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Information in Support of an Updated Recovery Potential Assessment of Lake Chubsucker (*Erimyzon sucetta*) in Canada, 2011–2020

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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TABLE OF CONTENTS

ABSTRACT

The Lake Chubsucker (*Erimyzon sucetta*) is a small member of the Catostomidae family requiring clear, still, well-vegetated waters. In Canada, it is found in watersheds of southern Lake Huron through Lake Erie. The species was first assessed as Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 1994, reassessed as Threatened in 2001, and was listed as Threatened under Schedule 1 of the *Species at Risk Act* (SARA) in June 2003. Lake Chubsucker was subsequently re-assessed by COSEWIC in 2008 (and again most recently in May 2021) as Endangered and is listed as Endangered under SARA owing to a decline in suitable habitat and extant locations, and multiple habitat-related threats. The Recovery Potential Assessment (RPA) provides background information and scientific advice needed to fulfill various requirements of SARA. This research document provides the current state of knowledge of the species including its biology, distribution, population trends, habitat requirements, and threats, with updated information from 2011 through 2020. Limited information exists to adequately assess the status of most populations, as records generally represent few individuals caught over a limited number of sampling events using varied sampling protocols. A threat assessment identified the greatest threats to Lake Chubsucker in Ontario as aquatic invasive species, natural system modifications, pollution, and climate change; however, the impacts of these threats are not well understood. Mitigation measures and alternative activities related to the identified threats are presented. Important knowledge gaps remain regarding population trends, physiological tolerances to environmental conditions and pollutants, and habitat requirements by life stage.

INTRODUCTION

A meeting of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in April 1994 recommended that Lake Chubsucker (*Erimyzon sucetta* Lacepède 1803) be designated Special Concern. This status was re-assessed as Threatened in November 2001. When re-examined in November 2008, Lake Chubsucker status was changed to Endangered. The reason given for this designation was that the Lake Chubsucker is "a species with a restricted geographic Canadian range with small extant populations having very specific and narrow habitat preferences, which are under continued stress. It is extremely susceptible to habitat change driven by urban, industrial and agricultural practices resulting in increased turbidity. Two populations have been lost, and of the 11 extant populations, three are in serious decline as a result of the continuing and increasing threats posed by agricultural, industrial and urban development that are expected to impact the remaining populations of lakes Erie and St. Clair." The Lake Chubsucker was re-assessed by COSEWIC in May 2021, again as Endangered, with increased emphasis on the severity of threats of numerous aquatic invasive species (AIS), notably European common reed (*Phragmites australis australis*). Subsequent to the November 2001 COSEWIC designation, Lake Chubsucker was listed on Schedule 1 of the *Species at Risk Act* (SARA) when the Act was proclaimed in June 2003. Lake Chubsucker is now listed as Endangered on Schedule 1. A Recovery Potential Assessment (RPA) process was developed by Fisheries and Oceans Canada (DFO) to provide information and scientific advice needed to fulfill SARA requirements, including the development of recovery strategies and authorizations to carry out activities that would otherwise violate SARA (DFO 2007). A RPA was completed for Lake Chubsucker in 2011 (DFO 2011). The RPA process has since been updated to include 22 recovery potential elements (DFO unpublished), and new information is available resulting from increased research and targeted sampling for Lake Chubsucker in Canada (COSEWIC 2021); data and information from 2011 through 2020 are included. This document provides updates to background information on the Lake Chubsucker covered in Bouvier and Mandrak (2011), and along with Fung and Koops (2023), informs the 22 elements of the RPA.

