lacustrine coastal wetlands are

Fig. 1 Barrier-protected coastal wetland of Lake Winnipeg (Photo Credit: G. Goldsborough © Rights remain with the author)

controlled directly by waters of their associated lakes and are strongly affected by lake-level fluctuations, nearshore currents, seiches, and ice scour. The riverine coastal wetland class occurs along and within rivers and creeks that flow into or between Great Lakes. Water levels and fluvial processes in these wetlands are directly or indirectly influenced by coastal processes because lake waters flood back into the lower portions of the drainage system. Nearshore and onshore processes have separated barrier-protected wetlands from the Great Lakes by a barrier beach or other barrier features. These wetlands are protected from wave action but may be connected directly to the lake by a channel crossing the barrier.

The values of Great Lakes are enhanced by their associated coastal wetlands (Simon and Stewart 2006). Coastal wetlands provide numerous ecosystem services such as flood storage; sediment traps; nutrient filters; shoreline erosion buffers; habitat for plants, fish, and other wildlife; and hotspots for biodiversity (Maynard and Wilcox 1996). Additionally, due to their high productivity, wetlands are critical in the global carbon cycle (Mitsch and Gosselink 2000), and coastal wetlands are important areas for carbon sequestration (Bernal and Mitsch 2012). Coastal wetlands are situated at the interface between the watershed and lake and are particularly vulnerable to land-based stressors (Morrice et al. 2008). These stressors can impact the function of coastal wetlands and impair their capacity to provide the ecosystem services described above. In the Manitoba Great Lakes, there is an increasing development pressure that directly affects coastal wetlands and the ecosystem services they provide (Fig. 2).

Fig. 2 Residential development, visible in the foreground of this photograph, threatens the ecological integrity of coastal wetlands on Lake Winnipeg (Photo credit: G. Goldsborough © Rights remain with the author)

Coastal Wetlands of the Manitoba Great Lakes

A GIS-based inventory of coastal wetlands within 10 km of the shorelines of the Manitoba Great Lakes shows they have six times more wetlands per km of shoreline than the comparatively more well-studied Laurentian Great Lakes (Watchorn et al. 2012; Fig. 3). Lake Winnipeg has a coastal wetland area of 1,404 km^2 (0.8 km^2/km), Lake Manitoba has 564 km^2 (0.6 km^2/km), and Lake Winnipegosis has 742 km^2 (0.8 km^2/km). Riverine wetlands are the most common type on Lakes Winnipeg and Winnipegosis, whereas barrier-protected wetlands are the most common type on Lake Manitoba. When Treed Muskeg habitat in the northern regions of the lake watersheds is included in the inventory, the coastal wetland areas for lakes Winnipeg and Winnipegosis are greater by 548% and 273%, respectively, whereas the total for more southerly Lake Manitoba is greater by only 18%. Netley-Libau Marsh (222 km^2; N50.35690, W96.79201) on Lake Winnipeg and Delta Marsh (185 km^2; N50.18333, W98.31667) on Lake Manitoba are, we believe, the two largest coastal wetlands in North America. The characteristics of, and anthropogenic threats to, these important coastal wetlands are described below. Other large coastal marshes of the Manitoba Great Lakes include Lake Francis (N50.30452, W97.97242), Marshy Point (N50.55479, W98.08963) and Big Point (N50.40414, W98.55819) on Lake Manitoba, and Willow Point (N50.59843, W96.96811) and Grand Marais (N50.55806, W96.61173) on Lake Winnipeg.

