Distribution and Ecology of a New Species of Water-lily, *Nymphaea loriana* (Nymphaeaceae), in Western Canada

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Nymphaea loriana Wiersema, Hellq. & Borsch (Lori's Water-lily) is a newly described, Canadian endemic species that has been found in central Manitoba and east-central Saskatchewan. To assess the status of a species, data regarding its distribution, population size, habitat, and search effort are needed. The purpose of this paper is to document these factors for this species. The extent of occurrence of *N. loriana* is approximately 15 100 km^2 but the known area of occupancy is a mere 20 km^2. The estimated population size of *N. loriana* is about 750 individual plants, although more may exist on poorly explored rivers and lakes within the extent of occurrence and possibly in northeastern Ontario. *Nymphaea loriana* occurs in fresh, stagnant, or slowly moving water in boreal lakes and rivers and is typically associated with *N. leibergii* (Dwarf Water-lily), *Schoenoplectus tabernaemontani* (Soft-stemmed Bulrush), *Potamogeton natans* (Floating-leaved Pondweed) and *Nuphar variegata* (Variegated Pond-lily). Potential threats to the persistence of this species include low water quality resulting from mining, forestry, and agriculture, and changes to water flow because of dam construction and climate change. Monitoring known populations and searching for additional ones may be needed to assess the status of this species.

Key Words: Lori's Water-lily; *Nymphaea loriana*; new species; Manitoba; Saskatchewan; conservation; distribution; ecology; endemic; rare

Introduction

Nymphaea loriana (Lori's Water-lily), is a newly described vascular plant found only in Manitoba and Saskatchewan, Canada (Figure 1). Taxonomic study of herbarium specimens of the water-lily genus for *Flora of North America North of Mexico,* volume 3 (Wiersema 1996, 1997) led to the discovery of plants from western Canada with unusual morphologies that were suspected of being hybrids between *N. leibergii* Morong (Dwarf Water-lily) and *N. odorata* Aiton (Fragrant Water-lily). Fieldwork to locate the unusual plants and subsequent DNA and other analyses occurred sporadically between 1996 and 2008 (Borsch *et al.* 2014). Morphological and molecular investigations have confirmed that *N. loriana* arose via hybridization between *N. leibergii* and *N. odorata* (Borsch *et al.* 2014). A detailed taxonomic description of this new species along with a new key to the *Nymphaea* of Canada is included in Borsch *et al.* (2014).

Figure 1. Flower of *Nymphaea loriana* (Lori's Water-lily). Photo: Manitoba Museum.

Canada is required to "monitor, assess and report regularly on the status of all wild species" to fulfill legal obligations under the Accord for the Protection of Species at Risk (CESCC 2011). Information on the status of species is then used by organizations, such as the International Union for Conservation of Nature and the Committee on the Status of Endangered Wildlife in Canada to identify and prioritize species for legal protection and conservation work. One of the main problems involved in achieving this goal is the lack of scientific data about wild species. As *N. loriana* is a newly recognized species, data on its distribution, population size, and habitat are needed to assess its status provincially, nationally, and globally. The objective of this paper is to provide some of the information needed for status assessment, identify areas where additional field surveys are needed, and assess any potential threats to its persistence.

Methods

Examination of herbarium specimens indicated three areas in Canada where *N. loriana* likely occurs (Borsch *et al.* 2014) (Figure 2). These areas were visited several times over 13 years to obtain genetic samples and document the population size and habitat (Table 1).

Extent of occurrence (EO) and area of occupancy (AO) are two parameters commonly used to help assess the rarity of a species (COSEWIC 2012; IUCN Standards and Petitions Subcommittee 2014). To determine EO, i.e., the area included in a polygon without concave angles that encompasses the geographic distribution of all known populations of a wildlife species (COSEWIC 2012) in Canada, all known populations of *N. loriana* in Manitoba and Saskatchewan were included in a polygon. Google Maps was then used to calculate the EO.

