Species at Risk Act
Management Plan Series

Management Plan for the Eastern Musk Turtle (*Sternotherus odoratus*) in Canada

Eastern Musk Turtle

2024

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For copies of the management plan, or for additional information on species at risk, including the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) Status Reports, residence descriptions, action plans, and other related recovery documents, please visit the Species at Risk (SAR) Public Registry[1].

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[1] www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html

Preface

The federal, provincial, and territorial government signatories under the Accord for the Protection of Species at Risk (1996)[2] agreed to establish complementary legislation and programs that provide for effective protection of species at risk throughout Canada[3]. Under the *Species at Risk Act* (S.C. 2002, c.29) (SARA), the federal competent ministers are responsible for the preparation of management plans for listed species of special concern and are required to report on progress within five years after the publication of the final document on the Species at Risk Public Registry.

The Minister of Environment and Climate Change and Minister responsible for the Parks Canada Agency is the competent minister under SARA for the Eastern Musk Turtle and has prepared this management plan, as per section 65 of SARA. To the extent possible, it has been prepared in cooperation with the governments of Ontario (Ministry of the Environment, Conservation and Parks) and Quebec (Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs) as per section 66(1) of SARA.

Success in the conservation of this species depends on the commitment and cooperation of many different constituencies that will be involved in implementing the directions set out in this plan and will not be achieved by Environment and Climate Change Canada (ECCC), the Parks Canada Agency, or any other jurisdiction alone. All Canadians are invited to join in supporting and implementing this plan for the benefit of the Eastern Musk Turtle and Canadian society as a whole.

Implementation of this management plan is subject to appropriations, priorities, and budgetary constraints of the participating jurisdictions and organizations.

[2] www.canada.ca/en/environment-climate-change/services/species-risk-act-accord-funding.html#2
[3] The Province of Quebec is not signatory of the Accord for the Protection of Species at Risk (1996). It does, however, cooperate with the federal government in the conservation of species at risk of common interest.

Acknowledgments

This management plan was prepared by Karolyne Pickett (Environment and Climate Change Canada, Canadian Wildlife Service (CWS – Ontario Region). A previous draft was prepared by Lee Voisin (CWS – Ontario Region). The management plan benefited from input, review and suggestions from the following individuals: Sylvain Giguère and Pierre-André Bernier (CWS – Quebec Region); Jude Girard and Krista Holmes (CWS – Ontario Region); Megan Stanley (CWS – National Capital Region); Josh Van Wieren (Parks Canada Agency); Karin Roberts and Scott Chiu (Department of Fisheries and Oceans Canada); staff from the Ontario Ministry of the Environment, Conservation and Parks and the National Heritage Information Centre (Ontario Ministry of Natural Resources and Forestry); and Yohann Dubois, Laurie Bisson-Gauthier and Isabelle Gauthier (Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs du Québec).

This management plan was informed by the *Recovery Strategy for the Eastern Musk Turtle (*Sternotherus odoratus*) in Canada [Proposed]* (2016). Numerous individuals contributed to the Recovery Strategy, including Patrick Galois (Amphibia-Nature); David Seburn (Seburn Ecological Service); Scott Gillingwater (Upper Thames River Conservation Authority); Rachel deCatanzaro, Angela McConnell and Marie-Claude Archambault (CWS – Ontario Region); Barbara Slezak, Bruna Peloso, Kari Van Allen and Louis Gagnon (formerly with CWS – Ontario Region); and Gabrielle Fortin and Carollynne Smith (CWS – Quebec Region). Recovery documents developed by the Équipe de rétablissement des tortues du Québec and the Ontario Multi-Species Turtles at Risk Recovery Team informed earlier drafts of the Recovery Strategy.

Executive Summary

The Eastern Musk Turtle (*Sternotherus odoratus*), also known as the Stinkpot, is listed as Special Concern on Schedule 1 of the *Species at Risk Act* (SARA). It is a small-sized freshwater turtle with an arched, grey-brown to black carapace. Eastern Musk Turtles typically inhabit slow-moving water in shallow wetlands connected to larger permanent water bodies, and shallow bays of lakes and rivers.

The species' range extends from southern Ontario and Quebec, south to Florida and west to central Texas. In Ontario, the Eastern Musk Turtle has been recorded primarily on and near the shores of Lake Huron, Lake Erie, and Lake Ontario, and in the south-eastern portion of the Canadian Shield. In Quebec, the species occurs along the northern shores of the Ottawa River and in one area along the St. Lawrence River, west of Valleyfield. It is estimated that roughly 5% of the global distribution of the Eastern Musk Turtle occurs in Canada.

Within the range of the Eastern Musk Turtle in Canada, habitat loss and fragmentation have been most severe in southwestern Ontario (Ecoregion 7E). Based on negative survey results or date of last observation in this region, 15 out of 26 subpopulations may be extirpated. Further north in Ontario, within the southern portion of the Canadian Shield, suitable habitat is more abundant but there is limited information on population abundance trends. The overall abundance of the Eastern Musk Turtle in Canada likely consists of 10,000 or more mature individuals.

The main threats to the species in Canada consist of by-catch from the commercial trap fishery and recreational angling, injury from boats and powerboat propellers, and loss of natural riparian habitat and tree cover. Secondary threats include water control structures, roads, and invasive plant species. The impact of threats from elevated mesopredator abundance, pollution and climate change are unknown. The Eastern Musk Turtle attains sexual maturity at a late age and reproductive success is low, making the species highly vulnerable to any increases in adult mortality rates.

The management objective for the Eastern Musk Turtle in Canada is to prevent the population from becoming Threatened or Endangered by maintaining or increasing the population abundance and index of area of occupancy and maintaining the subpopulations located in southern Ontario, by reducing and mitigating the main and secondary threats to the species. The broad strategies to be taken to achieve the management objective include use of legislative and administrative tools; implementing mitigation measures to reduce mortality and injury of individuals; protecting, managing and restoring habitat; conducting communication and outreach activities; undertaking abundance and distribution surveys and monitoring, and conducting research to fill knowledge gaps.

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1. COSEWIC* Species Assessment Information

Date of Assessment: November 2012

Common Name: Eastern Musk Turtle

Scientific Name: *Sternotherus odoratus*

COSEWIC Status: Special Concern

Reason for Designation: This species occupies shallow waters of lakes, rivers, and ponds. In southwestern Ontario, the species has declined substantially and is now restricted to a few tiny, scattered populations. Throughout its Canadian range, this species is vulnerable to increased mortality of adults and juveniles from recreational boating, development and loss of shoreline habitat, and fisheries by-catch. The species has delayed maturity and a low reproductive rate with a small clutch size. Since the previous assessment in 2002, increased survey effort has found more populations in eastern Ontario and adjacent areas of Quebec. The species distribution range remains unchanged, but losses in the southern half of its range make it near Threatened.

Canadian Occurrence: Ontario, Quebec

COSEWIC Status History: Designated Threatened in May 2002. Status re-examined and designated Special Concern in November 2012.

* COSEWIC – Committee on the Status of Endangered Wildlife in Canada

2. Species Status Information

The Eastern Musk Turtle was initially listed as a Threatened[4] species on Schedule 1 of the *Species at Risk Act* (SARA) in January 2005. In February 2018, the status of the Eastern Musk Turtle under SARA was changed to Special Concern[5], in accordance with the species status reassessment by COSEWIC in 2012 (see section 1 above). In the province of Ontario, the species is listed as Special Concern[6] under the *Endangered Species Act* (ESA) and as a specially protected reptile under the provincial *Fish and Wildlife Conservation Act*. In Quebec, the species is listed as Threatened[7] under the *Act Respecting Threatened or Vulnerable Species* (ARTVS).

[4] Threatened (SARA): A species likely to become an endangered species if nothing is done to reverse the factors leading to its extirpation or extinction.
[5] Special Concern (SARA): A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
[6] Special Concern (ESA): A species that lives in the wild in Ontario, is not endangered or threatened, but may become threatened or endangered because of a combination of biological characteristics and identified threats.
[7] Threatened (ARTVS) – a species that is in danger of disappearing.

The Eastern Musk Turtle occurs in Canada and the U.S. Approximately 5% of the global distribution of the Eastern Musk Turtle extends into Canada (COSEWIC 2012). NatureServe has ranked the conservation status of the Eastern Musk Turtle on a global scale as Secure (G5) but Vulnerable (N3) at the national scale for Canada (NatureServe 2023). Other national/state/provincial NatureServe rankings are presented in Appendix A. The Eastern Musk Turtle has a status of "Least Concern"[8] on the International Union for Conservation of Nature's Red List of Threatened Species (van Dijk 2015).

3. Species Information

3.1. Species Description

The Eastern Musk Turtle, also known as Stinkpot, is a small-sized freshwater turtle with a carapace (upper shell) length of 15 cm or less (Ewert 2005). Hatchlings are miniscule, with an average carapace length of 27.4 mm (Tucker et al. 2008). The species has a highly arched, grey-brown to black carapace, often obscured by a layer of algae (Behler and King 2002), and its plastron (lower shell) is yellowish-brown (Ernst and Lovich 2009). Its skin is grey to black with two yellow or white stripes on each side of the head, one line passing above the eye, and the other below; stripes may be faded, broken (mottled) or absent in some individuals (Ernst and Lovich 2009). There are tiny fleshy projections on the throat and chin (barbels), and four musk glands at the margins of the plastron which produce and release a liquid with a musky odor characteristic of the species (Behler and King 2002). The Eastern Musk Turtle cannot enclose its entire skin surface within its shell and is consequently much more vulnerable to desiccation and body mass loss when on land compared to other freshwater turtle species (Murphy et al. 2016). Further details of the species morphological description are summarized in COSEWIC (2012).

The average lifespan of Eastern Musk Turtles is unknown. Ernst (1986) aged one wild individual at 28 years old, and a captive individual reportedly lived for more than 54 years (Snider and Bowler 1992 in COSEWIC 2012). In a Georgian Bay subpopulation, males matured at an average carapace length of 63.6 mm (between 5 and 6 years old) and females matured at an average carapace length of 80.7 mm (between 8 and 9 years old) (Edmonds 1998).

3.2. Species Population and Distribution

The Eastern Musk Turtle is found only in Canada and the U.S. The species' global range extends from southern Ontario and Quebec to the north, and south to central Texas in the west and eastward to Florida (Figure 1). The Canadian range of the Eastern Musk Turtle includes all of southern Ontario, and extends to the Sudbury area to the northwest and into southwestern Quebec to the northeast (Figure 2).

[8] Least Concern: the taxon does not qualify for a status of Critically Endangered, Endangered, Vulnerable or Near Threatened under IUCN criteria. Widespread and abundant taxa are included in this category.

In Ontario, the Eastern Musk Turtle has been recorded primarily along the shores of Georgian Bay (in Lake Huron), Lake Erie and Lake Ontario, as well as along the southern edge of the Canadian Shield between the Peterborough area and Ottawa (Figure 2). In 2019, the species was reported for the first time near Brampton, in the Region of Peel (Dupuis-Désormeaux et al. 2019); the last sighting of the species in the Region of Peel dates back to 1969 (COSEWIC 2012). Recently, Eastern Musk Turtle eDNA has been detected in areas where the species had not been previously recorded, notably in parts of the Madawaska Highlands in the north-central region of the province (Feng and Lougheed 2023); the authors suggest that the reported northern distribution of the species in Ontario is likely incomplete. In Quebec, the species occurs along the northern shore of the Ottawa River and in one area along the south shore of the St. Lawrence River, west of Valleyfield (Chabot and St-Hilaire 1991; Belleau 2008; Desrosiers and Giguère 2008; Saumure 2009; Atlas des amphibiens et des reptiles du Québec 2013; CDPNQ 2019).

The paucity of historical occurrence records for the species may be due to a relatively recent acknowledgment that targeted aquatic surveys are necessary to detect Eastern Musk Turtles. Whereas other freshwater turtles bask out of the water and are thus detectable during land-based visual surveys, the Eastern Musk Turtle is prone to rapid desiccation (Ernst 1968, Murphy et al. 2016) and usually basks while resting in shallow water or floating at the surface, often under floating vegetation (Ernst and Lovich 2009, Carrière 2007). Although adult Eastern Musk Turtles have been observed basking aerially on muddy edges of ponds (Janzen et al. 1992), survey protocols based on visually encountering basking turtles from shore are not effective at detecting Eastern Musk Turtles.

As a result of increased targeted survey effort following the publication in 2002 of the Status Report for the Eastern Musk Turtle in Canada (COSEWIC 2002), 36 new subpopulations were discovered in Ontario (mainly in the eastern part of the province), and seven subpopulations were confirmed in the province of Quebec: six subpopulations along the northern shore of the Ottawa River, and one subpopulation along the St. Lawrence River, west of Valleyfield (CDPNQ 2019). The other Canadian subpopulations occur in southern and central Ontario. Despite the increased survey effort in recent years, there remains survey gaps in some portions of the Canadian range of Eastern Musk Turtle, particularly in the Richelieu River watershed and Lac Champlain areas in Quebec.

When including all known records of the species, the Extent of Occurrence[9] (EOO) of the Eastern Musk Turtle in Canada is 170,617 km^2, the species' Index of Area of Occupancy (IAO)[10] is 1,408 km^2, and the number of known subpopulations[11] is 113 (COSEWIC 2012).