Netley-Libau Marsh

Netley-Libau Marsh lies along the south shore of Lake Winnipeg, separated from the lake by a 25-km series of barrier islands (Fig. 4). The postglacial origins of the marsh have not been studied, but it likely originated when barrier beach formation along the southern shore of Lake Winnipeg isolated the southernmost part of the lake; southward migration of Lake Winnipeg due to isostatic uplift of the northern basin has eroded the barrier beach (Nielsen and Conley 1994). The marsh consists of a complex of shallow lakes, bays (lagoons), and channels, bisected by the Red River of the North that passes through the marsh on its way to Lake Winnipeg. Netley Marsh lies on the west side of the river and Libau Marsh lies on the east. Openings in the barrier islands (currently, eleven) allow water exchange between Lake Winnipeg and Netley-Libau Marsh. Strong wind setup on Lake Winnipeg can result in significant, short-term fluctuations in marsh water level, sometimes exceeding 1 m.

Netley-Libau Marsh provided resources for early aboriginal people and subsequently for European settlers who began to arrive in abundance in the early 1800s. The vicinity developed into an important recreational and agricultural area through the twentieth century. Its importance has much to do with the abundant fish and wildlife that can be found there. It has been recognized internationally as major habitat for nesting, staging, and molting waterfowl. It is also used for recreational activities such as hunting, fishing, boating, bird-watching, and ecotourism. The marsh has been recognized as an Important Bird Area (IBA). Migratory Neotropical songbirds and