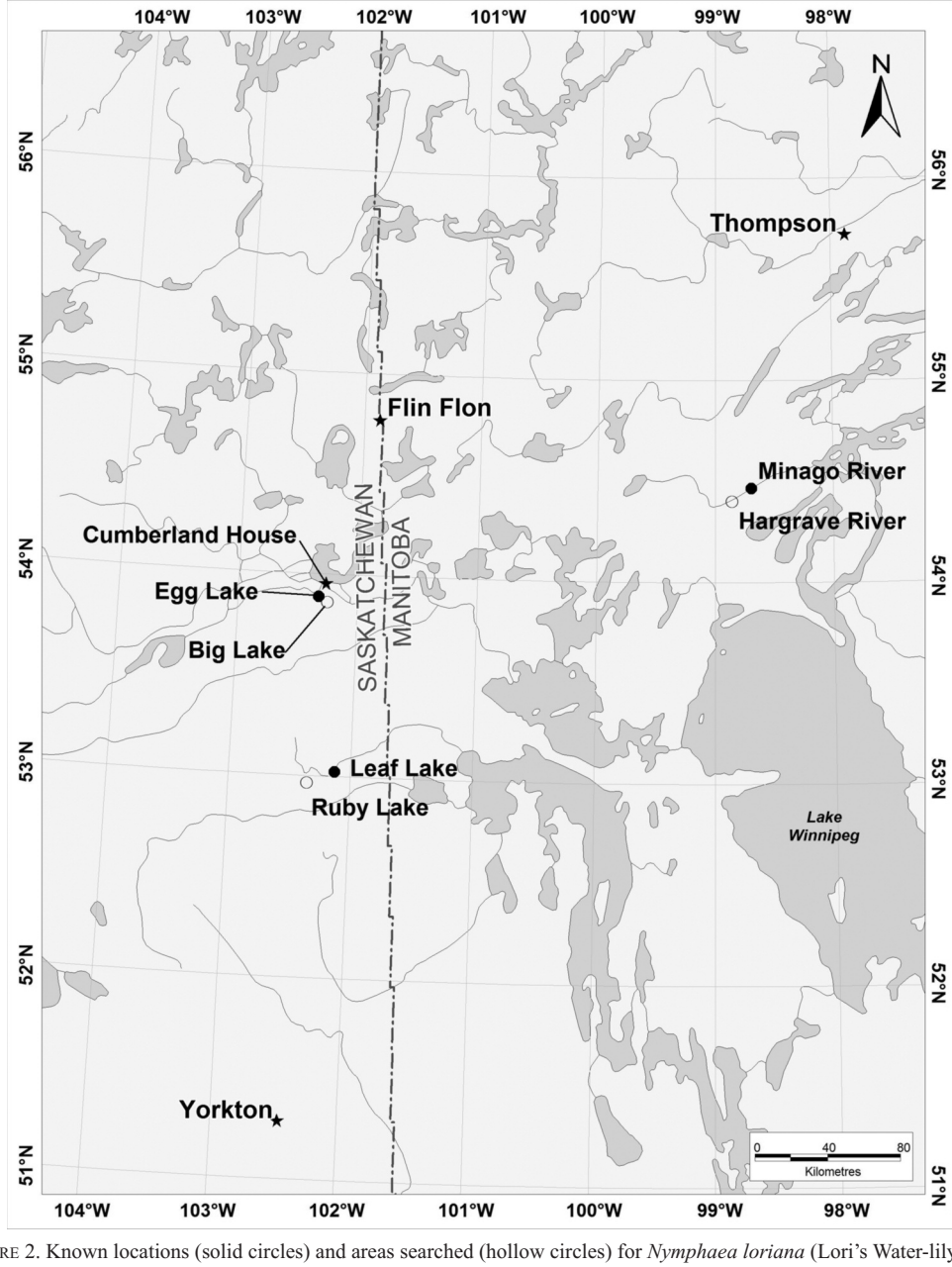

FIGURE 2. Known locations (solid circles) and areas searched (hollow circles) for *Nymphaea loriana* (Lori's Water-lily) in Manitoba and Saskatchewan, Canada.