BIOLOGY, ABUNDANCE, DISTRIBUTION AND LIFE HISTORY PARAMETERS

Element 1: *Summarize the biology of Lake Chubsucker*

SPECIES DESCRIPTION

Lake Chubsucker is a small, deep-bodied member of the sucker family (Catostomidae) (Holm et al. 2009). It has a thick caudal peduncle, and a wide head with a blunt snout ending in a small, slightly inferior mouth (COSEWIC 2008). Coloration on the back and upper sides can range from deep olive-green to bronze, and these areas have a cross hatching pattern in adults (Holm et al. 2009). The lower sides are generally gold to silver, while the belly ranges from greenish-yellow to whitish-yellow (Holm et al. 2009). Juvenile Lake Chubsucker generally have a black stripe along the front edge of the dorsal fin and a wide, prominent black lateral stripe terminating in a dark spot at the base of the tail; the lateral stripe can either be continuous or broken in adults, if present (Holm et al. 2009). A distinguishing characteristic of the Lake Chubsucker is that it lacks a lateral line. Males are known to develop a falcate-shaped anal fin and 3–4 nuptial tubercles on each side of the snout prior to spawning (Mandrak and Crossman 1994).

Lake Chubsucker is one of 13 known sucker species currently in the Canadian Great Lakes basin (Holm et al. 2009). It can be differentiated from members of the genera *Carpiodes,* and *Ictiobus* by the presence of a dorsal fin with a short base lacking a rounded or pointed anterior lobe (COSEWIC 2008) and from *Catostomus*, *Minytrema,* and *Moxostoma* by the smaller, nearly terminal mouth, somewhat laterally compressed body shape, and lack of spots in rows (Holm et al. 2009). Although not reported from Canada, Lake Chubsucker closely resembles Creek Chubsucker (*Erimyzon oblongus*), which is present in the American tributaries of both lakes Ontario and Erie (COSEWIC 2008). Characteristics used to distinguish these two species include a larger eye diameter, lower lateral-line scale count, higher dorsal ray count, and a stouter body form for Creek Chubsucker when compared to Lake Chubsucker (COSEWIC 2008).

Lake Chubsucker frequently co-occurs with warmwater fishes that have strong associations with aquatic macrophytes. Species such as Blacknose Shiner (*Notropis heterolepis*), Brown Bullhead (*Ameiurus nebulosus*), Central Mudminnow (*Umbra limi*), Grass Pickerel (*Esox americanus vermiculatus*), Golden Shiner (*Notemigonus crysoleucas*), Pugnose Shiner (*Notropis anogenus*), and Tadpole Madtom (*Noturus gyrinus*) co-occurred frequently with Lake Chubsucker in an analysis of Lake Chubsucker populations from the Old Ausable Channel and L Lake, Ontario (D. Jackson, University of Toronto, pers. comm.).

LIFE CYCLE

In Ontario, Lake Chubsucker is thought to be a spring spawner, spawning between late April and June when temperatures reach approximately 20°C (COSEWIC 2008). Adults may make short migrations towards shallow marsh areas to spawn (Goodyear et al. 1982; Loftus and Kushlan 1987). Spawning behaviour involves males clearing an area in the sand, silt, or often gravel, which is then used by the female to deposit between 3 000 and 20 000 eggs (number of eggs is thought to be size dependent) (Shireman et al. 1978, Eberts et al. 1998, COSEWIC 2008). Eggs may also be deposited over vegetation, but are demersal and non-adhesive (Fuiman 1982). Winter (1984) reported observations from an earlier study in Florida of Lake Chubsucker spawning in Largemouth Bass nests with a guarding male. The eggs incubate for six to seven days and subsequently hatch when water temperature reaches between 22 and 29°C (Fuiman 1982, Cooper 1983). Larvae are approximately 5–6 mm at hatch with yolk sac.