Abundance has been estimated for five subpopulations in Canada (see COSEWIC 2012). Based on these studies, the size of the Canadian Eastern Musk Turtle population has been estimated to comprise at least 10,000 mature individuals (COSEWIC 2012).

In 2012, a decline in the abundance of the Canadian population of Eastern Musk Turtles was inferred based in part on not having found the species since 1986 in eight out of 29 Ontario Census Divisions where the species historically occurred (COSEWIC 2012). During the preparation of this Management Plan, species records from 2007 and onwards were found for four of these eight Census Divisions, namely: Middlesex County, Norfolk County (part of the former Haldimand-Norfolk County), Simcoe County and Sudbury District. Except in one instance however, these post-2006 observations were recorded in different locations than the pre-1986 records, suggesting that some subpopulations may indeed be extirpated. In southwestern Ontario's Ecoregion 7E (Lake Erie-Lake Ontario Ecoregion, also known as the Carolinian Life Zone), a potential 15 out of the 26 documented subpopulations may have been extirpated since 1986, resulting in extant subpopulations that are severely fragmented (COSEWIC 2012). Ongoing and projected loss of habitat in southern Ontario suggests that loss of mature individuals will continue into the future (COSEWIC 2012). Within the Canadian Shield part of its Ontario range, the species can be locally abundant (DeCatanzaro and Chow-Fraser 2010); however, fewer surveys have been conducted in this region and there is limited information on subpopulation abundance trends.

In Quebec, two out of the seven subpopulations have a viability ranking[12] of Excellent-Good; for the other five, there is either not enough data to rank viability, or viability has been ranked as Fair or Poor (CDPNQ 2019).

[9] Extent of Occurrence: the area included in a polygon without concave angles that encompasses the geographic distribution of all known populations of a wildlife species (COSEWIC 2009).
[10] Index of Area of Occupancy: the area within "extent of occurrence" that is occupied by a taxon, excluding cases of vagrancy, usually based on a grid with a cell size of 2 km X 2 km (COSEWIC 2009).
[11] A subpopulation is a subset of the Canadian population of Eastern Musk Turtle. A subpopulation is comprised of individuals that occur in a particular geographic area and that interbreed. See COSEWIC (2012) for the parameters used to delineate Eastern Musk Turtles subpopulations.
[12] Viability ranks "provide a succinct assessment of the estimated viability (probability of persistence) of occurrences of a given species." (See NatureServe 2019 for full description).

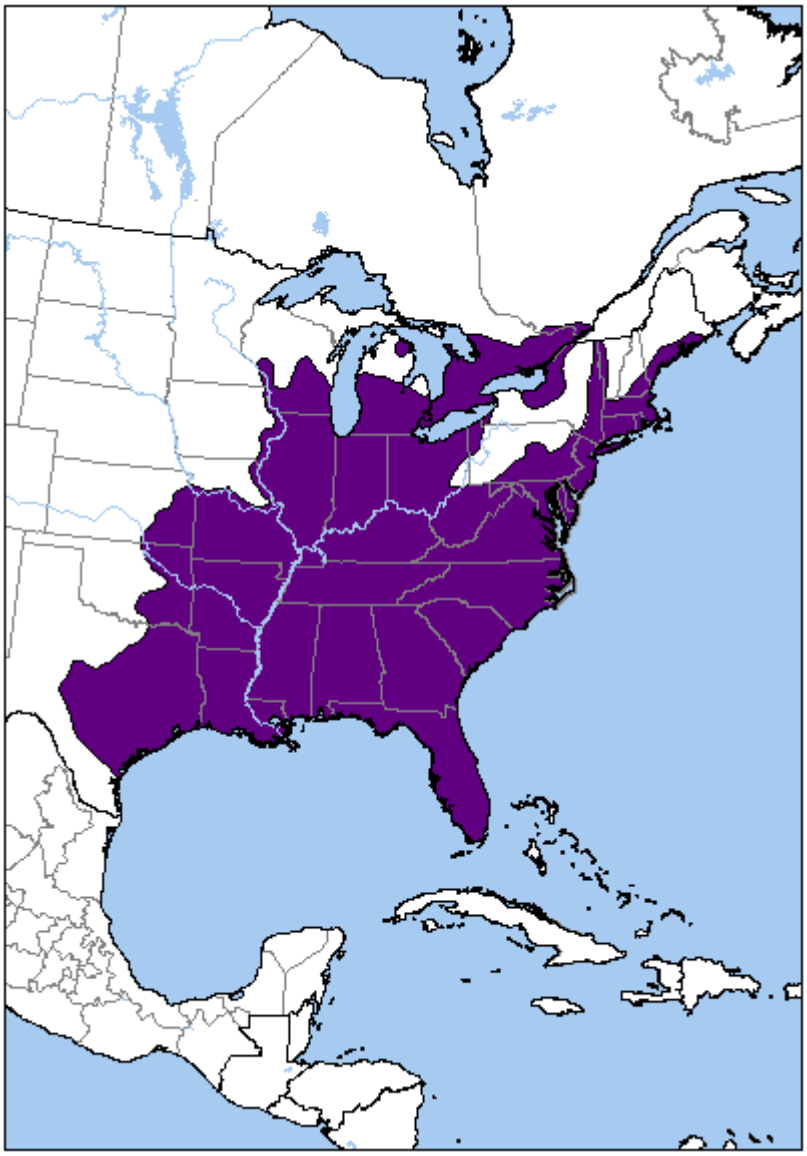

Figure 1. North American range (area in purple) of the Eastern Musk Turtle (adapted from NatureServe 2012). This map represents the general range of the species and does not depict detailed information on the presence and absence of observations within the range.

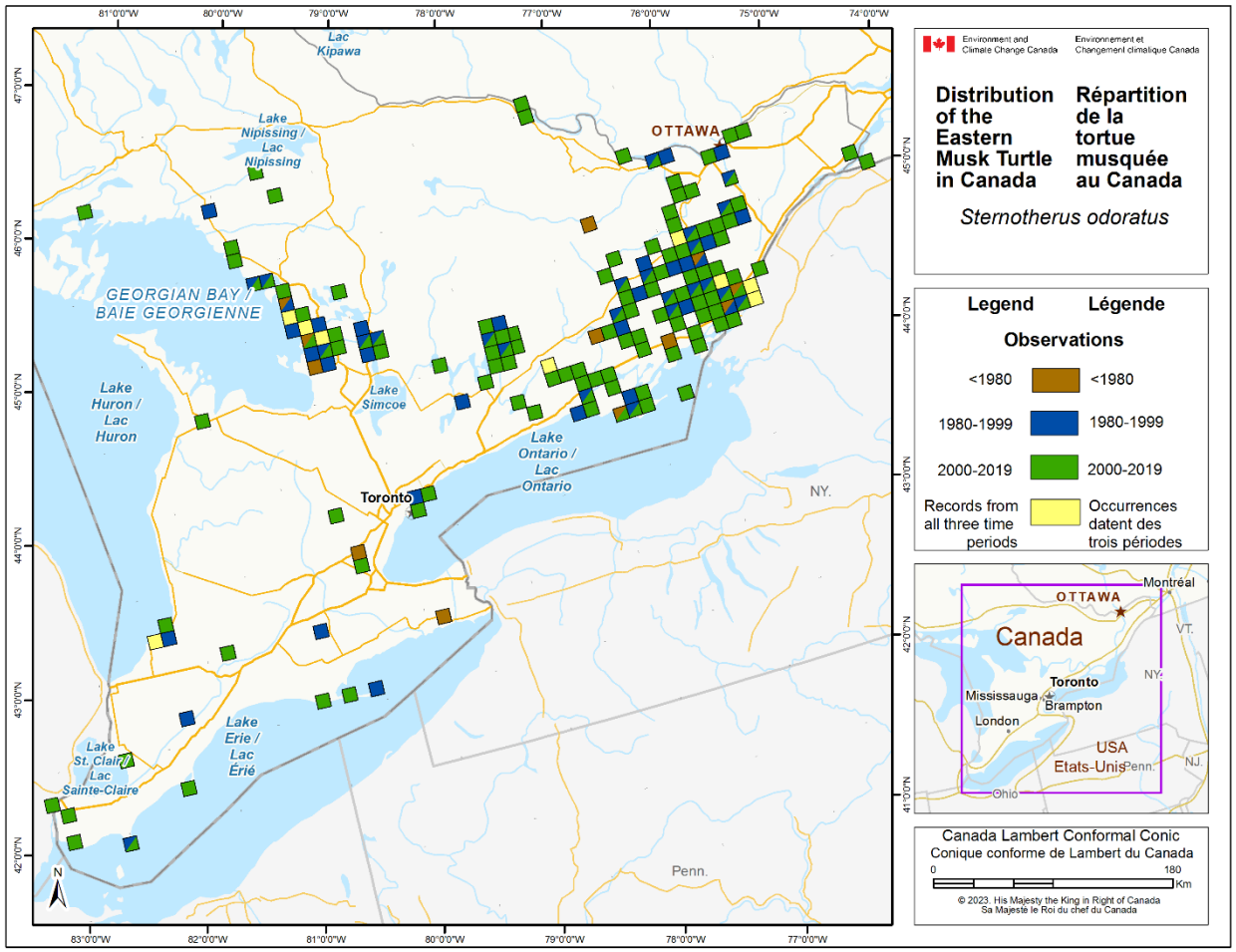

Figure 2. Distribution of Eastern Musk Turtle in Canada. Coloured squares contain one or more observation records collected during the time period corresponding to the colour identified in the legend. Bi-coloured squares contain at least one observation record from each of the two time periods identified by the corresponding colours. Data sources : Canadian Wildlife Service (CWS), Parks Canada Agency, Natural Heritage Information Centre, Centre de données du patrimoine naturel du Québec.

3.3. Needs of the Eastern Musk Turtle

General Habitat Needs

The Eastern Musk Turtle is a primarily aquatic turtle species that inhabits stagnant or slow-moving waters in wetlands connected to larger permanent waterbodies, or shallow bays of lakes and rivers (see review in COSEWIC 2012). Generally, they require waterbodies that comprise both shallow areas with aquatic vegetation for foraging, and areas deep enough to allow brumation[13] (Feng and Lougheed 2023). In coastal wetlands of the Great Lakes specifically, greater numbers of Eastern Musk Turtles are found in wetlands that are less exposed to wave energy and longshore currents, and that have a much greater accumulation of deep organic matter (Wieten et al. 2012).

The Eastern Musk Turtle is commonly found in shallow waters close to the shoreline (e.g., Rowe et al. 2009, Wilhelm & Plummer 2012), though the species has been found at depths of up to 9 m (Ernst and Lovich 2009). On the north shore of the Ottawa River in southwestern Quebec, the average depth at which the species was caught was 0.43 m (Belleau 2008). In the Thousand Islands National Park area on the St. Lawrence River, Carrière (2007) found the majority of Eastern Musk Turtles close to shore (average of 5 m from the shoreline, maximum 25 m) and in water less than 1 m deep (except when overwintering).

The species occurs in waters with abundant emergent, floating, and submerged aquatic vegetation. In the Ottawa River, individuals were most frequently found in emergent wetland habitat, and never in cattail patches (Belleau 2008). Eastern Musk Turtles were also found in areas with a soft substrate such as sand or organic mud, but never in habitat with a rocky bottom (Belleau 2008). This result is consistent with Carrière (2007), who reported that Eastern Musk Turtles in the St. Lawrence River were most often observed burrowed in the mud.

Habitat patches occupied by the species commonly contain underwater shelters such as rocks, submerged logs, Muskrat (*Ondatra zibethicus*) lodges (Wilhelm & Plummer 2012), and Beaver (*Castor canadensis*) lodges (the latter were used more than expected based on their availability in the study site, Belleau 2008). The microhabitat of Eastern Musk Turtles shares many similarities (e.g. water depth) with that used by Painted Turtles (*Chrysemys picta*) and Snapping Turtles (*Chelydra serpentina*) (Anthonysamy et al. 2014). The specific habitat needs of Eastern Musk Turtle hatchlings are not well known.

Two landscape scale studies in Ontario have found that amount of forest cover is the most important predictor of the presence of Eastern Musk Turtles in adjacent wetlands (Quesnelle et al. 2013; Markle et al. 2018a). This surprising result may be due to greater accessibility to nesting sites where the extent of riparian forest cover is higher (Quesnelle et al. 2013).

[13] Period of inactivity or torpor exhibited by reptiles during the winter.

Overwintering

The overwintering season for Eastern Musk Turtles begins when ambient water temperature dips below 10°C (Ernst and Lovich 2009); as such the timing varies across subpopulations according to their geographical location and annual temperature fluctuations. For example in Pennsylvania, the species overwinters between November and March (Ernst 1986) whereas in Florida, the species may be active all year long (Iverson and Meshaka 2006). Eastern Musk Turtles in the Ottawa River begin to aggregate on rocky shores near their overwintering sites in late August, and overwinter between November and April (Belleau 2008). Eastern Musk Turtles in the St. Lawrence start overwintering in September (Carrière 2007).