TABLE 1. Summary of field excursions to obtain genetic samples and document the population size and habitat of *Nymphaea loriana* (Lori's Water-lily) in Manitoba and Saskatchewan.

Location	Searcher	Survey method*	Year	Total time (h)	Observation success†
Big Lake	J. Wiersema, D. Clayton, R. A. Wright	Targeted	2007	~ 1	−
Egg Lake	D. L. Dabbs and D.C. Surrendi	General	1962	?	+
	G. H. Townsend	General	1965	?	+
	J. Wiersema, B. Hellquist	Targeted	1996	~ 4	+
	J. Wiersema, B. Hellquist, T. Borsch	Targeted	2000	~ 7	+
	J. Wiersema, D. Clayton, R. A. Wright	Targeted	2007	~ 3	+
	D. Clayton, S. Greer	Targeted	2009	?	+
Hargrave River	J. Wiersema, D. B. Robson	Targeted	2008	1	−
Leaf Lake	E. Kuyt	General	1959	?	+
	J. Wiersema, B. Hellquist	Targeted	1996	~ 6	+
Minago River	H. Scoggan	General	1948	?	+
	J. Wiersema, B. Hellquist	Targeted	1996	1	−
	J. Wiersema, B. Hellquist, T. Borsch	Targeted	2000	6	−
	J. Wiersema, D. B. Robson	Targeted	2007	3	−
	J. Wiersema, D. B. Robson	Targeted	2008	11	+
Ruby Lake	J. Wiersema, B. Hellquist	Targeted	1996	~ 1	−

* General surveys involved collecting many species, whereas targeted ones involved searching specifically for *N. loriana*.
† + indicates that *N. loriana* was found during the excursion; − indicates that it was not found.

AO is the area within the EO that is occupied by a taxon, excluding cases of vagrancy (COSEWIC 2012). The AO for each population was determined by collecting GPS points around the perimeter of the population and calculating the area or, if the population was small, by visually estimating the area covered by the plants.

The population size was estimated by traveling the entire perimeter of the population by boat and keeping a running tally of plants observed. However, it is impossible to determine the exact number of plants, as the rooting zone cannot be seen from the surface; for this reason, population sizes are only approximate. Plant species that were intermingled with or growing within 25 m or so of the perimeter of the *N. loriana* populations were collected and considered to be associated species. Plant specimens collected during these excursions were identified and deposited in various herbaria (Botanischer Garten und Botanisches Museum Berlin-Dahlem, Harvard University, and the Manitoba Museum) (Borsch *et al.* 2014).

Results and Discussion

Distribution

There are three known populations of *N. loriana* in Canada (Figure 2): one in Manitoba and two in Saskatchewan (Table 2). The populations in Saskatchewan and Manitoba appear to be disjunct with a gap of about 240–260 km in between. The two Saskatchewan populations are about 90 km away from each other. The EO was calculated to be approximately 15 100 km^2.

The Manitoba population is along the Minago River, north of Lake Winnipeg. In total, an 80-km stretch of the river, from Highway 6 east to Highway 373, was examined during various field trips. A portion of the Hargrave River was also navigated, but the low water clarity was considered to be unsuitable for water-lilies. The Minago population consists of three locations along an 8-km stretch of the river giving it an AO of approximately 12 km^2. *Nymphaea loriana* seeds appear to have been spreading downstream to the easternmost portions. This is the largest known population in Canada, estimated at around 500 plants.

The second population, found in Leaf Lake, north of Hudson Bay, Saskatchewan, has an AO of about 4 km^2. Nearby Ruby Lake was also visited but no *N. loriana* was detected. The third population was found in Egg Lake, which forms part of the Cumberland Marshes south of Cumberland House, Saskatchewan; its AO is approximately 4 km^2. Big Lake to the southeast of Egg Lake was also visited, but no *N. loriana* sightings were made. Thus, the total AO in Canada is about 20 km^2. Although only a few plants were found during initial reconnaissance of the Saskatchewan sites, and additional plants were found during a subsequent visit to the

TABLE 2. Populations of *Nymphaea loriana* (Lori's Water-lily) in Canada.