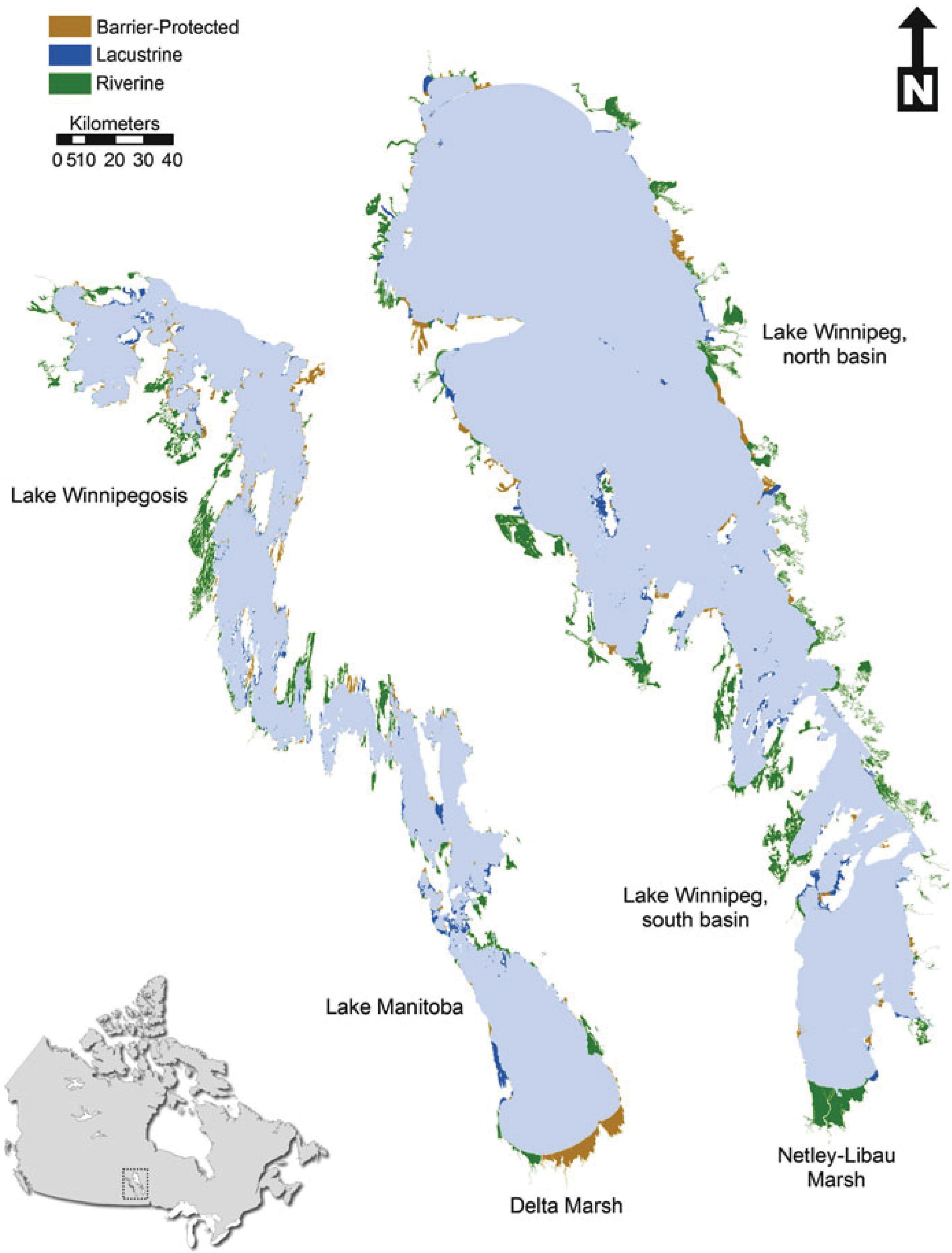

Fig. 3 Coastal wetlands of the Manitoba Great Lakes, excluding the Treed Muskeg that is abundant around the north ends of Lake Winnipeg and Lake Winnipegosis (Watchorn et al. 2012)

waterfowl use the marsh for nesting or during migration. Currently, over 90% of the marsh is publicly owned and includes a 1,073-ha Game Bird Refuge. Abundant bird species that use the marsh for nesting or during migration include Franklin's gull *Leucophaeus pipixcan*, Forster's tern *Sterna forsteri*, black-crowned night heron

Fig. 4 An aerial photograph of Netley-Libau Marsh with Lake Winnipeg visible in the upper, right and the Red River passing from left to right in the center (Photo credit: D. Wrubleski © Rights remain with the author)

Nycticorax nycticorax, western grebe *Aechmophorus occidentalis*, and several waterfowl species, including mallard *Anas platyrhynchos*, redhead *Aythya americana*, and blue-winged teal *Anas discors*. The marsh also provides spawning, nursery, and feeding habitat for fish species that are important for commercial and sport fisheries on Lake Winnipeg and the Red River (Janusz and O'Connor 1985), including northern pike *Esox lucius*, sauger *Sander canadensis*, yellow perch *Perca flavescens*, goldeye *Hiodon alosoides*, and shiners *Notropis* spp. The predominant marsh furbearer is the muskrat *Ondatra zibethicus* (Manitoba Wildlife Branch 1986).

However, the ecological integrity of Netley-Libau Marsh is under threat (Grosshans et al. 2004). Introductions of exotic species such as purple loosestrife *Lythrum salicaria* and common carp *Cyprinus carpio* have altered its structure. The Red River, which drains an enormous geographic area and supports large urban centers, is a source of nutrients and pollutants. Erosion of uplands that formerly divided the marsh into smaller units has led to the creation of large, open, windswept bays that have lost their fundamental marsh character. Dredging of a channel into Netley Lake in 1913 (Fig. 5) has permitted greater inflow of polluted water from the Red River. Habitat for fish and wildlife has been compromised through the loss of aquatic plants and uplands that provide cover, habitat diversity, and breeding sites. Changes in the marsh have been ongoing for a long period of time, and a combination of factors (e.g., lake-level regulation, Red River water quality, river dredging) are responsible.

Fig. 5 The "Netley Cut" shown here was originally excavated from the Red River into Netley-Libau Marsh in 1913 but has eroded into a channel that now redirects from one-third to one-half of the entire river flow in the marsh (Photo credit: G. Goldsborough © Rights remain with the author)

Efforts to restore marsh vegetation to Netley-Libau Marsh are predicated on the benefits that it would provide in capturing nutrients flowing through the Red River into Lake Winnipeg and reducing its eutrophication rate, providing habitat for fish and furbearing mammals, and using harvested marsh plants as a source of biofuel and fertilizer (from absorbed nutrients). At present, most of the marsh is too deep (over 2 m) for natural plant regeneration to occur. Initially, attention was placed on the creation of artificial reefs that would be planted with hybrid cattail *Typha x glauca*. It is now believed this approach would have high associated construction costs and low likelihood of successful plant regrowth. We are now investigating floating cattail bioplatforms that would grow the plants hydroponically, in theory in any depth of water so long as ambient nutrient levels are sufficient to sustain plant growth.