Overwintering sites in regions with cold winters are located underwater, where respiration may occur through the membranes of the throat and mouth (Ultsch 2006). Typically, these sites have an organic substrate in which turtles can bury themselves up to 30 cm deep in mud (Ernst and Lovich 2009). In the St. Lawrence River, the sites are usually located at a depth approaching 3 m (Carrière 2007). Because Eastern Musk Turtles can only survive in anoxic water[14] for about three weeks (Ultsch 2006 and references therein) they would not survive the length of a typical winter within their Canadian range if completely buried in mud, without access to oxygen in the water column; as such, the species must select overwintering sites where ice-covered water remains oxygenated.

In some locations such as South Carolina, hatchlings were found to overwinter in the nest (Gibbons and Nelson 1978), though further north in Pennsylvania, the species appears to almost always emerge from their nests before the onset of winter (Lovich et al. 2014). Based on their low tolerance to freezing when exposed to soil containing ice crystals (Costanzo et al. 2001, 2006), hatchlings almost certainly lack the physiological capability of overwintering in the nest within their range in Canada. The characteristics of overwintering sites used by juveniles remains unknown.

Mating

In the U.S., mating has been reported to occur in water less than 30 cm deep in April and May, with a second mating period in September and October (e.g., Ernst 1986). In Quebec however, mating has only been observed in September (Saumure 2009). In the Ottawa River, males and females have been observed aggregating around beaver lodges in September and October, possibly for mating (Belleau 2008).

Nesting

In Canada, Eastern Musk Turtle females lay no more than one clutch annually, in early June to late July, and hatchlings emerge from the nest in August and September (see summary in COSEWIC 2012). In Frontenac County, Lindsay (1965) observed clutches containing 2 to 6 eggs. Most Eastern Musk Turtle nests are dug less than 10 cm deep, in variable substrate such as decaying vegetation, rotting stumps or logs, Beaver or

[14] Water that is completely depleted of oxygen.

Muskrat lodges, exposed soil or sand between tufts of grass in beach areas and, on the Canadian Shield, in shallow gravel and soil-filled rock crevices (see summary in COSEWIC 2012). As is the case for many freshwater turtle species, Eastern Musk Turtle females also nest on road shoulders (Aresco 2003, 2005). Females may share nesting sites and exhibit site fidelity (unpubl. data in COSEWIC 2012).

Eastern Musk Turtles are thought to nest close to the shoreline throughout their range, though the average distance travelled to nesting sites by females in Canada is not available. The average and maximum distances between a nest and the shoreline were, respectively, 5.5 m and 50 m in Massachusetts; 7 m and 11 m in Pennsylvania, and; 14 m and 15 m in Tennessee (see review in Steen et al. 2012).

Thermoregulation

As ectotherms, turtles regulate their body temperature by varying exposure to sun (known as basking), shade and water (Bulté and Blouin-Demers 2010). Contrary to many freshwater turtle species that bask on rocks and logs protruding from the water, Eastern Musk Turtles usually bask by floating at or just below the surface of the water, often among or under aquatic vegetation such as lily pads (see literature summary in COSEWIC 2012).

Foraging

Eastern Musk Turtles are typically omnivorous[15]. They often walk along the bottom of a waterbody, using their head to probe into soft mud, sand, and rotting vegetation to find food (Ernst and Lovich 2009). Smaller individuals (carapace length <5 cm) typically feed on aquatic insects, algae, and carrion, while larger individuals consume a variety of food including leeches, clams, snails, aquatic insects, spiders, crayfish, fish (eggs, larvae, and adults), filamentous algae, plant material, and carrion (Schneider 1998; Ford and Moll 2004; Iverson and Meshaka 2006; Ernst and Lovich 2009). The species may be able to shift its diet in favour of the most abundant food source even when the prey is a non-native species (Wilhelm & Plummer 2012). The majority of foraging occurs in the water; however, individuals have been known to occasionally leave the water at dusk to feed on terrestrial slugs (Ernst and Lovich 2009).

Eastern Musk Turtles feed when water temperatures are between 13°C and 35°C (Mahmoud 1969), but somewhat divergent findings have been reported regarding the species' diel activity patterns. According to Carrière (2007), individuals undertake long distance movements between 21h and 8h, and in the case of the Quebec subpopulations, individuals actively move about in the evening and early nighttime (Giguère pers. comm. 2021). With respect to foraging however, Smith and Iverson (2002) suggested that Eastern Musk Turtles are not nocturnal feeders because none entered traps during the night. Results from Glorioso and Cobb (2012) support a bimodal (crepuscular) feeding activity pattern for the species, with the biggest peak being between 6 am and 11 am.

[15] Omnivorous: feeding on food of both plant and animal origin.

Movement between habitat patches

Eastern Musk Turtles use primarily aquatic habitat to travel between habitat patches used for various life cycle activities (e.g., foraging, nesting, overwintering), even if it results in traveling longer distances to reach their destination (Carrière 2007). Movement habitat includes shallow vegetated littoral zones (<2 m deep) (Rowe 2003; Belleau 2008; Rowe et al. 2009) or relatively deep water with little to no vegetation (Carr 1952).

Daily individual movements average between 23 m to 131 m, depending on the subpopulation (Carrière 2007; Belleau 2008; Laverty 2010; Wilhelm & Plummer 2012; Laverty et al. 2016), although one-day movements up to 1 km have been observed (Belleau 2008). The mean daily travel distance was approximately 26 m in the St. Lawrence River (Carrière 2007) and 38 m in the Ottawa River (Belleau 2008). The maximum long distance movement (over multiple years) ever recorded is 14 km (Toussaint and Caron, in prep.).

Estimates of home range size[16] for the Eastern Musk Turtle in Canada varies considerably amongst sites and according to the method of calculation (see review in COSEWIC 2012). In stark contrast to estimates of 0.02 to 2.8 ha from U.S. locations (Mahmoud 1969; Ernst 1986; Rowe et al. 2009), home range size estimates in Canada range from 6.2 ha in the St. Lawrence River (Carrière 2007) to 155.4 ha in Georgian Bay (Edmonds 1998).

3.4 Biological Limiting Factors

Eastern Musk Turtles share certain life history traits with other turtle species that limit the ability of subpopulations to withstand chronic increases in mortality rates without experiencing declines in abundance (Congdon et al. 1993, 1994; Gibbons et al. 2000):

1) Late sexual maturity;
2) Low fecundity (number of female eggs laid annually, per female);
3) High rate of natural predation on eggs and juveniles under two years of age; and,
4) Dependence on environmental conditions for the internal development of embryos and incubation of eggs.

Turtle subpopulation persistence thus hinges on high survival rates of adults and older juveniles (Congdon et al. 1993, 1994; Cunnington and Brooks 1996); population declines and extirpations can occur even when increases in adult mortality rates are small (Midwood et al. 2014).

The climate parameters within which Eastern Musk Turtles can survive limit the species' northern range boundary (Bleakney 1958; McKenney et al. 1998). Recent models predict the absence of the species where mean summer temperature is lower than 16°C and the mean annual temperature is below 4°C; at elevations above 400 m; and in

[16] Home range: The area needed by an animal to complete its normal activities (Burt 1943).

areas that receive more than 270 mm of precipitation during the summer, which lowers surface water temperature (Feng and Lougheed 2023). Eastern Musk Turtles also rely on sufficient solar heat for successful egg incubation, such that the length of the summer season constitutes a major limitation for subpopulations at northern latitudes (Brooks 2007). As a result of this shorter nesting season, females typically produce only one clutch per year in Canada (see Nesting section above).

Availability of suitable overwintering sites may also be a limiting factor for the Canadian population of Eastern Musk Turtles, because the species is intolerant of anoxic conditions, which can develop in northern latitude lakes in winter as a result of longer periods of ice cover (Ultsch and Cochran 1994).

3.5 Species Cultural Significance

Turtles play an important role in Indigenous spiritual beliefs and ceremonies. To the First Nations peoples, the turtle is a teacher, possessing a great wealth of knowledge. It plays an integral role in the Creation story, by allowing the Earth to be formed on its back. For this reason, most First Nations peoples traditionally call North America “Turtle Island”. Indigenous peoples also use the turtle shell to represent a lunar calendar, with the 13 scutes (broad, flat scales) representing the 13 full moons of the year. Rattles made from turtle shells are used in traditional ceremonies, and often represent the Turtle in the Creation story. Turtles also appear in other traditional stories including the Anishinaabe story “How the turtle got its shell” and the Haudenosaunee story “Turtle races with beaver” (Bell et al. 2010).

4. Threats

Threats to the Canadian population of Eastern Musk Turtle were assessed by a group of species experts during the development of this Management Plan (ECCC 2018). Threats with an impact rank of Low, Medium or Unknown are presented in Table 1 and are described in more detail under section 4.2. Threats with an impact ranked as Negligible include residential development and agriculture, and are discussed in ECCC (2018).

4.1. Threat Assessment

The Eastern Musk Turtle threat assessment is based on the IUCN-CMP (Conservation Measures Partnership) unified threats classification system (Salafsky et al. 2008). Threats are defined as the proximate activities or processes that have caused, are causing, or may cause in the future the destruction, degradation, and/or impairment of the entity being assessed (population, species, community, or ecosystem) in the area of interest (global, national, or subnational scale). Limiting factors are not considered during this assessment process. For purposes of this threat assessment, only present and future threats are considered. Historical threats, indirect or cumulative effects of the threats, or any other relevant information that would help understand the nature of the threats, are discussed under section 4.2.

Table 1. Threat assessment summary for the Eastern Musk Turtle.

IUCN Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]
4	Transportation & service corridors	Low	Large	Slight	High
4.1	Roads & railroads	Low	Large	Slight	High
5	Biological resource use	Medium - Low	Pervasive	Moderate - Slight	High
5.4	Fishing & harvesting aquatic resources	Medium - Low	Pervasive	Moderate - Slight	High
6	Human intrusions & disturbance	Low	Large	Slight	High
6.1	Recreational activities	Low	Large	Slight	High
7	Natural system modifications	Low	Restricted	Slight	High
7.2	Dams & water management/use	Low	Restricted	Slight	High
7.3	Other ecosystem modifications	Low	Small	Slight	High
8	Invasive & other problematic species & genes	Low	Small	Moderate	High
8.1	Invasive non-native/alien species	Low	Small	Moderate	High
8.2	Problematic native species	Unknown	Pervasive	Unknown	High
9	Pollution	Unknown	Pervasive	Unknown	High
9.1	Household sewage & urban waste water	Unknown	Large	Unknown	High
9.3	Agricultural & forestry effluents	Unknown	Small	Unknown	High
9.5	Air-borne pollutants	Unknown	Pervasive	Unknown	High
11	Climate change & severe weather	Unknown	Large	Unknown	High
11.2	Droughts	Unknown	Large	Unknown	High
11.3	Temperature extremes	Unknown	Restricted	Unknown	High
11.4	Storms & flooding	Unknown	Restricted	Unknown	High

[a] **Impact** – The degree to which a species is observed, inferred, or suspected to be directly or indirectly threatened in the area of interest. Impact is based on Severity and Scope ratings, and includes present and future threats only. Threat impact reflects a reduction of a species population or decline/degradation of the area of an ecosystem. The median rate of population reduction or area decline for each combination of scope and severity corresponds to the following classes of threat impact: Very High (75% declines), High (40%), Medium (15%), and Low (3%). Unknown: used when impact cannot be determined (e.g., if values for either scope or severity are unknown); Not Calculated: impact not calculated as threat is outside the assessment timeframe (e.g., timing is insignificant/negligible or low as threat is only considered to be in the past); Negligible: when scope or severity is negligible; Not a Threat: when severity is scored as neutral or potential benefit.

[b] **Scope** – Proportion of the species that can reasonably be expected to be affected by the threat within 10 years. Usually measured as a proportion of the species' population in the area of interest. (Pervasive = 71–100%; Large = 31–70%; Restricted = 11–30%; Small = 1–10%; Negligible < 1%).

[c] **Severity** – Within the scope, the level of damage to the species from the threat that can reasonably be expected to be affected by the threat within a 10-year or three-generation timeframe. Usually measured as the degree of reduction of the species' population. (Extreme = 71–100%; Serious = 31–70%; Moderate = 11–30%; Slight = 1–10%; Negligible < 1%; Neutral or Potential Benefit ≥ 0%).

[d] **Timing** – High = continuing; Moderate = only in the future (could happen in the short term [< 10 years or 3 generations]) or now suspended (could come back in the short term); Low = only in the future (could happen in the long term) or now suspended (could come back in the long term); Insignificant/Negligible = only in the past and unlikely to return, or no direct effect but limiting.

4.2. Description of Threats

This section describes the threats outlined in Table 1. Although threats are listed individually, multiple threats can act together over the long term to have greater impacts on the species (cumulative effects). The overall threat impact, which takes into account the additive effect of the threats identified in Table 1, was assigned a ranking of 'Medium' because the score for scope and/or severity of several threats fell at the lower end of the categories' range of values, and because most threats have a greater scope and severity in the southern portion of the species, whereas the majority of the Canadian population is located further north (ECCC 2018). Some threats apply only during the active season (if turtles are not exposed to these threats during overwintering).