Location	Latitude, longitude	First observation	Last observation	Population size
Egg Lake, Saskatchewan	52˚53'N, 102˚19'W	1962	2009	< 200
Leaf Lake, Saskatchewan	52˚58'N, 102˚9'W	1959	1996	< 50
Minago River, Manitoba	54˚28'N, 98˚38'W	1948	2008	< 500
Total for Canada				< 750

Egg Lake population, a thorough survey of these areas has not been conducted; thus, there may be more individuals present.

The distribution of water-lilies, and many other aquatic species of plants in northern Saskatchewan and Manitoba, is poorly known. There are only 49 documented populations of water-lilies from Manitoba and 27 from Saskatchewan (Table 3). This is a result of several factors: poor accessibility because of the low density of roads in this area, the presence of water-lilies in deep water rather than along the shore, logistical problems involved in bringing watercraft into remote lakes and rivers, and the high cost of botanical collecting expeditions.

Targeted searches along streams, rivers, and shallow lakes within the EO are needed to determine exactly how widespread *N. loriana* and other more common species of water-lilies are. In particular, maps of the Saskatchewan River Delta area indicate several water-lily–bulrush mixtures similar to that found in Egg Lake at Deep Lake, Cow Lake, Highbank Lake, and Bewley Lake and these should be examined (R. A. Wright, personal communication, 2008). The Overflowing and Pasquia Rivers in Saskatchewan and Manitoba should also be searched. Areas in north-central Manitoba that should be searched for water-lilies include Clearwater Lake Provincial Park, Saskeram and Tom Lamb Wildlife Management Areas, and Moose and Cedar Lakes. Areas outside the EO, including the Nelson River and associated tributaries, and areas in northern Ontario where *N. leibergii* and *N. odorata* are known to coexist (north of Thunder Bay) should be searched. The discovery of just three more occurrences of this species would likely alter its status. Alerting the public about the need for more information about this species may result in additional sightings.

Habitat

Nymphaea loriana occurs in lake and river systems that are part of the Hudson Bay–Nelson Drainage Basin (Atlas of Canada 2006). Plants occur mainly several metres from shore in slow-moving rivers or shallow lakes. *Nymphaea loriana* was growing in water 1–2 m deep. Water-lilies are less tolerant of fast currents and water fluctuations than *Nuphar* spp. (pond-lilies) and, as their habitat is rarer, water-lilies are less common.

The Minago River begins northeast of Moose Lake and flows in a northeasterly direction. The river widens to form Hill Lake then receives water draining from Hargrave Lake via the Hargrave River and from Black Duck Lake via Black Duck Creek and Drunken Lake. The Minago eventually drains into Cross Lake, then the Nelson River and finally Hudson Bay. The surficial geology in this area consists of glacio-lacustrine deposits with periodic rock outcrops (Manitoba Mineral Resources Division 1981). West of Highway 6, the Minago flows through some exposed Ordovician dolomitic limestone, but east of the highway any exposed rock is Precambrian granite and gneiss. The area where *N. loriana* was found is part of the Hayes River Upland Ecoregion of the Boreal Shield Ecozone (Marshall and Schut 1999).