Delta Marsh

Delta Marsh is a large coastal wetland stretching approximately 32 km along the south shore of Lake Manitoba (Fig. 6). The marsh covers an area of between 150 and 250 km^2, depending on water levels and areas included as part of the marsh (Delta Marsh Technical Committee 1968; Shay et al. 1999; Batt 2000). It consists of a series of large and small open water bays and ponds, former river channels, flooded emergent vegetation, wet meadows, low prairie, and uplands. Average water depth in the open water areas is about 1 m, but depths of up to 3 m can be found in some of the former river channels. There are four openings in the forested barrier beach that

Fig. 6 An aerial photograph of Delta Marsh showing Lake Manitoba at the right (Photo credit: D. Wrubleski © Rights remain with the author)

allow the exchange of water between the lake and Delta: Clandeboye Channel on the far east side, Delta Channel near the middle of the marsh, and Cram and Deep Creeks on the far west side (Fig. 7). Depending on wind direction and wind setup on Lake Manitoba, flows in the connecting channels can reverse direction frequently, and water levels on the marsh fluctuate accordingly.

Much like Netley-Libau Marsh, Delta Marsh has its origins in a river depositing sand and silt into a remnant of glacial Lake Agassiz, but in this case, it was the Assiniboine River and the lake is Lake Manitoba. From approximately 4,500 to 2,000 years ago, all or part of the Assiniboine River flowed into the south end of Lake Manitoba (Last 1980). However, at approximately 2,000 years ago, the river stopped flowing northward and changed course toward the east. Wave action eroded and redistributed the river-deposited sediments and created the barrier beach that now separates Delta Marsh from Lake Manitoba.

Delta Marsh is a wetland of international importance, being designated a Ramsar wetland in 1982 (Gillespie and Boyd 1991) for its importance to waterfowl. It was designated a Manitoba Heritage Marsh in 1988 (Manitoba NAWMP Technical Committee 1988) and an Important Bird Area (IBA) in 1999. In 2006, Manitoba Conservation designated over 110 km^2 of the marsh as a Wildlife Management Area (WMA), providing some protection from industrial development. In addition, parts of the marsh are also designated as a Game Bird Refuge. Three research facilities operated on Delta Marsh and contributed significantly to our understanding of the marsh and Lake Manitoba. A major flood in 2011 resulted in the closure of the Delta