IUCN Threat 4.1 Roads & railroads – Impact: Low

Vehicle collisions

Multiple studies documenting direct mortality of freshwater turtles from vehicle collisions, as well as potential sub-lethal impacts of roads and traffic, are reviewed in Andrews et al. (2006). Roads have been found to reduce genetic diversity (Jackson and Fahrig 2011) and create barriers to movement, however road-kill remains the most impactful effect of roads on turtles (Paterson et al. 2019). In Ontario, high turtle road-kill numbers have been documented on many road sections that bisect wetlands in urban (e.g., Piczak et al. 2019) and non-urban settings (e.g., Reference Removed), as well as in protected areas (Crowley and Brooks 2005). A study conducted along the Long Point peninsula causeway in southern Ontario provided evidence that turtles are sometimes killed intentionally by drivers (Ashley et al. 2007).

Data on the impact of turtle mortality from roads at the population level is more limited. While undertaking a comprehensive review of empirical studies documenting the effects of roads and traffic on animal abundance, Fahrig and Rytwinski (2009) found three studies that pertained to turtles, though none explicitly included Eastern Musk Turtle as a study species. The documented effects on turtle populations in those studies were either negative (Fowle 1990; Boarman and Sazaki 2006) or negative and neutral (Gibbs and Shriver 2002). Fahrig and Rytwinski (2009) attributed the general negative effect of roads on turtles and other reptiles to vulnerability to mortality (as opposed to traffic-related disturbance) because of low vehicle avoidance behaviour (e.g., turtles are slow-moving) and their attraction to roads (e.g., gravel roads and roads shoulders are attractive to female turtles as nesting sites).

Female turtles are encountered on roads in greater proportions than males, and are therefore likely to be particularly susceptible to road-kill (Aresco 2003, 2005; Steen et al. 2006; but see Carstairs et al. 2018). Higher female road mortality may be the reason why several studies conducted in water bosies surrounded by dense road networks/bisected by a highlway have reported turtle populations with a male-biased sex ratio (Aresco 2003; Marchand and Litvaitis 2004; Steen and Gibbs 2004; Gibbs and

Steen 2005; but see Smith and Iverson (2002) for other potential explanations). More recent studies have determined that road mortality rates are sufficient to lead to some subpopulations' declines and extirpations (e.g., Aresco 2003; Piczak et al. 2019) but not others (e.g., Dorland et al. 2014).

Eastern Musk Turtles are likely less susceptible to road mortality than other co-occurring freshwater turtle species given their more limited use of terrestrial habitat. Based on the parameters used by Brehme et al. (2018) to assess reptile species' susceptibility to road mortality and fragmentation in California, Eastern Musk Turtle would fall in the 'Very Low' risk category, due to the species' once-a-year, short-distance travel on land to reach terrestrial nesting areas. Small-bodied and predominantly aquatic species of turtles were also predicted to be the least susceptible to road mortality by Gibbs and Shriver (2002). Nevertheless, Eastern Musk Turtles have been reported as road-kill in the U.S. (e.g. Aresco 2003; Smith and Dodd 2003) and in Ontario (Reference Removed; Carstairs et al. 2018; Seburn and Burns 2021). More than 80 citizen science observations of road-killed Eastern Musk Turtles have been reported in Ontario on iNaturalist (https://inaturalist.ca/projects/canadian-amphibians-reptiles-on-roads). Road mortality is of minor concern for the Eastern Musk Turtle subpopulations in Quebec (Giguère pers. comm. 2021).

Flooding events may affect the road-kill rate of female Eastern Musk Turtle. For example, record high water levels in Lake Ontario in 2017 and 2019 (National Oceanic and Atmospheric Administration 2021) led to flooding of some St. Lawrence River riparian zones; this in turn appeared to increase the number of turtles along roads, particularly where the riparian zone is thinner and provides a more narrow nesting area (Van Wieren, pers. comm. 2020). The impact of flooding is further discussed under Threat 11.4 below.

The threat from vehicle collisions will continue to rise assuming that the 2% rate of increase in total road length in southern Ontario between 1985 and 2005 is maintained (Ontario Biodiversity Council 2015). Due to the important impact of mortality rates of adult female turtles at the population level (Congdon et al. 1993, 1994), the impact of roads on Eastern Musk Turtles subpopulations in Ontario should be factored in the planning of road network expansions (e.g., by avoiding wetlands) and road upgrades (e.g., by installing exclusion fences along roads in conjunction with crossing structures (road underpasses, which have been shown to be effective at reducing turtle road mortality rates and improving connectivity at the population level (Boyle et al. 2021; Read and Thompson 2021)). Road-kill mitigation measures can benefit multiple turtle species simultaneously (e.g., Heaven et al. 2019), however they must be appropriately designed to be effective for the target species assemblage[17]. Models predicting the location of road mortality 'hotspots' have been developed (e.g., Langen et al. 2012; Chyn et al. 2021), and using such models to inform placement of mitigation measures may increase their effectiveness (Boyle et al. 2021).

[17] For example, Eastern Musk Turtles are capable of climbing over 0.6 m high woven vinyl erosion control fencing (temporary silt fences) (Aresco 2003).

Road construction and maintenance

Construction of new roads, as well as replacement or repair work of existing roads and bridges in wetlands or along shorelines in the wintertime could cause mortality of turtles if activities include the installation and dewatering of coffer dams in overwintering habitat.

Activities related to the maintenance of roads and rights-of-way, such as grading and vegetation removal, have the potential to destroy eggs during the nesting season. These activities are unlikely to have an impact if undertaken during the overwintering season given that hatchlings probably do not overwinter in the nest in Canada (see Overwintering under section 3.3).

Lastly, the expansion of road networks and road maintenance may facilitate the spread of invasive plant species (Gelbard and Belnap 2003; Rauschert et al. 2017); the impact of invasive plants is further discussed under Threat 8.1 below.

IUCN Threat 5.4 Fishing & harvesting aquatic resources – Impact: Medium-Low

Commercial entrapment fisheries

Despite the few peer-reviewed studies of animal by-catch rates in freshwater (compared to marine) commercial fisheries, incidental killing of non-target freshwater animals has been documented in fish, birds, mammals and turtles (see review in Raby et al. 2011). For instance, thousands of freshwater turtles belonging to nine different species were caught as by-catch during a multi-year fish-sampling program in the Mississippi River in the U.S. (Braun and Phelps 2016). In Ontario, hoop nets targeting commercially fished species such as Bluegill (*Lepomis macrochirus*) and Pumpkinseed (*Lepomis gibbosus*) have captured Painted Turtles, Snapping Turtles, Northern Map Turtles (*Graptemys geographica*) and Eastern Musk Turtles (Larocque et al. 2012a). In fact, commercial fishing gear is so successful at catching freshwater turtles that it is often used by researchers to capture Eastern Musk Turtles; effective trapping methods include hoop/fyke nets (e.g., Attum et al. 2013; Stoot et al. 2013), wire funnel traps (e.g., Smith and Iverson 2002), and crawfish nets (e.g., Glorioso and Cobb 2012).

Unfortunately, freshwater turtles risk drowning when trapped in commercial fishing gear for a prolonged period of time. Barko et al. (2004) reported a 10.3% mortality rate in freshwater turtles captured in passive fishing techniques in the Mississippi River. In Ontario, turtle by-catch and mortality in freshwater commercial fishing traps was first documented by Carrière (2007), who reported sixteen Northern Map Turtles drowned in hoop nets deployed in the St. Lawrence River. One commercial fisher reported finding an Eastern Musk Turtle once in a hoop net in Lake Saint-François (Bourgeois and Rouleau 2015).

In Ontario commercial fisheries, hoop and trap nets are permitted to remain unchecked for an unlimited period of time (MNRF 2020a, 2020b), except in Lake Erie’s Inner Long

Point Bay where hoop nets must be lifted every 48 hours unless set in such a manner that access to air is available (MNRF 2020c). Hoop nets must be lifted every 48 hours in Lake Saint-François (Bourgeois and Rouleau 2015). Although placing floats inside nets can reduce turtle mortality (Larocque et al. 2012b), approximately 33% of all captured Snapping Turtles and Painted Turtles perished in hoop nets despite being fitted with plastic jugs to maintain airspace (Larocque et al. 2012a). On the other hand, Larocque et al. (2012a) reported that none of the 52 Eastern Musk Turtles captured during their study died as a result of entrapment in hoop nets which were set for a maximum of 48 hours.

There may be sub-lethal impacts on turtles of capture in fishing gear, but this has not been demonstrated so far in Eastern Musk Turtles. For example, a 3-hour entrapment period did affect physiological parameters in Eastern Musk Turtles, but it did not lead to behavioural impairment (Stoot et al. 2013). While Gutowsky et al. (2016) detected reduced locomotion in Eastern Musk Turtles within the first 40 minutes of their release from a 4-hour submersion, activity levels were thereafter no different than the control group and no mortality was detected. Overall these studies suggest that Eastern Musk Turtles fully recover from short (3-4 hours) entrapment periods, and can survive 48 hour-long submersions under certain circumstances.

Population viability models have shown that additional mortality at seemingly low levels can nevertheless lead to subpopulation declines in Eastern Musk Turtles and other turtle species (Midwood et al. 2014). The number of animals killed annually from by-catch, and the ensuing effect on probability of subpopulation extirpation, will necessarily vary according to the species, the amount of time that traps are left submerged between lifts, and the original size of the turtle subpopulation in question.

The scope of the threat to Eastern Musk Turtles from commercial fisheries in Ontario has remained constant over the last ten years based on the largely unchanged number of hoop and trap net licences issued since 2011, except for a 6-fold increase in hoop net licences issued for the St. Lawrence River in 2021 (MNRF unpubl. data). The severity of the threat may have decreased slightly for a few subpopulations following the inclusion of best fishing practices in some licence conditions in Lake Ontario in 2019 (Larocque et al. 2020), and as a result of fisheries closures during a portion of the turtles' active season in specific locations (e.g., closure between May 13th and August 31st in Lake Erie's Long Point Inner Bay, MNRF 2020b). In Quebec, there is some commercial entrapment fishing occurring in Lake Saint-François from May to mid-December (Bourgeois and Rouleau 2015), but no commercial fishing licences are currently active where the species occurs in the Ottawa River (Giguère pers. comm. 2021).

The threat to Eastern Musk Turtles from drowning in commercial fishing gear can be mitigated by: 1) taking turtle seasonal activity into account when regulating the timing and length of the fishing season (for example, the amount of turtle by-catch can be twice as high in the spring than in the fall (Larocque et al. (2012a)); 2) using certain handling and recovery methods for captured turtles (e.g., LeDain et al. 2013), and; 3) using fishing gear fitted with a modified entrance that reduces turtle captures and/or with

devices that allow turtles to escape if captured. Several gear modifications have been tested for fyke nets (e.g., Larocque et al. 2012c; Cairns et al. 2013, 2017; Moos and Blackwell 2018), eel-traps and carp-traps (Lowry et al. 2005), and hoop nets (Fratto et al. 2008), with many designs successful in reducing turtle by-catch.

IUCN Threat 6.1 Recreational activities – Impact: Low

Collisions with recreational powerboats (inboards, outboards and personal watercraft)

Injuries due to collisions with boats and powerboat propellers have been documented in many North American freshwater turtle species including Northern Map Turtle (e.g., Bulté et al. 2010), Spiny Softshell (*Apalone spinifera*) (Reference Removed), Painted Turtle and Pond Slider (*Trachemys scripta*) (Smith et al. 2006), Snapping Turtle (Smith et al. 2006) and Eastern Musk Turtle (Bancroft et al. 1983; Bennet and Litzgus 2014).

Given their common behaviour of floating just below the water surface underneath floating vegetation (Carrière 2007), it has been surmised that Eastern Musk Turtles may be particularly vulnerable to collisions with boats. On the other hand Hollender et al. (2018) hypothesized that the species may be less vulnerable to collisions than other turtle species because they move through aquatic habitat by walking on the bottom. The boat-related injury rate for Eastern Musk Turtle was estimated at 4% by Bancroft et al. (1983) and at 2% by Bennett and Litzgus (2014) (compared to their estimated 17% to 20% injury rate for Northern Map Turtle). Mortality rates are however difficult to estimate because a fatally injured turtle will retreat/sink to deeper water while leaving little possibility of retrieving a carcass (Laverty et al. 2016). Given evidence that collisions with powerboats led to declines in some Northern Map turtle subpopulations in Ontario, even in water bodies with low to moderate levels of boat traffic (Bulté et al. 2010), it is possible that, similar to entrapment in fishing gear, small increases in turtle mortality rates can nevertheless have population-level impacts.

The scope of this threat is likely increasing, based on significant year over year increases in outboard engine retail sales (e.g., 17% increase in 2020 over 2019, NMMA 2021) and steady increases in the number of pleasure craft licences issued in Ontario (e.g., 32% increase in total pleasure craft licenses in February 2021 over February 2020, Transport Canada 2020, 2021). This trend is relevant to the management plan objectives for Eastern Musk Turtle because overall injury rate of freshwater turtles was found to increase with increasing boat traffic (Hollender et al. 2018).

Measures to mitigate this source of mortality include regulation of powerboat use in habitats with high turtle densities (e.g., reduced speed) and educating boaters about impacts of boats to aquatic wildlife (Lester et al. 2013).