Water-lily populations along the Minago typically occur in small tributary streams that are dammed by beavers or along portions of the river margins with slow-moving, shallow water. Both *N. leibergii* and *N. tetragona*, as well as *N. leibergii* × *N. tetragona* hybrids were observed along the Minago River system. *Nymphaea leibergii* was associated with all three subpopulations of *N. loriana* but *N. tetragona* was found in the relatively still water in the mouths of tributaries. *Nymphaea loriana* was only found along a several-kilometre stretch of shallow water in the river channel proper. The vegetation in this area consisted of a broad, wet meadow of grasses and *Salix* spp. (willows), which likely flood in the spring but dry up later in the year. Near the shore, marginal and emergent plants including *Acorus americanus* (American Sweetflag), *Carex lacustris* (Lake Sedge), *Equisetum fluviatile* (Water Horsetail), *Schoenoplectus tabernaemontani*, *Sparganium angustifolium* (Narrow-leaved Burreed), *Eleocharis palustris* (Common Spikerush), and *Typha latifolia* (Broad-leaved Cattail) were common. Submerged and

TABLE 3. Number of water-lily (*Nymphaea*) populations in Manitoba and Saskatchewan based on herbarium specimens* and their rarity rank according to NatureServe (2015b).

	Manitoba		Saskatchewan		
Species	Number of populations	Status†	Number of populations	Status†	Canadian status
Nymphaea leibergii	18	S4	22	S2	N4N5
Nymphaea loriana	1	SNR	3	S1	N1
Nymphaea odorata	12	S2	0	n/a	N5
Nymphaea tetragona	17	S2	2	— §	N5
Nymphaea tetragona × *N. leibergii*	1	— §	0	n/a	— §

Note: n/a = not applicable as the taxon does not occur in this jurisdiction.

*Herbaria consulted include the Manitoba Museum (MMMN), the University of Manitoba (WIN), W. P. Fraser Herbarium (SASK), and the National Vascular Plant Herbarium (DAO).

† 1 = critically imperiled, 2 = imperiled, 4 = apparently secure, 5 = secure, NR = not ranked/under review.

§ Although there are herbarium specimens of this taxon from this jurisdiction, it was not ranked by NatureServe (2015b) for unknown reasons.

floating-leaved plants associated with *N. loriana* included *Myriophyllum sibiricum* (Siberian Water Milfoil), *Nuphar variegata*, *Potamogeton pusillus* (Small Pondweed), *P. natans*, *Ranunculus aquatilis* (White Water Buttercup), and *Utricularia vulgaris* ssp. *macrorhiza* (Greater Bladderwort). The presence of these plants may affect the habitat of *N. loriana* by contributing organic matter to the river bottom, as well as helping to decrease the water velocity.

The Cumberland Marshes receive water from both the North and South Saskatchewan rivers to the southwest, which have their headwaters in the Rocky Mountains of Alberta. Water from the Cumberland Marshes eventually drains into Cedar Lake, Lake Winnipeg, and the Nelson River ending up in Hudson Bay. The surficial geology in this area consists of clayey, calcareous alluvial materials underlain by glacial till (Acton *et al.* 1990). It is part of the Saskatchewan Delta landscape area in the Mid-Boreal Lowland Ecoregion of the Boreal Plain Ecozone (Acton *et al.* 1998). The species was found at least 500 m from the shore of Egg Lake. Associated floating and emergent plant species included *N. leibergii*, *Nuphar variegata*, and *Schoenoplectus tabernaemontani* (R. A. Wright, personal communication). Most of the *N. loriana* individuals were not in open water, unlike the other two floating-leaved species, but were dispersed within the *S. tabernaemontani* beds (R. A. Wright, personal communication). Other submerged plants in Egg Lake included *Potamogeton zosteriformis* (Flat-stemmed Pondweed), *P. natans*, *M. sibiricum*, and *Utricularia minor* (Lesser Bladderwort) (R. A. Wright, personal communication). The water depth where *N. loriana* was growing was about 100–120 cm. The water was clear but somewhat tannin stained.

Leaf Lake receives water from several small streams originating in the Pasquia Hills. Water from Leaf Lake drains into the Overflowing River and then eventually into Lake Winnipegosis, Manitoba. The surficial geology of the area consists of glacial till plain and glaciofluvial materials that are highly calcareous (Broughton and Macdonald 1980). It is part of the Overflowing River Lowland landscape area in the Mid-Boreal Lowland Ecoregion of the Boreal Plain Ecozone (Acton *et al.* 1998). Only a few plants have been observed, again together with *N. leibergii*, in the clearer waters of one of Leaf Lakes' influent streams.