Lake Chubsucker likely matures at age 2–3 in Ontario (Eberts et al. 1998, Coker et al. 2001, COSEWIC 2021). In a Nebraska pond, Winter (1984) found that some age 1 fish were sexually mature, and all were mature over 100 mm total length (TL). Lake Chubsucker may reach 8 years of age (Scott and Crossman 1998). There have been few aging studies, but specimens examined from the Old Ausable Channel following a winterkill event ranging in total length from 91–199 mm TL were aged 1–6 years from otoliths and 1–5 years from scales (Bouvier and Mandrak 2011). In the literature, adult length has been noted as reaching a maximum of 410 mm TL (Page and Burr 2011), although Canadian specimens tend to be smaller than their southern counterparts. The Ontario record for the longest Lake Chubsucker measured 280 mm TL (Holm et al. 2009). Lake Chubsucker collected from 2011–2020 in Ontario (n = 603) using a variety of gears had a mean total length of 66 mm (range: 23–253 mm) (Figure 1; DFO unpublished data). Leslie and Timmins (1997) reported early growth of Lake Chubsucker from Long Point Bay in 1985. The first specimen was captured June 12 (22°C) and measured 7 mm TL; the mean TL on June 26 was 14.3 mm (± 3.9 mm (SD); n = 19), on July 4 was 19.1 mm (± 1.6 mm; n = 17), and on July 24, was 28.8 mm (± 1.5 mm; n = 5). Total lengths of Lake Chubsucker in Ontario from 2011–2020 by ordinal date of capture are shown in Figure 2. These data suggest Lake Chubsucker may reach approximately 85 mm TL by the end of the first growing season in Ontario and are likely ~ 120 mm TL by age 2 when maturity may be reached.

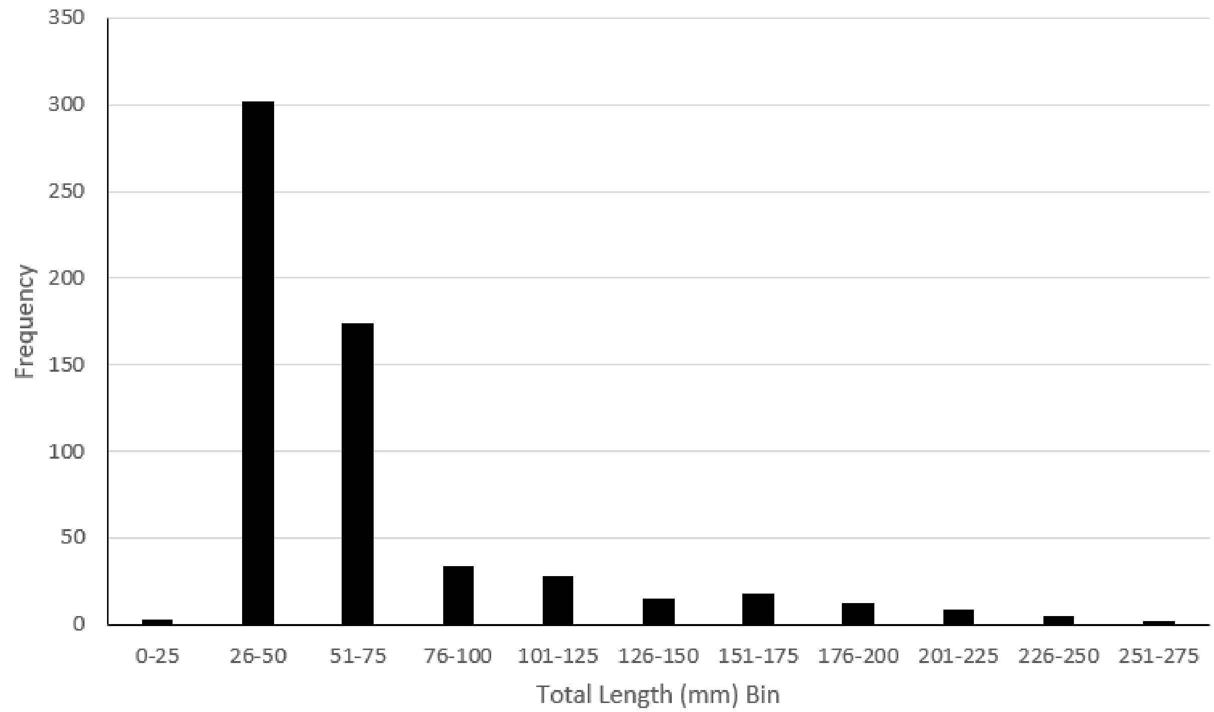

Figure 1. Length frequency distribution of Lake Chubsucker captured in Ontario from 2011–2020 from several waterbodies (DFO unpublished data).