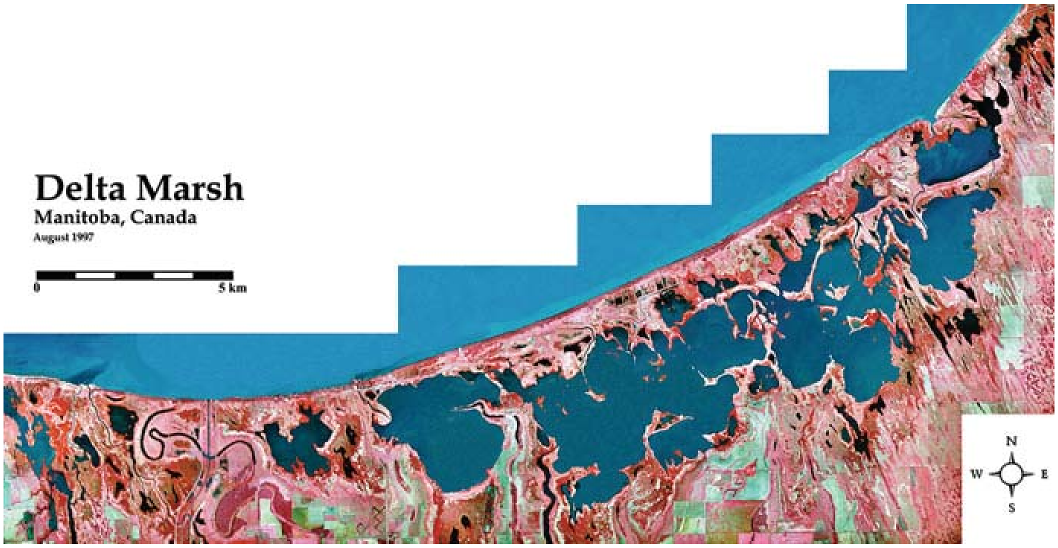

Fig. 7 Infrared color photomosaic of Delta Marsh showing the four connections between the marsh and Lake Manitoba, two on the extreme left side, one in the center, and one on the extreme right side (Photo credit: D. Wrubleski (Ducks Unlimited Canada) and G. Goldsborough (University of Manitoba) © Rights remain with the authors)

Marsh Field Station (University of Manitoba), the Delta Marsh Bird Observatory, and the Delta Waterfowl Research Station (Delta Waterfowl Foundation).

From the late 1800s, the marsh was known as an important area for waterfowl and waterfowl hunting (Fig. 8). Commercial hunting provided local employment and harvested birds were shipped to the market. Waterfowl hunting attracted a wide range of people to the marsh, including the rich and famous from around the world. Not only was the marsh important for waterfowl but also for other colonial waterbirds, including most of the same species as found in Netley-Libau Marsh. An estimated 307 species of birds have been recorded in the area, of which 136 species have been confirmed to breed (Underwood and den Haan 2000). Thirty-one species of fish use the marsh for spawning, rearing, and feeding habitat (Stewart et al. 1985; Wrubleski, unpublished data).

Starting the early 1960s, local residents and users began to report negative changes on the marsh. These changes have continued and include reduced clarity of the water column, loss of submersed aquatic vegetation, abundant populations of common carp, algal blooms, increasing dominance of the emergent plant community by the hybrid cattail and encroachment and loss of shallow ponds, loss of islands in the larger bays and ponds, and reductions in waterfowl, muskrats, and other wildlife that use the marsh. Reasons for the changes in the marsh are many and include stabilization of water levels on Lake Manitoba, abundant populations of common carp, and eutrophication of the marsh as a result of increased nutrient loading (Goldsborough and Wrubleski 2001).

Water levels on Lake Manitoba and adjacent Delta Marsh historically fluctuated within a range of 1.7 m. However, in 1961, completion of a control structure on the Fairford River, the only major outlet to Lake Manitoba, reduced fluctuations to less than 0.6 m. Stabilization of water levels has likely contributed to encroachment of hybrid cattail into shallow ponds, erosion of the islands in the larger bays, and increased

Fig. 8 The practice of waterfowl hunting has a long history at Delta Marsh and other coastal wetlands of the Manitoba Great Lakes (Photo credit: G. Goldsborough and Delta Marsh History Group (www.deltahistory.org) © Rights remain with the author)

turbidity within the larger bays due to increased wave action. In 2003, a stakeholder group, the Lake Manitoba Regulation Review Advisory Committee, recommended that the lake be allowed to fluctuate to a greater extent than allowed under the previous management plan. The province accepted this recommendation in principle. A 1-in-400-year flood in 2011 did significant damage to private property and infrastructure around the lake. On the marsh, it resulted in a significant dieback in the invasive hybrid cattail. As a result of the flood, a government-appointed stakeholder group recommended that the operating range for Lake Manitoba should be lowered by 0.15 m. Lower water levels may have benefits for recruitment of vegetation in Delta Marsh but could accelerate the encroachment by hybrid cattail.