Conservation Issues

In Manitoba, the Minago River is on provincial crown land and is not part of any national or provincial park or wildlife reserve. In Saskatchewan, both the Cumberland Marshes and Leaf Lake are also on provincial crown land. The Cumberland Marshes, a 364 000-ha wetland that is part of the Saskatchewan River Delta, is internationally recognized as a Canadian Important Bird Area (IBA Canada 2009). Ducks Unlimited Canada has approximately 130 000 ha of the Cumberland Marshes under conservation easements with the Saskatchewan government to ensure the protection of wildlife in this area (Patterson 2005).

Three factors might negatively affect *N. loriana* populations: changes in water quality and water levels and collecting by the horticulture industry. *Nymphaea loriana* appears to require high water clarity, which may be negatively affected by the release of sediments resulting from natural resource development in the boreal forest: forestry, toxic chemicals and sediments from mining operations, and agricultural nutrients and pollutants (Chow-Fraser *et al.* 1998; Kreutzweiser *et al.* 2013).

The Minago River area in Manitoba is considered too remote to be commercially logged, at least at the present time. The forests immediately surrounding the Cumberland Marshes are also not part of any current forest management agreement (FMA). However, those around Leaf Lake are part of the Pasquia/Porcupine FMA. Industrial logging has been occurring in this area since the 1940s, and will continue in the near future. Some forestry practices may cause soil erosion, increasing sediment flow into the lake and negatively affecting *N. loriana*. Leaving unlogged buffer zones between riparian and logged areas would help decrease soil erosion.

Mining activities may increase turbidity and release toxic compounds into aquatic systems, as well as increasing acidity (Beamish *et al.* 1975; Kreutzweiser *et al.* 2013). A nickel mine is planned for an area north of Grand Rapids; the environmental impact statement prepared for the project states that a "site water management plan" and an "erosion and sediment control plan" will be implemented to mitigate the effects of polishing-pond discharges into the Minago River (Victory Nickel 2010).

The population of *N. loriana* in the Cumberland Marshes area may be affected by lower water quality as the Saskatchewan River runs through agricultural areas and several urban centres that contribute fertilizers, pesticides, sewage, and household chemicals to the water. The anticipated spread of agriculture further north into the Boreal Transition ecoregion as climate change occurs may alter nutrient concentrations and result in increased pollution from agricultural operations (Bayley *et al.* 1992). The Minago River, with its headwaters originating in north-central Manitoba, and Leaf Lake, with headwaters originating in the undeveloped Wildcat Hills, are less likely to become contaminated, as agricultural land does not occur adjacent to them or their tributaries at present. However, Leaf Lake receives a considerable nutrient load from migrating waterfowl.

Nymphaea loriana is restricted to habitats with relatively shallow water and is vulnerable to drastic changes in water levels, which may occur as a result of both climate change and dam construction. The Saskatchewan River has several dams already: Gardiner, Francois-Finlay, and E. B. Campbell. The E. B. Campbell

dam results in less water flowing downstream at certain times of the year (Patterson 2005). A dam at Grand Rapids in Manitoba has impacted the Cumberland Marshes by causing higher water levels and flooding west of The Pas (Patterson 2005). No new hydroelectric projects are planned for the immediate future along either the Minago or Saskatchewan River or the streams providing water to, and draining, Leaf Lake. However, higher oil prices could result in a greater demand for hydroelectricity and may spur the creation of another dam on the Saskatchewan River. Changes in the water level in these river systems because of the loss of glaciers in the Rocky Mountains may also decrease *N. loriana* habitat (Schindler 2001). Thus global climate change may eventually have a negative impact on this species (Nelson *et al.* 2014).