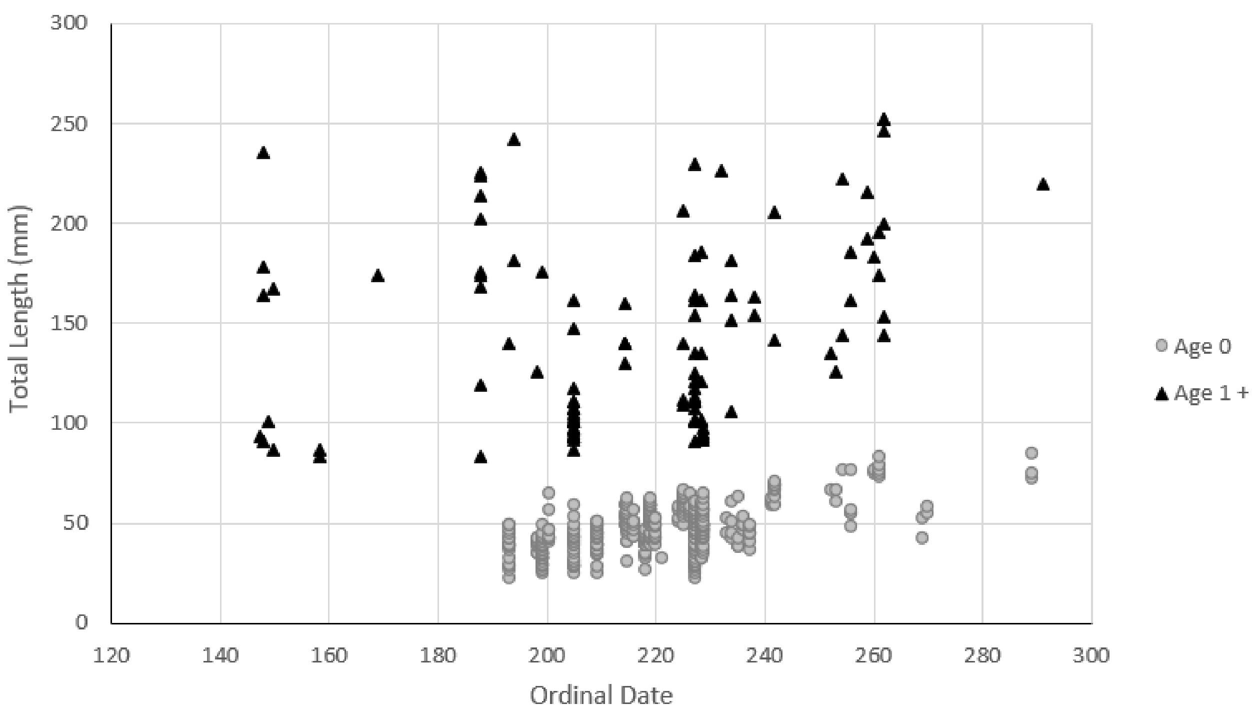

Figure 2. Total length by ordinal date of Lake Chubsucker captured in Ontario from 2011–2020 from several waterbodies. Day 140 is May 20, and day 300 is October 27. Fish presumed to be young of year (age-0) are represented with grey circles, and fish presumed to be age-1 and older are represented with black triangles.