Recreational angling

Several species of freshwater turtles are incidentally caught by recreational anglers, but there have been few studies on by-catch and survival rates (Browne et al. 2020).

Evidence of fishing hook-related injury has been recorded in Snapping Turtle (Borkowski 1997), Spiny Softshell (Reference Removed), and Eastern Painted Turtle (*Chrysemys picta picta*) (Browne et al. 2020). Ingested fish hooks have been detected by X-ray in Pond Sliders, Spiny Softshells and Snapping Turtles (Steen et al. 2014). Anecdotal observations of injury in Eastern Musk Turtles have been reported (e.g., Ernst 1986; Laverty et al. 2016), and Steen et al. (2014) observed Eastern Musk Turtles with baited hooks in the mouth. According to a model developed by Steen and Robinson (2017), the probability that a turtle would ingest a hook and die (1.2-11%) was sufficient to cause population declines.

Pressure on freshwater turtles from recreational angling in Ontario is lower than it was in 1995, but has remained relatively constant over the last 15 years. In 2015, the number and percentage of Ontarians that were active resident anglers (754,617 and 5.5%, respectively) were similar to those in 2005 (DFO 2007, 2019). Fishing effort also remained unchanged between 2005 and 2015, with an average of 17 days fished per resident angler per year (DFO 2007, 2019). In Quebec, there is recreational fishing in Lake Saint-François where the species occurs (Bourgeois and Rouleau 2015); generally speaking, Eastern Musk Turtle habitat is also productive for target fish species such as Northern Pike (*Esox lucius*) and Bass (*Micropterus dolomieui, M. salmoides*).

IUCN Threat 7.2 Dams & water management/use – Impact: Low

Dams and locks

Several Eastern Musk Turtle subpopulations in Canada are isolated by dams, including all of the subpopulations in Quebec. Given the species' almost exclusive use of the aquatic environment, it is reasonable to hypothesize that dams and locks are having some level of impact on the Canadian population of Eastern Musk Turtles, however no studies of the effect of water control structures on the species in particular have been found in the literature.

The potential effects of impoundment and flow regulation on freshwater turtles in general are reviewed in Bodie (2001). First, water level fluctuations caused by the operation of dams may cause direct mortality of turtle individuals: an increase of water levels during the nesting season may submerge nest and drown embryos, whereas a decrease of water levels during the fall and winter may lead to freezing and death of overwintering turtles. Pitt et al. (2021) attributed the reduction in Eastern Musk Turtle abundance in a Missouri river following a record-breaking flood and dam removal to their inability to cope with the velocity of the discharged water.

Fluctuating or permanent changes to water levels due to water control operations may also affect overwintering, nesting, and foraging habitat by altering upstream and downstream water depth, downstream sediment transport and water temperature (see review in Bunn and Arthington 2002). Conversely, artificially stabilized water levels can also impact near shore aquatic habitat by enabling an increase in the abundance of

invasive cattail hybrids in coastal wetlands, thus reducing the availability of open water habitat (further discussed under threat 8.1).

Water control structures may impede movement of animals and thus restrict home range size and access to particular habitats. For instance, Bennett et al. (2010) found that dams and locks restricted mobility in Northern Map Turtles in the Trent-Severn Waterway, Ontario. Water control structures also have the potential to isolate turtle subpopulations from one another; if preventing the immigration of individuals, dams and locks may compromise rescue effect[18] (Stockwell et al. 2003) and/or lead to loss of genetic variation within subpopulations (Rizkalla and Swihart 2006; Gray 1995). In both cases, the likelihood of subpopulation extirpation in the wake of a catastrophic event is increased (Frankham 1995; Reed and Frankham 2003).

IUCN Threat 7.3 Other ecosystem modification – Impact: Low

Shoreline modification

Human use of shorelines can have various impacts on freshwater turtles depending on the species and the life cycle activity in question (Bodie 2001; Marchand and Litvaitis 2004; Carrière and Blouin-Demers 2010; Hill and Vodopich 2013). Alterations to the terrestrial portion of shorelines would primarily impact the nesting activity of Eastern Musk Turtles, given that thermoregulation and other life cycle activities of this species seldom occur in terrestrial habitat (see section 3.3). Shoreline modification includes the removal or degradation of native terrestrial vegetation, which provides nesting substrate for Eastern Musk Turtles, and shoreline hardening, which refers to structures that are installed to prevent natural erosion processes (such as gabion walls, concrete walls, metal walls and riprap), that may by the same token prevent individual turtles from exiting the water and reaching terrestrial nesting habitat.

Shoreline modification may also negatively alter near shore aquatic habitat. For example, Eastern Musk Turtles prefer shallow waters with emergent and floating vegetation that provides surface cover (Picard et al. 2011), and this type of vegetation has been shown to be less abundant along developed shorelines compared to undeveloped shorelines (Radomski and Goeman 2001).

Finally, there is increasing evidence that the amount of forest cover at the landscape scale affects freshwater turtle communities. For instance, a higher percentage of riparian forest cover was positively correlated with species evenness (Sterrett et al. 2010). In Ontario, two recent studies investigating the effect of landscape-scale parameters on the occurrence of Eastern Musk Turtle – one in the Thousand Islands area (Quesnelle et al. 2013) and the other in Georgian Bay coastal wetlands (Markle et al. 2018a) - both found that probability of occurrence of Eastern Musk Turtle increased with greater forest cover within a 500 m radius and within a 250 m radius of a wetland, respectively.

[18]Rescue effect: Immigration of individuals that have a high probability of reproducing successfully, such that extirpation or decline of a subpopulation can be mitigated.

Dredging and other riparian management activities

Riparian management activities such as channel dredging and removal of in-stream vegetation and woody debris can have various impacts on several freshwater turtle species, including subpopulation decline and extirpation (see review in Bodie 2001). Dredging may have direct and indirect effects on freshwater turtles: if dredging occurs during the turtles' non-active season, overwintering individuals could be killed if accidentally extracted from overwintering sites or crushed by the operation of heavy equipment. Dredging can also degrade or destroy freshwater turtle habitat regardless of when it occurs by physically altering the morphology of the water body (e.g., depth, shoreline slope) and by removing aquatic vegetation and submerged woody debris (which may affect the supply of food and shelter).

IUCN threat 8.1 Invasive non-native/alien species – Impact: Low

Non-native plant species

- *Phragmites australis australis*

The invasive European Common Reed (*Phragmites australis australis,* hereafter "Phragmites") occurs throughout the entire Canadian range of Eastern Musk Turtle (OIPC 2016; EDDmapS 2021) and in the same habitat types (i.e. wetlands and lakeshores). Phragmites now occupies almost every coastal wetland in Lake Erie and Lake Huron (OIPC 2016).

Because it grows in very thick monoculture stands that quickly overtake shallow water habitat, it is surmised that Phragmites has negative impacts on dozens of species across multiple taxa (see review in Nichols 2020). In actuality, there is a paucity of empirical studies on the effect of Phragmites on animals at the population level, and findings have been contradictory. For example, Whyte et al. (2015) found that bird species evenness was lowest in Phragmites-dominated sites compared to sites with native vegetation, whereas Lupien et al. (2015) found few differences in bird species evenness between those two types of sites. With increasing Phragmites cover, Mifsud (2014) reported significantly lower reptile richness, but Krzton-Presson et al. (2018) found that turtle species diversity was higher.

A handful of studies have investigated the effect of Phragmites on turtles, though none pertaining to Eastern Musk Turtles specifically. In Ontario, Phragmites lengthened the incubation period of Spiny Softshell eggs by decreasing nest exposure to solar radiation (Reference Removed), and Blanding's Turtle (*Emydoidea blandingii*) individuals avoided Phragmites patches within their home ranges (Reference Removed). It is hypothesized that Phragmites stands structurally hinder movement of freshwater turtles both within the aquatic environment and when they attempt to reach the shoreline in order to nest on land (Markle et al. 2018b; Reference Removed).

There are anecdotal reports that Phragmites may reduce the amount of available Eastern Musk Turtle nesting habitat by filling in open ground and replacing native shoreline vegetation used for nesting (Gillingwater 2005 in COSEWIC 2012; Reference Removed). It can also be hypothesized that Phragmites is impacting the Eastern Musk Turtle's food supply by outcompeting native shallow water vegetation, and decreasing the availability of basking habitat by reducing the amount of open water.

Several different methods have been employed in an attempt to remove non-native Phragmites from its host environment in the U.S. (see review in Hazelton et al. 2014). Best management practices to control Phragmites have been developed for Ontario, with a stated goal of improving species at risk habitat (Nichols 2020). However no studies on the impact of Phragmites removal on species at risk have been found in the literature, and studies of such management action on other native species are few, with mixed results so far. For instance, even though Marsh Wrens were found to prefer cattail marsh over Phragmites stands (Lupien et al 2015), paradoxically, a large-scale herbicide application conducted to remove Phragmites had a negative effect on the species (Lazaran et al. 2013). Likewise, a small number of studies have found a beneficial effect of Phragmites management on native plant re-establishment (Zimmerman et al. 2018; Bonello and Judd 2020) but others have not (Judd and Francoeur 2019; Rohal et al. 2019). In Ontario, a large-scale Phragmites eradication program implemented in two coastal marshes along the Lake Erie shoreline where Eastern Musk Turtle occurs has led to a secondary invasion by the non-native European Frogbit (*Hydrocharis morsus-ranae*) (discussed below) (Robichaud and Rooney 2021). The impact of Phragmites management on freshwater turtles is currently unknown.

The range expansion of Phragmites in Canada predicted by Catling and Mitrow (2011) has certainly materialized in southern Ontario coastal wetlands, particularly in the Long Point Peninsula area (Jung et al. 2017). Despite this expansion in the Mixedwood Plains ecozone however, the overall impact of Phragmites on the Canadian population of Eastern Musk Turtles was assessed as low because a large portion of its range overlaps with the Canadian Shield ecozone, where prevalence of Phragmites is currently much lower and its expansion is not expected to be as severe.

- *Trapa natans*

The aquatic European Water Chestnut (*Trapa natans*) produces floating leaves that can form dense mats at the water's surface. The plant has been reported in a few locations within the Eastern Musk Turtle's Canadian range over the last few years. In Ontario, the plant has been found in one section of the Ottawa River within Voyageur Provincial Park, where eradication actions are on-going (MNRF 2019). In Quebec, where an eradication program is also in place, the plant is present in the St-François River, the South River and other small rivers in the province's southwest (CQEEE 2014). It is hypothesized that by shading out native submerged aquatic vegetation (SAV), its colonization of aquatic habitat will result in large amounts of decomposing plant material in the water which could in turn reduce dissolved oxygen levels. However, *T. natans*

does not necessarily overtake native SAV (Tinoco et al. 2017). To date, studies on the impact of *T. natans* on turtles have not been found in the scientific literature.

- *Typha angustifolia* and the hybrid *T. x glauca (T. angustifolia x T. latifolia)*

Since 1960, Lake Ontario water levels have been regulated by the Moses-Saunders dam on the St. Lawrence River. The operation of the dam has resulted in a reduction in the amplitude of water level fluctuations in Lake Ontario's coastal wetlands. Stabilized water levels have in turn favoured the expansion of invasive *Typha* species, which are less tolerant to natural water level fluctuations than the native Common Cattail (*Typha latifolia*) (see review in Bansal et al. 2019). In coastal wetlands of Lake Ontario, *Typha* invasives spread landward into sedge and grass plant communities, and to a lesser extent, lakeward as floating mats (Wilcox et al. 2018 and references therein). Though the impact of *Typha* expansion on reptiles, if any, is not discussed by Bansal et al. (2019), Belleau (2008) found that in the Ottawa River, the species avoided cattail patches. The lakeward expansion of *Typha* mats may also reduce the amount of open water along shorelines, which is an important habitat component for Eastern Musk Turtles (Van Wieren pers. comm. 2020).

- *Hydrocharis morsus-ranae*

The European Frogbit (*Hydrocharis morsus-ranae*) is an aquatic plant that has colonized slow-moving water habitats in a number of Canadian waterbodies where the Eastern Musk Turtle occurs, including Lake Ontario, Lake Erie, the St. Lawrence River and the Ottawa River (see review in Zhu et al. 2018). European Frogbit was also present in one area of Eastern Musk Turtle habitat in Lake Saint-François (Bourgeois and Rouleau 2015). Like the European Water Chestnut, European Frogbit forms dense floating mats, with similar potential impacts on native vegetation. Studies on the impact of European Frogbit on turtles have not been found in the scientific literature.

<u>Non-native animal species</u>

- *Trachemys scripta elegans*

The Red-eared Slider (*Trachemys scripta elegans*), a freshwater turtle native to the Mississippi River Valley in the U.S., has become a globally invasive species due to its release in the wild as a result of the pet trade, with documented negative impacts on native turtle species in Europe via competition for resources (see review in Spear 2018). *Trachemys scripta* has been observed at 130 sites throughout the Ontario range of Eastern Musk Turtle (Seburn 2015), and the area suitable for the Red-eared Slider in all three overlapping Great Lakes basins (Lake Huron, L. Erie and L. Ontario) is projected to increase with climate change (Spear 2018). That being said, only one or a few individuals have been observed at most sites in Ontario, and 80% of observations were reported in urban areas (Seburn 2015). Self-sustaining subpopulations of sliders in the wild have not been confirmed in Ontario, but possibly exist given reports of nesting and observations made in early spring suggestive of successful overwintering. To date

however, documented negative impacts of the Red-eared Slider on native turtle species in Ontario have not been found in the scientific literature.