Since the 1940s, a series of small dams have been created in the Cumberland Marshes to increase habitat for muskrat, which were trapped for fur. Nowadays, management of this area focuses on restoring some of the hydrologic variability that no longer occurs because of the presence of dams on the river. Any drastic changes in the water level in the Cumberland Marshes as a result of a dam may impact the *N. loriana* population located there (Kreutzweiser *et al.* 2013).

Water-lilies are important horticulturally, as they are attractive additions to water gardens, and many species are being used in breeding experiments to create new hybrids (Slocum 2005). The popularity of *N. odorata* in water gardening has resulted in this species spreading to areas where it was not found naturally, and, in fact, it is becoming invasive in parts of the United States (Else and Riemer 1984). The popularity of water-lily gardening may make *N. loriana* the target of overzealous collectors, who could endanger the population. The remote locations of *N. loriana* in deep wetlands will help protect the species, as these populations are not easily accessible. The NatureServe threat assessment calculator shows the overall threat impact for *N. loriana* to be "Low" (NatureServe 2015a).

Conclusions

Nymphaea loriana is a newly identified species that appears to be limited to clear, non-turbid rivers, streams, and lakes in the Boreal Plains and Boreal Shield of Manitoba and Saskatchewan. Monitoring known populations would help to determine whether *N. loriana* is spreading or declining. Additional surveys of potentially appropriate habitats in northern Saskatchewan, Manitoba, and possibly even Ontario may reveal additional populations.

Although *N. loriana* does not appear to be in any immediate danger of extinction, circumstances may change in the near future to alter that. Measures to decrease the release of toxic contaminants from mining operations and prevent soil erosion and increased nutrient flow into nearby rivers from forestry and agriculture would help decrease any negative impact on this, and many other species, in boreal wetlands. Additional surveys and monitoring work would provide the information needed to help scientists determine whether *N. loriana* is in need of legal protection.

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Literature Cited

Acton, D. F., G. A. Padbury, and **J. A. Shields.** 1990. Soil landscapes of Canada: Saskatchewan. Supply and Services Canada, Ottawa, Ontario, Canada.

Acton, D. F., G. A. Padbury, and **C. T. Stushnoff.** 1998. The ecoregions of Saskatchewan. Canadian Plains Research Center, University of Regina, Regina, Saskatchewan, Canada.

Atlas of Canada. 2006. Watersheds. Natural Resources Canada, Ottawa, Ontario, Canada. Accessed December 2015. http://ftp2.ctis.nrcan.gc.ca/pub/geott/atlas/archives/english/various/north_america_cec_watersheds.pdf.

Bayley, S. E., D. W. Schindler, B. R. Parker, M. P. Stainton, and **K. G. Beaty.** 1992. Effect of forest fire and drought on acidity of a base-poor boreal forest stream: similarities between climatic warming and acidic precipitation. Biogeochemistry 17: 191–204.

Beamish, R. J., G. A. McFarlane, J. C. VanLoon, and **J. Lichwa.** 1975. An examination of the possible effects of Sudbury nickel mining and smelting operations on fishes and the water chemistry of lakes within the Whitefish Lake Indian Reserve. Technical report 579. Research and Development Directorate, Fisheries and Marine Service, Environment Canada, Nanaimo, British Columbia, Canada.

Borsch, T., J. H. Wiersema, C. B. Hellquist, C. Löhne, and **K. Govers.** 2014. Speciation in North American water lilies: evidence for the hybrid origin of the newly discovered Canadian endemic *Nymphaea loriana* sp. nov. (Nymphaeaceae) in a past contact zone. Botany 92: 867–882.

Broughton, P. L., and **Macdonald, R.** 1980. Geological map of Saskatchewan. Energy and Resources, Government of Saskatchewan, Regina, Saskatchewan, Canada.

CESCC (Canadian Endangered Species Conservation Council). 2011. Wild species 2010: the general status of species in Canada. National General Status Working Group, Ottawa, Ontario, Canada. Accessed December 2015. http://publications.gc.ca/collections/collection_2011/ec/CW70-7-2010-eng.pdf.