FEEDING AND DIET

As an omnivorous bottom feeder, Lake Chubsucker diet is composed of small crustaceans, mollusks, aquatic insects, filamentous algae, and plant material (Holm et al. 2009). Lake Chubsucker stomach contents were sampled from a Nebraska pond and analyzed by size class (Winter 1984). *Bosmina* and *Daphnia* (cladocerans) dominated the diet of Lake Chubsucker 50–99 mm TL; Daphnia and mollusks dominated in individuals 100–149 mm TL; mollusks (predominantly gastropods and secondarily pelecypods) dominated the diet of the 150–199 mm TL class; and, cladocerans Bosmina and Daphnia, amphipods, and insects Odonata and Coleoptera dominated in the diet of the 200–249 mm TL size class. Stomach contents from Lake Chubsucker in Illinois lakes contained predominantly Cladocera (occurred in 62.5% of stomachs), Ostracoda (62%), and Chironomids (44%). These three food items made up 86% of the biomass in stomachs that contained food (Eberts et al. 1998). Crustaceans declined in importance in favour of insects as length increased.

POPULATION STRUCTURE

A population genetics study of Lake Chubsucker in Ontario was undertaken where tissue samples (caudal fin clips) were analyzed from 71 Lake Chubsucker specimens from seven locations collected between 2010 and 2016 (Hauser et al. 2019). Ontario populations sampled included: Big Creek, Long Point Bay, and Lyons Creek in the Lake Erie drainage; St. Clair River Delta and Lake St. Clair in the Huron-Erie Corridor; and the Old Ausable Channel and L Lake in the Lake Huron drainage. Additional sequences were obtained from GenBank for comparison, including: four Lake Chubsucker from Long Point Bay and five from South Carolina, four Sharpfin Chubsucker (*Erimyzon tenuis*) and 16 Creek Chubsucker from US populations. Most Canadian specimens analyzed shared the same haplotype with the exception of the Lyons Creek population, which had three unique haplotypes not found elsewhere in the Ontario samples. There was little genetic differentiation in the CO1 gene of Lake Chubsucker analyzed in this study. Hauser et al. (2019) suggested that the presence of the common haplotype across most populations sampled in Ontario is likely the result of a shared post-glacial dispersal history as well as historical connectivity of wetland habitats around the lower Great Lakes before many were drained or altered for agriculture. Due to the presence of physical barriers and disjunct or unsuitable habitat, it is unlikely that there is gene flow between populations currently (Hauser et al. 2019). COSEWIC (2021) determined that, although the Lyons Creek population may represent a genetically discrete unit relative to other populations in Canada, there is no evidence to suggest that it meets the criteria for evolutionary significance, and, thus, a single Designatable Unit was proposed for Canadian Lake Chubsucker. Further studies that include genetic samples across its North American range would be useful in understanding the uniqueness of the Lyons Creek population at a broader scale.

Element 2: *Evaluate the recent species trajectory for abundance, distribution and number of populations*

ABUNDANCE

Abundance estimates are lacking for most Lake Chubsucker populations in Canada. In 2010, depletion surveys were undertaken in Lyons Creek and L Lake to estimate population size; unfortunately, only three sites in Lyons Creek fulfilled the requirements to complete the analysis. Results indicated that the mean population density was 0.0105 (± 0.0156) individuals/m^2 (Ministry of Northern Development, Mines, Natural Resources and Forestry unpublished data). The survey in L Lake indicated a mean population density of 0.0861 (± 0.1385) and 0.0119 (± 0.0181) individuals/m^2 based on data from June and August sampling, respectively (NDMNRF unpublished data). In 2018, a mark-recapture study was conducted by DFO in L

Lake to estimate population size. During the first sampling period in August, 34 Lake Chubsucker were captured with a seine net and 21 were tagged; during the second sampling period in September, five individuals were captured but none of these were recaptures of tagged fish, precluding population estimates (Barnucz and Drake 2021).

In Long Point Bay, several fish community assessments have recently been undertaken to compare community structure across restored ponds of various ages (2012–2014; Rook et al. 2016), and to investigate effects of European common reed control on the fish community (2015–2018; Reid et al. 2023). Both studies had similar fish sampling designs, but not all sites were re-visited in each study. Mean relative abundance of Lake Chubsucker was calculated for Long Point Crown Marsh as 0.53 Lake Chubsucker per seine haul from 2012–2014, with the greatest mean relative abundance in 2012 (0.725 individuals/haul; Rook et al. 2016). Mean relative abundance was lower throughout the second study, with 0.05 Lake Chubsucker per seine haul from 2015–2018, and was highest in 2018 (0.13 individuals/haul; Ministry of Northern Development, Mines, Natural Resources and Forestry unpublished data).