- *Ctenopharyngodon idella*

Introduced from Eurasia, the Grass Carp (*Ctenopharyngodon idella*) is a fish species that feeds on various aquatic plants found in Eastern Musk Turtle habitat. As such, Grass Carp could potentially have indirect effects on the species by altering its habitat and/or food sources. In Ontario, there are reports of Grass Carp individuals being caught in southern Lake Huron, Lake Erie, the Grand River (a tributary to Lake Erie), and the Don River (a tributary to Lake Ontario) (EDDMapS 2023), however the species is not considered to be established in the province (OFAH 2023). In Quebec, Pouliot and Morissette (2019) recorded one Grass Carp individual in the fluvial segment of the St. Lawrence River and, through analysis of eDNA samples, confirmed its presence there as well as in two of its major tributaries, the Richelieu River and the Saint-François River.

Because of its likely impacts on ecosystems should it become established in Ontario and Quebec, provincial laws prohibit possession of Grass Carp under the *Invasive Species Act* and the *Loi sur la conservation et la mise en valeur de la faune*, respectively. Under *Ontario's Invading Species Awareness Program*, the government of Ontario and partners are actively monitoring Great Lakes waters to detect the species and are developing an action plan to respond to the species' potential establishment in the province (MNRF 2023). The government of Quebec established a similar program, the *Québec Program to Fight Invasive Carp*, in 2016 (MFFP 2023).

Ranaviruses

Viruses belonging to the genus *Ranavirus* infect fish, amphibians and reptiles worldwide. Several mass mortality events seen in frogs and salamanders starting in the 1990s in North America have been attributed to ranaviruses (see review in Gray et al. 2009). The ranaviruses associated with these amphibian die-offs likely originate from Europe and Asia, and spread to Canada from the U.S. in the first half of the 20th century (Vilaça et al. 2019).

In Ontario, infection and subsequent death of a reptile due to *Ranavirus* was first documented in 2017, in a Snapping Turtle (McKenzie et al. 2019). To date, only one other case of *Ranavirus* infection has been detected in a turtle in Ontario (Carstairs 2019). None of the 63 samples collected between 2014 and 2018 from 5 turtle species tested positive for *Ranavirus*, suggesting a population prevalence of less than 5% (none of the samples were from Eastern Musk Turtle) (Carstairs 2019). Ranavirus infection has not been reported in Eastern Musk Turtle and any impact on the Canadian population is unknown at this time.

IUCN threat 8.2 Problematic native species – Impact: Unknown

Northern Raccoon (*Procyon lotor*)

Freshwater turtle nests experience high predation rates, often exceeding 80% (e.g., Harding 1997; Reference Removed; Wirsing et al. 2012; Geller 2015). Eastern Musk Turtle eggs are predated upon by Northern Raccoon (*Procyon lotor*), Striped Skunk (*Mephitis mephitis*), crows (*Corvus sp.*), and Red Fox (*Vulpes vulpes*) (see full list in Ernst and Lovich 2009). The Northern Raccoon is likely the main predator of Eastern Musk Turtle eggs, assuming that results from experiments using artificial nests (e.g., Marchand et al. 2002) and studies on other turtle species are applicable (e.g., Snapping Turtle (Oddie et al. 2015), Map Turtles (Geller 2012), and Painted Turtles (Wirsing et al. 2012)).

Increased food availability from human sources (e.g., food handouts, garbage, crops), in combination with low density or absence of apex predators, has led to a greater abundance of some mesopredators than natural conditions would have historically supported (Mitchell and Klemens 2000). Studies suggest that the Northern Raccoon is one such species of so-called human-subsidized predators, based on raccoon density estimates which are higher in urban and suburban areas compared to rural areas (e.g. Prange et al. 2004 and references therein). However, it is unknown whether, or by how much, predation rates of Eastern Musk Turtle eggs by Northern Raccoons are above natural rates as a result of human food subsidies.

Predator-exclusion cages of various designs are effective at decreasing nest depredation for several species of freshwater turtles (e.g., Riley and Litzgus 2013; Buzuleciu et al. 2015; Bougie et al. 2020), however tests of their effectiveness at protecting Eastern Musk Turtle nests have not been found in the scientific literature. Installation of such cages should not be installed by members of the general public without professional oversight and wildlife permits where applicable, to allow for tracking device deployment at the provincial level, and information-sharing of the latest, most effective guidelines.

IUCN threats 9. Pollution – Impact: Unknown

Pollution (contaminants, siltation and fertilizers) have the potential to impact freshwater turtles (see review in Bodie 2001). Turtles may be impacted by water quality degradation due to water runoff containing environmental contaminants originating from industrial areas (e.g., heavy metals) and roads (e.g., de-icing salt), particulate matter (silt), as well as nutrients and pesticides originating from agricultural fields (Mitchell and Klemens 2000; Bishop et al. 2010).

Contaminants

Several types of environmental contaminants have been detected in North American freshwater turtles, including heavy metals (Smith et al. 2016), polychlorinated aromatic

hydrocarbons (PAHs) (reviewed in Zychowski and Godard-Codding 2017), and polychlorinated biphenyls (PCBs) (reviewed in Adams et al. 2016). Increased rates of developmental abnormalities and hatchling mortality in Snapping Turtles have been found in relation to contamination by PAHs (e.g., Van Meter et. al. 2006) and PCBs (e.g., Bishop et al. 1998), though Snapping Turtle juveniles may be able to metabolize low PCB concentrations (Colson et al. 2021).

Given the overlap in habitat type and geographic range with Snapping Turtles, it is likely that Eastern Musk Turtles are also exposed to, and possibly negatively impacted by, these contaminants. Exposure to contaminants may come from absorption by eggs via contact with contaminated soil and sediment, from ingestion of contaminated food sources by juveniles and adults, and via maternal transfer to embryos (Adams et al. 2016). Patterson and Lindeman (2009) found that Eastern Musk Turtles shifted their diet towards the consumption of non-native Zebra Mussels (*Dreissena polymorpha*) when present; this could lead to increased exposure to contaminants because Zebra Mussels are known to accumulate high levels of toxins due to the nature of their filter feeding (Hogan et al. 2007). However other studies found that reliance on benthic food items had little effect on mercury accumulation in Painted and Musk turtles (Châteauvert 2013). Finally, groundwater contamination may also affect overwintering sites, but the level of risk at the population level is unknown. Due to the limited number of ecotoxicological studies on reptiles in general and the lack of information on the prevalence and effect of contaminants on the Eastern Musk Turtle specifically, the impact of this type of pollution on the Canadian population is unknown.

Siltation

Inputs of sediments and organic matter from water runoff and riparian erosion can alter water quality and aquatic habitat structure. For example, the resulting increase in water turbidity has been shown to reduce prey capture efficiency in fish (e.g., Zamor and Grossman 2007), though this was not found to be the case for Painted Turtles (Grosse et al. 2010).

Siltation of deep pools is another example of a change to habitat structure that has been linked to the decline of some subpopulations of various freshwater turtle species (see review in Bodie 2001). By decreasing water depth beyond the species physiological requirements for winter survival, siltation could kill overwintering Eastern Musk Turtle individuals by exposing them to freezing conditions, and eventually eliminating overwintering habitat altogether. However no documented instances of such impacts have been found in the scientific literature.

Fertilizers/ nutrient loading (eutrophication)

The direct impact (toxicity) of nitrogenous fertilizers to turtle eggs deposited in agricultural fields is likely minor (de Solla and Martin 2007). However the augmentation of nutrient loads into the aquatic environment via agricultural run-off of fertilizers can lead to algal blooms in waters frequented by turtles (Carpenter et al. 1998). The floating

algae deplete the water of dissolved oxygen both through direct consumption and by preventing photosynthesis of submerged aquatic vegetation underneath. This results in low levels of dissolved oxygen levels (hypoxia) or even a total absence of oxygen (anoxia) in the water. Given that the Eastern Musk Turtle is anoxia-intolerant (Ultsch 2006), individuals could theoretically die if overwintering in aquatic habitat under anoxic conditions. Consistent with this scenario, Eastern Musk Turtle individuals have been observed moving away from shallow eutrophic bays and towards areas with less organic matter (more oxygen) observed in autumn in the Ottawa River (Giguère pers. comm. 2021). However, given that in Ontario anoxic conditions occur mainly in Lake Erie in the summertime (ECCC and USEPA 2021), the scope of the Canadian population of Eastern Musk Turtle exposed to anoxic conditions while overwintering is likely small or negligible.

Paradoxically, moderate nutrient loading may benefit the species by increasing food availability. Wieten et al. (2012) found a positive correlation between the number of Eastern Musk Turtle caught and abiotic parameters such as increased nitrate and lower dissolved oxygen, condition that reflect greater habitat productivity and anthropogenic disturbance.

IUCN threat 11. Climate change & severe weather – Impact: Unknown

Recent climate models for the Great Lakes Basin predict, on average, an increase of 7 to 15% in the annual amount of over-land precipitation, and an increase of 2.4 to 5.0°C in annual mean temperature between 2035 and 2094 relative to the period from 1951 to 2005 (Shrestha et al. 2022). On the whole, these predictions apply to the Ontario range of Eastern Musk Turtle, though an assessment of their impact on the species have not been found in the literature. The impact of climate change has been assessed however on other freshwater turtle species in the Great Lakes. For instance, models developed by King and Niiro (2013) predicted that 50-75% of localities currently occupied by the Northern Map Turtle in the Great Lakes basin, and 25-50% of localities occupied by Blanding's Turtle would remain climatically suitable in 2050. Brinker et al. (2018) assessed the relative vulnerability to climate change of 280 species in Ontario's Great Lakes basin based on climate predictions and species life history characteristics; vulnerability rankings for the five freshwater turtle species assessed were either 'Less vulnerable' (e.g., Snapping Turtle) or 'Moderately vulnerable' (e.g., Blanding's Turtle). Insofar as these assessments can be applied to Eastern Musk Turtle, the species likely has a low-medium vulnerability to climate change over the next three decades. More specific, potential impacts of climate change on Eastern Musk Turtle are discussed below.

IUCN threat 11.1 Habitat shifting and alteration – Impact: not assessed

Although not discussed in the threats assessment (ECCC 2018), there is new evidence that climate change is altering the physical and chemical properties of freshwater lakes in the temperate zone; Jane et al. (2021) analyzed data from more than 400 lakes globally and found a widespread decline in dissolved oxygen (DO) in surface and deep-

water habitats in 80% of cases. The long-term decline in surface water DO —attributed to lower solubility of oxygen with increasing surface water temperature— is particularly relevant to Eastern Musk Turtle which primarily inhabits shallow areas of large lakes and rivers. Because the Canadian population is dependent on dissolved oxygen to survive the winter underwater, decreases in DO could have a negative impact in the medium to long-term should amounts drop below the required threshold.

IUCN threat 11.2 Droughts – Impact: Unknown

In contrast to the climate predictions that were available at the time of the species threats assessment (ECCC 2018), recent models now predict increased water levels in the Great Lakes (see above). However, the models also project that the greater the increases in global temperatures, the wider the range of projected future water level values (i.e. both extreme highs and extreme lows) compared to pre-2020 data (Seglenieks and Temgoua 2022). In the event of extreme low water levels, availability of nesting sites could increase as more shoreline becomes dryland —though in the longer term, sustained extreme lows may result in vegetation encroachment that eventually renders the initially exposed ground unsuitable for nesting. Furthermore, despite the increase in precipitation predicted for the months of April and May in Ontario, a decrease of up to 6% is predicted for the month of August (Shresta et al. 2022); such conditions have the potential to result in soil moisture deficits and greater risk of egg desiccation.

IUCN threat 11.3 Temperature extremes – Impact: Unknown

Research on the influence of climate change on the sex ratio of reptile populations via temperature extremes is on-going and inconclusive at this time. For example, Janzen (1994) suggested that a mean increase of 4ºC in July temperatures might result in a complete lack of production of male Painted Turtles. On the other hand, Massey et al. (2019) predict that the influence of natural temperature fluctuations on sex determination during incubation may temper the impact of climate change on the sex ratio of Snapping Turtles. Whether climate change leads to temperature extremes that in turn, result in an impact to the sex ratio of Eastern Musk Turtle subpopulations in Canada is unknown.