Chow-Fraser, P., **V. Lougheed**, **V. Le Thiec**, **B. Crosbie**, **L. Simser,** and **J. Lord.** 1998. Long-term response of the biotic community to fluctuating water levels and changes in

water quality in Cootes Paradise Marsh, a degraded coastal wetland of Lake Ontario. Wetlands Ecology and Management 6: 19–42.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2012. Status reports. COSEWIC, Ottawa, Ontario, Canada. Accessed December 2015. http://www.cosewic.gc.ca/eng/sct2/index_e.cfm.

Else, M. J., and **D. N. Riemer.** 1984. Factors affecting germination of seeds of fragrant waterlily (*Nymphaea odorata*). Journal of Aquatic Plant Management 22: 22–25.

IBA (Important Bird Areas) Canada. 2009. Cumberland Marshes, Cumberland House, Saskatchewan. IBA Canada, Port Rowan, Ontario, Canada. Accessed December 2015. http://www.ibacanada.ca/site.jsp?siteID=SK102&lang=EN.

IUCN (International Union for Conservation of Nature) Standards and Petitions Subcommittee. 2014. Guidelines for using the IUCN red list categories and criteria. Version 11. IUCN, Gland, Switzerland. Accessed December 2015. http://www.iucnredlist.org/documents/RedListGuidelines.pdf.

Kreutzweiser, D., F. Beall, K. Webster, D. Thompson, and **I. Creed.** 2013. Impacts and prognosis of natural resource development on aquatic biodiversity in Canada's boreal zone 1. Environmental Reviews 21: 227–259.

Manitoba Mineral Resources Division. 1981. Surficial geological map of Manitoba. Manitoba Department of Energy and Mines, Winnipeg, Manitoba, Canada.

Marshall, I. B., and **P. H. Schut.** 1999. A national ecological framework for Canada. Ecosystems Science Directorate, Environment Canada and Research Branch, Agriculture and Agri-Food Canada, Ottawa, Ontario, Canada.

NatureServe. 2015a. NatureServe conservation status assessments: rank calculator. Version 3.185. NatureServe, Arlington, Virginia, USA. Accessed January 2016. http://www.natureserve.org/conservation-tools/conservation-rank-calculator.

NatureServe. 2015b. NatureServe explorer: an online encyclopedia of life. Version 6.0. NatureServe, Arlington, Virginia, USA. Accessed April 2015. http://explorer.natureserve.org/.

Nelson, T. A., N. C. Coops, M. A. Wulder, L. Perez, J. Fitterer, R. Powers, and **F. Fontana.** 2014. Predicting climate change impacts to the Canadian boreal forest. Diversity 6: 133–157.

Patterson, L. 2005. Shaped by change. Conservator 4: 26–31.

Schindler, D. W. 2001. The cumulative effects of climate warming and other human stresses on Canadian freshwaters in the new millennium. Canadian Journal of Fisheries and Aquatic Sciences 58: 18–29.

Slocum, P. D. 2005. Waterlilies and Lotuses. Species, Cultivars, and New Hybrids. Timber Press, Portland, Oregon, USA.

Victory Nickel. 2010. Minago Project Manitoba: environmental act proposal: environmental impact statement, volume 1, part 1. Victory Nickel Inc., Toronto, Ontario, Canada. Accessed April 2014. http://www.gov.mb.ca/conservation/eal/registries/5463minago/eis_execsumm.pdf.

Wiersema, J. H. 1996. *Nymphaea tetragona* and *Nymphaea leibergii* (Nymphaeaceae): two species of diminutive waterlilies in North America. Brittonia 48: 520–531.

Wiersema, J. H. 1997. *Nymphaea* Linnaeus. Pages 71–77 *in* Flora of North America North of Mexico, Volume 3: Magnoliophyta: Magnoliidae and Hamamelidae. *Edited by* Flora of North America Editorial Committee. Oxford University Press, New York, New York, USA.

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