Estimates of Lake Chubsucker abundance were made for the East cell of the St. Clair NWA based on catch data from September 2019 (Barnucz et al. 2021, DFO 2021). These estimates were generated using allometry relationships to convert lengths of captured fish to weights, and then applying a lake-based relationship using weights to estimate total fish density (Randall et al. 1995). Lake Chubsucker abundance was then estimated based on its relative abundance in the total fish catch, and a stable stage distribution was applied, adjusted for the time of year when sampling occurred. This approach yielded an estimate of 1 375 total Lake Chubsucker, of which 247 were adults. A more conservative estimate of 1 302 individuals (234 adults) was also made, assuming that only wetted area greater than 0.3 m in depth contributes to fish community production (DFO 2021).

DISTRIBUTION

The Lake Chubsucker has a disjunct distribution in North America, being somewhat widespread in the southeastern United States (eastern Texas through Atlantic and Gulf slope drainages), and more sporadic in the Mississippi River and lower Great Lakes drainages (eastern Wisconsin through western New York, including the south side of Lake Ontario) (Page and Burr 2011). In Canada, it is known from tributaries and wetlands of southern Lake Huron, Lake St. Clair, and Lake Erie (Figure 3). Minor changes in the Extent of Occurrence (23 478 km^2, 2009–2018; convex hull polygon method) and Index Area of Occupancy (164 km^2, 2009–2018; 2 x 2 km grid cell method) in recent years compared to historical records reflect an increase in sampling effort and slight increases in local distribution within known locations (i.e., additional data points, not a range expansion) (COSEWIC 2021).

CURRENT STATUS

In Canada, the current and historical distribution of Lake Chubsucker is limited to 14 confirmed areas, three of which are currently considered to be extirpated (Figure 3, Appendix 1). Extant areas include Old Ausable Channel (OAC), L Lake, Lake St. Clair (including Mitchell’s Bay, undyked marshes in the area, Chenail Ecarté, Little Bear Creek, and new localities Collop Drain and Prince Albert Drain), dyked marshes within the Lake St. Clair drainage, St. Clair National Wildlife Area (NWA; including new localities of St. Clair Unit – East cell, and Bear Creek Unit – Maxwell cell), Point Pelee National Park, Rondeau Bay, Big Creek NWA dyked marshes, Long Point Bay (including Big Creek undyked marshes, Turkey Point marshes and Long Point Inner Bay and Crown Marsh), Long Point NWA, and Lyons Creek. Areas separated by impassable barriers, where dispersal is not a possibility, are taken to be separate areas. Extirpated areas include upper Jeannette's Creek (a tributary of the Thames River), the upper tributaries of Big Creek (Silverthorn Creek, Lynedoch Creek, Trout Creek and Stoney Creek) and Tea Creek (a tributary of Lyons Creek).