From the early 1960s to the mid-1980s, several large-scale management plans were proposed to restore Delta Marsh. These plans primarily called for the isolation of the marsh from Lake Manitoba and to artificially manipulate water levels within the marsh. However, none of these plans were implemented. Beginning in 1997, several agencies began working on the marsh to document the extent of change and to reexamine options for improving marsh conditions (Goldsborough and Wrubleski 2001). Activities have included mapping the aquatic plants, both submersed and emergent, monitoring water quality, and documenting the large fish community of the marsh. Gillnet collections on the marsh confirmed the abundance of common carp. Subsequent experimental manipulations and controlled stocking of isolated ponds confirmed the significant effects of these large invasive benthivorous fish (Hnatiuk 2006; Parks 2006; Badiou and Goldsborough 2010; Hertam 2010).

Fig. 9 In early 2013, seven structures were constructed to exclude most large common carp from Delta Marsh as a means of restoring submersed macrophytes and other components of the coastal wetland ecosystem degraded by this invasive, benthivorous fish (Photo credit: D. Wrubleski © Rights remain with the author)

Recognizing the significant impacts of common carp on the marsh, a restoration plan was developed that called for carp exclusion. Research studies have been initiated to better understand the size structure of the large fish community and timing of the annual spring migration into the marsh. Based on this information, seven exclusion structures were constructed or modified in early 2013 (Fig. 9). These structures use temporary screens to selectively prevent common carp from accessing the marsh each spring. These structures are part of a larger restoration effort called "Restoring the Tradition at Delta Marsh." Besides excluding common carp, the project also initiated a 5-year research program to better understand the hydraulics and hydrology of the marsh, determine sources of nutrients, and examine effective control methods for hybrid cattail. This new information will inform a second phase of the restoration project to address eutrophication and hybrid cattail control.

Threats and Future Challenges

The overall threats to the Manitoba Great Lakes provide context for the specific threats mentioned above for Netley-Libau Marsh and Delta Marsh. Water quality in Lake Winnipeg has been declining steadily over the last half century, and the lake was recently declared the most threatened lake in the world. The frequency and severity of cyanobacterial blooms in Lake Winnipeg are the most noticeable symptom of the declining health of the Lake Winnipeg watershed. The ratio of watershed to lake area for all three Manitoba Great Lakes (range 9 to 40) is substantially larger and more variable relative those of the Laurentian Great Lakes (range 2 to 4). For this reason and due to the sheer size, as well as the fact that agricultural production dominates the watershed, nonpoint source nutrient pollution is suspected to be the main contributing factor in the ongoing eutrophication of Lake Winnipeg.

While water quality issues are at the forefront for Lake Winnipeg and its watershed, there are a number of other stressors that are acting on Manitoba Great Lakes and their associated coastal wetlands. Water levels on Lake Manitoba and Lake Winnipeg have been regulated since 1961 and 1976, respectively. In addition to eutrophication and water-level regulation, a number of invasive species have become established in Lake Winnipeg and its watershed. To date, 14 aquatic invasive species have been introduced to Manitoba waters: the common carp, rainbow smelt *Osmerus mordax*, white bass *Morone chrysops*, feral goldfish *Carassius auratus*, rusty crayfish *Orconectes rusticus*, spiny waterflea *Bythotrephes cederstroemi*, water flea *Eubosmina coregoni*, freshwater jellies *Craspedacusta sowerbyi*, black algae *Lyngbya wollei*, purple loosestrife, flowering rush *Butomus umbellatus*, invasive common reed *Phragmites australis*, Asian tapeworm *Bothriocephalus acheilognathi*, and koi herpesvirus (Environment Canada and Manitoba Water Stewardship 2011). Of great concern is the recent discovery of zebra mussels *Dreissena polymorpha* in the south basin of Lake Winnipeg during the fall of 2013.

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