IUCN threat 11.4 Storms & flooding – Impact: Unknown

Recent modelling projects, on average, an increase in total over-lake precipitation and an increase in overall water levels in the Great Lakes in response to the warming climate (Seglenieks and Temgoua 2022). Extreme high water levels have the potential to increase instances of nests being destroyed by flooding, given the assumed proximity of Eastern Musk Turtle nests to the shoreline. For instance, above average precipitation over Lake Ontario in 2017 led to record high water levels (International Lake Ontario-St. Lawrence River Board 2018), and Lake Ontario reached its peak (and record-breaking) water level in June that year, coinciding with the beginning of the species' nesting season in Canada (see section 3.3. above). The highest ever recorded water level in

Lake Ontario occurred in 2019, also during the month of June (NOAA 2021). On the other hand, a study conducted in Thousand Islands National Park determined that high water levels in the St. Lawrence River in 2017 (resulting from high water levels in Lake Ontario) led to an increase in the amount of Eastern Musk Turtle habitat within the park's boundaries that year by increasing the amount of open marsh habitat (MacDougall and Windle 2019). Pitt et al. (2021) reported an increase in extent of freshwater turtle nesting habitat in response to flooding which scoured the riparian zone of woody vegetation. In Georgian Bay, models predict that higher lake water levels will result in a greater extent of deeper (0.5-2.0 m) coastal wetlands which have a more structurally complex submerged aquatic vegetation community (Weller and Chow-Fraser 2019). Therefore, increased water levels in may therefore Eastern Musk Turtles by increasing the extent of better quality foraging habitat.

5. Management Objective

The management objective for the Eastern Musk Turtle in Canada is to prevent the population from becoming Threatened or Endangered by:

a) Maintaining or increasing population abundance;
b) Maintaining or increasing the Index of Area of Occupancy (IAO); and
c) Maintaining the subpopulations located in southwestern Ontario.

Based on the quantitative criteria used by COSEWIC to evaluate a species' status, abundance must be maintained above 10,000 mature individuals, and the IAO must be prevented from experiencing a continuing decline and from becoming severely fragmented in order to prevent the population from becoming Threatened (COSEWIC 2019).

Maintaining the subpopulations located in southwestern Ontario's Lake Erie-Lake Ontario Ecoregion (Ecoregion 7E, Crins et al. 2009) is included as a component of the management objective because a potential 15 out of 26 subpopulations in Ecoregion 7E have been extirpated since 1986 (COSEWIC 2012); a continuing, incremental loss of subpopulations in Ecoregion 7E would result in a declining IAO, a decrease in the Extent of Occurrence, and an increase in the risk of the species becoming severely fragmented in Canada. It is highly improbable that the species would be able to naturally re-colonize extirpated subpopulations sites in southwestern Ontario due to their isolation from extant sites.

Given the species' late age at sexual maturity and small clutch size, in addition to the high rate of natural predation on eggs and juveniles (see sections 3.3 and 3.4), the Eastern Musk Turtle is vulnerable to even small increases in adult mortality above natural rates. Reducing and mitigating threats in order to maintain the highest possible survival rate of adult females is of particular importance in order to achieve the management objective. Reducing the scope of threats and mitigating their severity across the species range over the next 10 years (see section 6) is the overall strategy to

maintain or increase Eastern Musk Turtle population abundance and IAO, and maintain the subpopulations in southwestern Ontario.

6. Broad Strategies and Conservation Measures

6.1. Actions Already Completed or Currently Underway

The Government of Canada has been funding projects related to Eastern Musk Turtle conservation throughout Quebec and Ontario through the Habitat Stewardship Program (HSP) and Aboriginal Fund for Species at Risk (AFSAR) since 2001, and the Interdepartmental Recovery Fund (IRF, now called the Critical Habitat Interdepartmental Program, CHIP) since 2004. Projects have included activities such as targeted species surveys; identification of important habitat at the local scale; studies on the severity of threats such as fisheries by-catch and respective mitigation measures; solicitation of species observations from the public; and education initiatives for landowners and the general public on species identification, threats, and stewardship options.

The Government of Canada is a participant, along with the U.S. government, to the International Joint Commission (IJC), a binational organization responsible for managing transboundary waters that include the Great Lakes-St Lawrence River watershed. The IJC's activities include the regulation of water levels for the purposes of producing hydroelectric power, enabling commercial navigation and providing drinking water, as well as improving water quality.

Environment and Climate Change Canada is a participating organization under the Great Lakes Coastal Wetland Monitoring Program (CWMP), a Canada-U.S. program initiated in 2011 with the goal of monitoring the condition of coastal wetlands in the Great Lakes basin. The CWMP uses standardized protocols to sample marsh birds, anurans, water quality, wetland vegetation, aquatic macroinvertebrates and fish; incidental observations of Eastern Musk Turtle and other turtle species are also recorded.

The Canadian Herpetological Society (CHS) is the main non-profit organization devoted to the conservation of amphibians and reptiles in Canada, including turtles, and conducts the following activities: scientific studies, public education programs and community projects, compilation and analysis of historical data and the undertaking of projects that support conservation or habitat restoration.

Ontario

Over the last several years, the Government of Ontario has funded numerous turtle conservation and habitat stewardship projects across the province through the Species at Risk Stewardship Fund and other provincial funding programs. In 2007, a recovery team co-chaired by the Ontario Ministry of Natural Resources (MNR) and the Parks Canada Agency, prepared a recovery strategy for six turtle species that included the Eastern Musk Turtle (Seburn 2007). In 2010, the MNR released the *Forest*

Management Guide for Conserving Biodiversity at the Stand and Site Scales (The Stand and Site Guide) (MNR 2010); this tool, designed for forest managers, provides direction on planning and conducting forest operations at different geographical scales (from less than one hundred square meters to hundreds of square kilometers) so that forest biodiversity will be conserved. The Guide includes standards, guidelines and best management practices for turtle species found in the Area of the Undertaking[19] including the Eastern Musk Turtle. More recently, the Ontario Ministry of Natural Resources and Forestry (MNRF) has published two guidance documents to inform the design and implementation of measures to mitigate turtle road mortality, such as eco-passages (road underpasses, appropriately designed culverts) and exclusion fencing: the *Best Management Practices for Mitigating the Effects of Roads on Amphibians and Reptile Species at Risk in Ontario* (MNRF 2016), and the *Reptile and Amphibian Exclusion Fencing: Best Practices* (MNRF 2020). In addition, the MNRF's Natural Heritage Information Center (NHIC) has created a project on iNaturalist that provides a way for the public to submit species observations of rare species, including Eastern Musk Turtle (https://inaturalist.ca/projects/nhic-rare-species-of-ontario).

In 2016, the Parks Canada Agency (PCA) published three SARA Actions Plans that include conservation measures for Eastern Musk Turtle: the Multi-species Action Plan for Georgian Bay Islands National Park of Canada, the Multi-species Action Plan for Point Pelee National Park of Canada and Niagara National Historic Sites of Canada, and the Multi-species Action Plan for Thousand Islands National Park of Canada. The PCA has undertaken various conservation measures for the species within National Parks, including protection of nests and hatchlings, and removal of Phragmites in nesting areas. ECCC's Canadian Wildlife Service has also recently collected records of Eastern Musk Turtle as part of its monitoring of the response of turtles and snakes to the removal of Phragmites at the Big Creek National Wildlife Area (NWA) and Long Point NWA.

From 2009 to 2019, Ontario Nature, a non-governmental environmental organization, developed and managed the Ontario Reptile and Amphibian Atlas (https://ontarionature.org/programs/citizen-science/reptile-amphibian-atlas/). By soliciting occurrence records from the public, researchers, government and non-government organizations, this project has improved our knowledge of the distribution and status of reptiles and amphibians, including the Eastern Musk Turtle, in Ontario (Ontario Nature 2018).

Several large-scale inventories and monitoring programs targeting turtles, including Eastern Musk Turtles, have been conducted in Ontario by the following organizations: Toronto Zoo (Ontario Turtle Tally), Trent University (Kawartha Turtle Watch) Nature Conservancy of Canada, Ontario Nature, Parks Canada Agency and many other local survey and monitoring programs. In addition, research has been conducted on Eastern Musk Turtle in Ontario to fill knowledge gaps, including studies on home ranges,

[19] Ontario's Area of the Undertaking: a forest management area of Ontario consisting of approximately 43.8 million hectares, of which 27.1 million hectares is Crown forest. (MNRF 2010).

population sizes, demographics, habitat use, and landscape ecology (see References section).

Various habitat restoration, threat mitigation, and other conservation initiatives have been undertaken by numerous organizations in Ontario to benefit Eastern Musk Turtle. For example, the Ontario Turtle Conservation Centre (OTCC) in Peterborough coordinates research and conservation efforts (e.g., protection of nests, egg incubation), and rehabilitates wild turtles that were injured in the hopes of recovering and releasing them (https://ontarioturtle.ca/).

Many organizations and agencies offer outreach/educational programs about turtle species at risk to school groups, First Nations, and the general public (e.g., Scales Nature Park, Reptiles at Risk on the Road Project, The Georgian Bay Biosphere Reserve (and previously the Georgian Bay Reptile Awareness Program), Ontario Nature, MNRF, Ontario Parks, OTCC, PCA, Toronto Zoo, Upper Thames River Conservation Authority). The Toronto Zoo Adopt-A-Pond program (www.torontozoo.com/adoptapond) is one of several projects that have developed turtle conservation curricula for schools, while the Toronto Zoo Turtle Island Conservation program (www.torontozoo.com/conservation/tic.asp) promotes turtle conservation and awareness among First Nations and non-Indigenous groups. Turtle SHELL (Safety, Habitat, Education and Long Life) has prepared booklets and installed turtle crossing signs.

Quebec

The Quebec Turtles Recovery Team was created in 2005. One of its mandates was to develop and implement a recovery plan for five species of turtles: the Wood Turtle (*Glyptemys insculpta*), the Northern Map Turtle, the Blanding's Turtle, the Eastern Musk Turtle and the Spotted Turtle (*Clemmys guttata*) (Équipe de rétablissement des tortues du Québec 2005). In 2012, this team merged with the Spiny Softshell Recovery Team, thus including a sixth species of turtle. Four Implementation Groups were established, each working on the implementation of recovery actions for a specific turtle species or subset of species. One of these groups is the Blanding's Turtle and Eastern Musk Turtle Implementation Group, comprising partners from various organizations (including, over the years, MFFP[20], Environment and Climate Change Canada, Hydro-Québec, National Capital Commission, Nature Conservancy Canada, and McGill University) and independent consultants. The activities of the Implementation Group assisted in filling some knowledge gaps regarding the species and its threats in Quebec, implementing protection measures for the species and its habitat, and raising awareness about Eastern Musk Turtle in Quebec. In March 2021, a recovery plan for the Quebec subpopulations of Eastern Musk Turtle was published by the provincial government (Équipe de rétablissement des tortues du Québec 2021).

[20] "Ministère de la Forêt, de la Faune et des Parcs" (formerly "Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs).

Over the past few decades, inventories (e.g. Chabot and St-Hilaire 1991; Desrosiers and Giguère 2008; Caron 2010; Bourgeois and Rouleau 2015; Toussaint and Caron in prep.) and research on habitat selection, movement patterns, and demography of Eastern Musk Turtles (Belleau 2008) have been conducted along the north shore of the Ottawa River and in the St. Lawrence River in Quebec. All sightings of the species in the province are collected and archived in the Centre de données sur le patrimoine naturel du Québec (CDPNQ). Moreover, mapping of Eastern Musk Turtle element occurrences has been completed and is kept up to date by the CDPNQ. The viability of the subpopulations and applicable threats have also been assessed.

Several land acquisition projects along the Ottawa River in Quebec have been carried out by the MFFP and partners such as Nature Conservancy Canada to protect habitat for a variety of species, including the Eastern Musk Turtle. Meanwhile, stewardship and communication initiatives have been developed (e.g., distribution of brochures and pamphlets to the public, presentations in schools, and training sessions for municipal jurisdictions regarding the needs of the species). All these actions have been conducted by government and non-government organizations, conservation organizations, research or zoological institutions and volunteers.

6.2 Broad Strategies

Six broad strategies for recovery have been established to help achieve the management objectives for the Canadian population of Eastern Musk Turtle:

1. Use legislative and administrative tools to conserve individuals and habitat.
2. Reduce mortality and injury of Eastern Musk Turtle individuals.
3. Protect, manage, and restore Eastern Musk Turtle habitat.
4. Conduct communication and outreach activities.
5. Survey and monitor Eastern Musk Turtle subpopulations, habitat, and threats.
6. Conduct research on population demographics, habitat characterization and use, and threats/threat mitigation to fill knowledge gaps.

For the reasons outlined in section 5, measures to conserve the Eastern Musk Turtle subpopulations located in south-western Ontario should be implemented in short order.

6.3 Conservation Measures

The broad strategies and conservation measures needed to address the threats described in section 4 of this management plan (listed below for ease of reference) and meet the management objectives for the species (see section 5) are identified in Table 2.