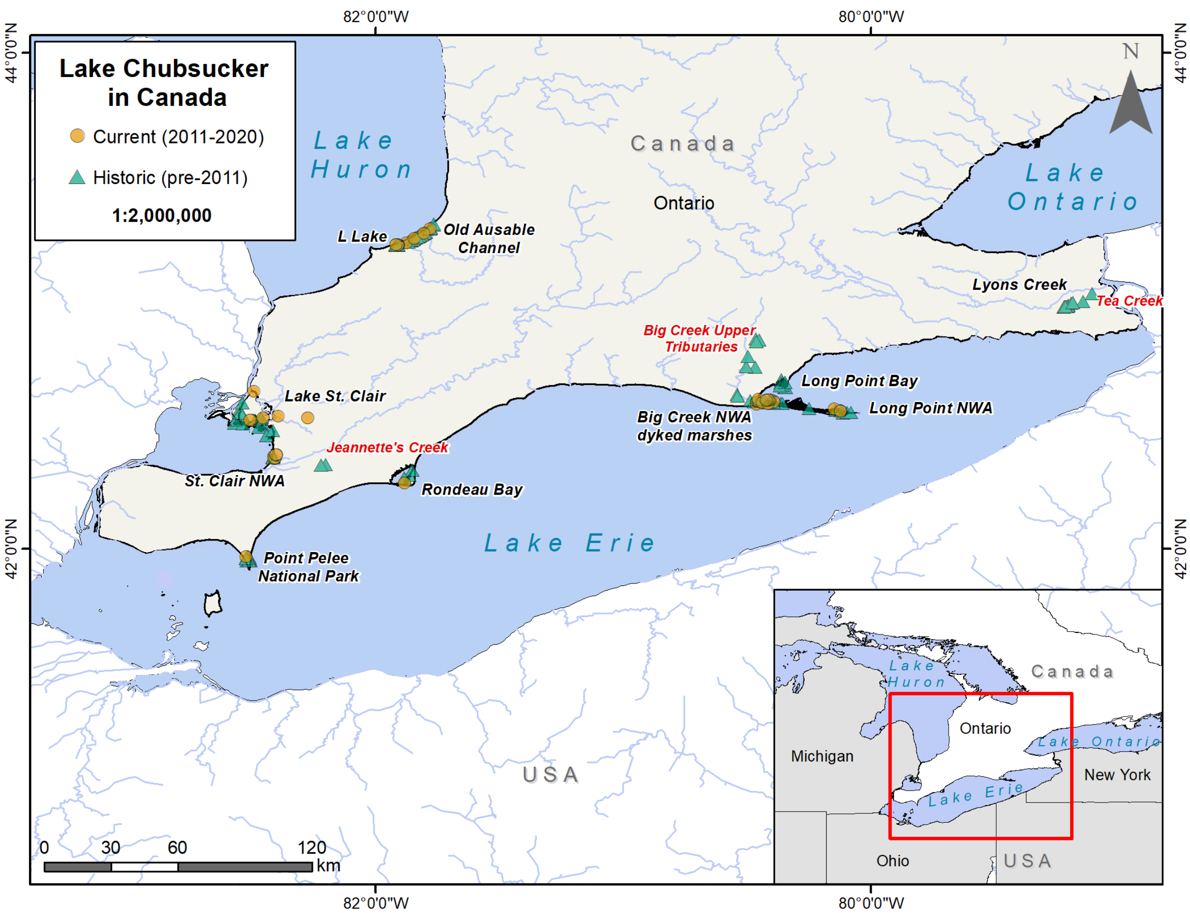

Figure 3. Lake Chubsucker detections in Canada. Historical records (pre-2011) are shown as blue triangles, and recent detections (2011–2020) are shown as orange circles. Symbols represent a sampling event. Extant populations are labelled in black text, and populations that are presumed to be extirpated are labelled in red text. Records in dyked marshes of the Lake St. Clair drainage are not depicted.

AUSABLE RIVER[1]

It is thought that the Lake Chubsucker occupied the lower Ausable River prior to its diversion in the late 1800s (ARRT 2005). The diversion and the surrounding agricultural land use has since caused a highly turbid system, and the species is thought to be extirpated from this system. In August 2018, two Lake Chubsucker were captured by boat electrofishing in the lower Ausable River where the OAC connects to the Ausable River (Colm et al. 2019b). They measured 155 mm and 163 mm TL. Given that extensive sampling with gears suitable for targeting this species has occurred in the lower Ausable River in recent years, it is unlikely that these specimens

[1] Preliminary sampling results from DFO in September 2021 yielded a single adult Lake Chubsucker in the lower Ausable River captured by boat electrofishing (TL 131 mm; DFO unpublished data).

represent a reproducing population, but rather breached the barrier at the OAC (i.e., during high water events) or their dispersal over the barrier was human mediated. Additional sampling is recommended to determine if reproduction of Lake Chubsucker is occurring in the lower Ausable River.