4.1 Roads & railroads
5.4 Fishing & harvesting aquatic resources
6.1 Recreational activities
7.2 Dams & water management/use
7.3 Other ecosystem modifications
8.1 Invasive non-native/alien species
8.2 Problematic native species
9. Pollution
11. Climate change & severe weather

Table 2. Conservation Measures and Implementation Schedule

Conservation Measures	Priority[a]	Threats Addressed
Broad Strategy 1: **Develop and enforce legislative and administrative tools to conserve Eastern Musk Turtle individuals and habitat**		
Continue to enforce existing federal and provincial legislation that directly and indirectly protects Eastern Musk Turtle and its habitat (e.g. legislation pertaining to water quality, wetlands, fish and wildlife).	High	All
Develop or amend regulations and policies that regulate activities that threaten Eastern Musk Turtles and their habitat such as: • Recreational and commercial fisheries (e.g., timing, location and other licence conditions) to reduce turtle bycatch; • Recreational boating (e.g., speed limits and restricted zones) to reduce risk of collisions with boats; • Operation of water control structures to reduce habitat loss and fragmentation; • Shoreline development and logging, to reduce loss of natural riparian habitat and tree cover; • Planning of road network expansions and road upgrades (e.g., placement and design of roads and associated mitigation measures) to prevent loss of habitat connectivity and reduce risk of vehicle collisions.	High	4.1 5.4 6.1 7.2 7.3

Conservation Measures	Priority[a]	Threats Addressed
Broad Strategy 2: **Implement threat mitigation measures to reduce mortality and injury of Eastern Musk Turtles**		
• Implement existing techniques and approaches to reduce injury and mortality from commercial entrapment fisheries bycatch (e.g. deploy modified fishing gear that reduce turtle capture and increase survival).	High	5.4
• Implement mitigation measures to reduce mortality from vehicle collisions (e.g., construction of eco-passages).	Low	4.1
Broad Strategy 3: **Protect, manage, and restore aquatic and shoreline habitat and surrounding terrestrial areas**		
Conserve areas of occupied habitat, adjacent riparian zones and the surrounding terrestrial landscape through land stewardship agreements (e.g., conservation easements) and land acquisition, in order to improve subpopulation viability and connectivity.	High	7.2 7.3 8.1
Manage occupied habitat to halt and reverse habitat loss and degradation (e.g. loss of shallow marsh habitat[21], hardened shorelines) and reduce fragmentation by removing/ mitigating barriers to movement and dispersal (e.g., water control structures).	High	7.2 7.3 8.1
Restore degraded shorelines and reforest riparian areas adjacent to, or in proximity (i.e. within 500 meters) of occupied habitat, in order to enable a natural increase in the Canadian population's area of occupancy and abundance.	Medium	7.2 7.3 8.1
Support non-government organizations in the delivery of habitat (nesting, foraging, and overwintering) stewardship programs to private landowners.	Medium	7.2 7.3 8.1
Broad Strategy 4: **Conduct communication and outreach activities**		
Develop specific communication programs targeting the commercial fisheries and the recreational boating and angling sectors, to increase awareness about the impacts of these activities on aquatic wildlife, to promote compliance with licence conditions (e.g., bycatch reporting requirements) and to encourage uptake of modified gear and new mitigation measures to reduce Eastern Musk Turtle mortality and injury from fishing bycatch and collisions with boats.	High	5.4 6.1

[21] See Markle et al. 2018b.

Conservation Measures	Priority[a]	Threats Addressed
Engage with provincial governments and Fisheries and Oceans Canada to encourage practices that reduce turtle fisheries bycatch and boating collisions.	High	5.4 6.1
Engage with provincial governments to encourage practices that reduce impacts of logging, development and roads on riparian habitat.	Medium	4.1 7.2 7.3
Engage with provincial governments, Indigenous peoples and private landowners to encourage habitat restoration to mitigate shoreline erosion and maintain natural nesting habitat.	Medium	7.2 7.3
Encourage the transfer and archiving of information and tools, including Traditional Ecological Knowledge (TEK).	Medium	All Threats
Encourage the submission to provincial conservation data centres of records of Eastern Musk Turtle sightings collected by: a) conservation professionals and the commercial and recreational fishing communities; b) the general public.	Medium Low	All Threats
Implement communication and outreach tools to help address other threats to Eastern Musk Turtles and measure changes to public awareness levels.	Low	4.1 7.2 7.3 8.1
Broad Strategy 5: **Survey and monitor Eastern Musk Turtle subpopulations**		
Develop a standardized protocol for monitoring trends in abundance at the subpopulation scale.[22]	High	Supports status assessment accuracy
Monitor abundance, habitat conditions and threat levels of all extant subpopulations to identify which ones are most severely impacted by threats and/or declining in abundance.	High	All threats
Prioritize and survey sites with suitable habitat and/or historical records of the species to determine if Eastern Musk Turtles are present.	Medium	Supports status assessment accuracy
Survey extant subpopulations to better quantify the population's area of occupancy.	Low	Supports status assessment accuracy

[22] For example, Haydt et al. 2022.

Conservation Measures	Priority[a]	Threats Addressed
Broad Strategy 6: **Conduct research to fill knowledge gaps related to threats and threat mitigation measures, habitat use and population demographics.**		
Continue to document instances of turtle bycatch in commercial fisheries in order to identify locations and gear types with the highest bycatch rates. Continue to develop and test new fishing gear modifications designed to reduce turtle bycatch while minimizing concurrent fish escapement.	High	5.4
Develop methods to detect and document instances of injury and mortality due to boat collisions, in order to effectively target outreach activities to the recreational boating community and implement effective regulations.	High	6.1
Measure the direct and indirect (habitat destruction) impacts caused by dredging and dam operation.	Medium	7.2
Continue to document presence of invasive species and determine severity of impact.	Medium	8.1
Increase knowledge on the habitat types used during the overwintering season, particularly by hatchlings and juveniles.	Medium	All threats
Conduct studies to document terrestrial habitat use by the species (e.g., distance travelled to nesting sites, habitat characteristics of nesting site locations).	Medium	4.1 7.2 7.3 8.1 8.2 11
Characterize road mortality locations in order to effectively site and design road mortality mitigation measures, and to inform future road placement and design in order to reduce the number of turtle-vehicle collisions.	Low	4.1
Assess the scope, and if warranted the severity, of the threat from pollutants (e.g., contaminants, sedimentation and nutrients).	Low	9
Determine the level of predation by native predators.	Low	8.2
Evaluate the impact of droughts, temperature extremes, storms and flooding due to climate change.	Low	11
Increase knowledge of the cumulative effect of threats to the Eastern Musk Turtle and its habitat.	Low	All threats
Increase knowledge of species' demography (e.g., determine what constitutes a viable population size and whether the amount of existing suitable habitat is sufficient to meet the management objectives) and genetic composition of subpopulations, particularly those in southwestern Ontario (e.g., to inform appropriateness of subpopulation augmentation via translocated individuals).	Low	All threats

[a] “Priority” reflects the degree to which the measure contributes directly to the conservation of the Canadian population of Eastern Musk Turtle. At the provincial level, priorities may rank differently depending on the jurisdiction. High priority measures are considered those most likely to have an immediate and/or direct influence on attaining the management objective for the species, or are essential precursors to such measures. Medium priority measures may have a less immediate or less direct influence on reaching the management objective, but are still important for the management of the population. Low priority conservation measures will likely have an indirect or gradual influence on reaching the management objective, but are considered important contributions to the knowledge base and/or public involvement and acceptance of the species.

7. Measuring Progress

The performance indicators presented below provide a way to measure progress towards achieving the management objectives and monitoring the implementation of the management plan. Every ten years, success of the implementation of the management plan will be measured against the following performance indicators:

- Number of mature individuals in Canada is 10,000 or more.
- The index of area of occupancy is at least 1,408 km^2 and increasing.
- Extant subpopulations in southwestern Ontario (between 11 and 26 subpopulations in Ecoregion 7E) are maintained.
- Viability ranks of subpopulations in Quebec are maintained or improved.

8. References

Due to the vulnerability of some turtle species to illegal collection, specific references providing information about the location of sensitive turtle species have been removed from this version of the management plan. To support protection of these species and their habitat, the full list of references may be requested on a need-to-know basis by contacting Environment and Climate Change Canada at ec.planificationduretablissement-recoveryplanning.ec@canada.ca.

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Appendix A: Subnational Conservation Ranks of the Eastern Musk Turtle (*Sternotherus odoratus*) in Canada and the U.S.

Table A-1. Ranks of Eastern Musk Turtle in Canada and the U.S.. (NatureServe 2023)

Global (G) Rank	National (N) Rank	Sub-national (S) Rank (Canada)	Sub-national (S) Rank (U.S.)
G5	Canada (N3) U.S. (N5)	Ontario (S3) Quebec (S2S3)	Alabama (S5), Arkansas (S5), Connecticut (S4), Delaware (S5), District of Columbia (S4), Florida (S5), Georgia (S5), Illinois (S5), Indiana (S4), Iowa (S2), Kansas (S4), Kentucky (S5), Louisiana (S5), Maine (S3), Maryland (S5), Massachusetts (S4S5), Michigan (S5), Minnesota (SNR), Mississippi (S5), Missouri (S5), New Hampshire (S5), New Jersey (S5), New York (S4), North Carolina (S5), Ohio (SNR), Oklahoma (SNR), Pennsylvania (S4), Rhode Island (S4), South Carolina (S5), Tennessee (S5), Texas (S5), Vermont (S2), Virginia (S5), West Virginia (S5), Wisconsin (S4)

Rank Definitions (Master et al. 2012)

S1: Critically Imperiled - At very high risk of extirpation in the jurisdiction due to very restricted range, very few populations or occurrences, very steep declines, severe threats, or other factors.

S2: Imperiled - At high risk of extirpation in the jursidction due to restricted range, few populations or occurrences, steep declines, severe threats, or other factors.

N3 /S3: Vulnerable - At moderate risk of extirpation in the jurisdiction due to a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors.

S4: Apparently Secure - At a fairly low risk of extirpation in the jurisdiction due to an extensive range and/or many populations or occurrences, but with possible cause for some concern as a result of local recent declines, threats, or other factors.

S4S5: Secure/Apparently Secure - At no risk to fairly low risk of extirpation in the jurisdiction due to an extensive to very extensive range, abundant populations or occurrences, with little to some concern as a result of local recent declines, threats or other factors.

G5/N5/S5: Secure - At very low risk of extinction or elimination due to a very extensive range, abundant populations or occurrences, and little to no concern from declines or threats).

SNR: Unranked - Subnational conservation status not yet assessed.

Appendix B: Effects on the Environment and Other Species

A strategic environmental assessment (SEA) is conducted on all SARA recovery planning documents, in accordance with the *Cabinet Directive on the Environmental Assessment of Policy, Plan and Program Proposals*[23]. The purpose of a SEA is to incorporate environmental considerations into the development of public policies, plans, and program proposals to support environmentally sound decision-making and to evaluate whether the outcomes of a recovery planning document would affect any component of the environment or any of the Federal Sustainable Development Strategy's[24] (FSDS) goals and targets.

Conservation planning is intended to benefit species at risk and biodiversity in general. However, it is recognized that strategies may also inadvertently lead to environmental effects beyond the intended benefits. The planning process based on national guidelines directly incorporates consideration of all environmental effects, with a particular focus on possible impacts upon non-target species or habitats. The results of the SEA are incorporated directly into the strategy itself, but are also summarized below in this statement.

Activities undertaken to protect Eastern Musk Turtle and its habitat will also be beneficial to other species that use similar habitat. The protection of wetland habitats will contribute to maintaining the rich biodiversity supported by those habitats. Moreover, threat reduction and mitigation measures targeting the Eastern Musk Turtle can contribute to reduce mortality in other animal species (e.g. use of eco-passages to reduce road mortality, efforts to eliminate pollution from aquatic environments). Some of these measures are likely to be found in other recovery documents, particularly those that deal with aquatic and riparian species. Table B-1 presents examples of species that may benefit from the recovery of the Eastern Musk Turtle population in Canada.

[23] www.canada.ca/en/environmental-assessment-agency/programs/strategic-environmental-assessment/cabinet-directive-environmental-assessment-policy-plan-program-proposals.html
[24] www.fsds-sfdd.ca/index.html#/en/goals/

Table B-1. Some of the species at risk that may benefit from conservation and management of Eastern Musk Turtle and its habitat.

Common Name	Scientific Name	SARA Status
Blanding's Turtle (Great Lakes/St. Lawrence population)	*Emydoidea blandingii*	Threatened
Cutlip Minnow	*Exoglossum maxillingua*	Special Concern
Eastern Foxsnake (Great Lakes/St. Lawrence population)	*Pantherophis gloydi*	Endangered
Eastern Foxsnake (Carolinian population)	*Pantherophis gloydi*	Endangered
Eastern Hog-nosed Snake	*Heterodon platirhinos*	Threatened
Eastern Milksnake	*Lampropeltis triangulum*	Special Concern
Eastern Ribbonsnake (Great Lakes population)	*Thamnophis sauritus*	Special Concern
Eastern Sand Darter	*Ammocrypta pellucida*	Threatened
Fowler's Toad	*Anaxyrus fowleri*	Endangered
Grass Pickerel	*Esox americanus vermiculatus*	Special Concern
King Rail	*Rallus elegans*	Endangered
Lake Erie Watersnake	*Nerodia sipedon insularum*	Special Concern
Least Bittern	*Ixobrychus exilis*	Threatened
Massasauga (Great Lakes / St. Lawrence population)	*Sistrurus catenatus*	Threatened
Midland Painted Turtle	*Chrysemys picta marginata*	Special Concern
Northern Map Turtle	*Graptemys geographica*	Special Concern
Snapping Turtle	*Chelydra serpentina*	Special Concern
Spiny Softshell	*Apalone spinifera*	Endangered
Spotted Turtle	*Clemmys guttata*	Endangered