OLD AUSABLE CHANNEL[2]

Following habitat modifications and water diversions in the lower Ausable River, the distribution of Lake Chubsucker has been limited to the protected waters of the OAC (Staton et al. 2010). Lake Chubsucker was first detected in the OAC in 1982. Subsequent to this first detection, Lake Chubsucker has been recorded from this area in 1997 (n ≥ 2), 2001 (n ≥ 1), 2002 (n = 13), 2004 (n = 53), 2005 (n = 39), 2009 (n = 28), 2010 (n = 1), 2012 (n = 51), and 2015 (n = 23). It should be noted that a large Lake Chubsucker winterkill occurred in the OAC in 2010, which may explain the noticeable difference in the number of individuals caught between 2008–2009 and 2010. The majority of the fish killed were found in the southern end of the residential area (near the Pinery Provincial Park boundary) and upstream of the dam in the Pinery; however, it should be noted that dead fish were observed throughout the system from the origin of the OAC to below the Pinery dam (K. Jean, Ausable-Bayfield Conservation Authority, pers. comm.). From the winterkill, 68 individuals were collected, ranging in size from 91 to 199 mm TL. Otoliths and scales of all mortalities were aged. Otolith-based ages ranged between 1–6 years; while scale-based ages ranged between 1–5 years; no age 0 fish were observed. A previous winterkill of this magnitude was observed in the OAC in 2003 and it is believed that the contributing factors included a prolonged snow cover and a thick ice pack that led to oxygen depletion and possibly anoxic waters (K. Jean, Ausable-Bayfield Conservation Authority, pers. comm.). Analysis of dissolved oxygen based on field monitoring during 2017 and 2018 revealed a seasonal pattern of late-summer and over-winter hypoxia in the OAC (Ziegler et al. 2021).

L LAKE[3]

L Lake is an oxbow lake located approximately 3.5 km WSW of the OAC. The first known L Lake sampling event occurred in 2007 with the aid of a boat electrofisher and a seine net. At least 18 individuals were captured during a 7-day sampling event. Subsequently, L Lake was re-visited in June and August 2010 as part of a depletion survey and a total of 215 individuals were recorded from 154 seine hauls. The length of these individuals ranged from 12 to 143 mm TL (DFO unpublished data). In 2018, a total of 39 Lake Chubsucker were captured at 21 of 43 seining sites around L Lake, 34 in August and 5 in a follow-up sampling event in September (Barnucz and Drake 2021).

In 2012, targeted, exploratory sampling for Lake Chubsucker occurred in Old Mouth Lake, immediately northwest of L Lake and presumably once hydrologically connected, but no individuals were detected.

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[2] Preliminary sampling results from the Ausable-Bayfield Conservation Authority from September 2021 yielded 46 Lake Chubsucker in the Old Ausable Channel using boat and shore seining (K. Jean, Ausable-Bayfield Conservation Authority, pers. comm.).

[3] Preliminary sampling results from the University of Toronto Scarborough 2021 sampling yielded four Lake Chubsucker (an additional deceased individual was recovered) from summer and 15 from fall in L Lake captured in fyke nets (J. Powell, University of Toronto Scarborough, pers. comm.).

LAKE ST. CLAIR

For the purposes of the Lake Chubsucker population assessment, all waterbodies directly connected to Lake St. Clair, including Mitchell's Bay, undyked coastal marshes in the drainage, Chenail Ecarté, Little Bear Creek, and Collop and Prince Albert drains were grouped because movement between subpopulations is possible. Lake Chubsucker was first recorded from Lake St. Clair in 1949. Subsequent records are sparse and include captures in 1952 and 1979 in Mitchell's Bay, and records scattered from St. Anne Island to the north end of Chemotogan Channel from 1999, 2001 and 2002. Extensive sampling completed in the spring, summer and fall in Mitchell's Bay in 2003 and 2004 using fyke netting and boat electrofishing failed to collect any individuals. Two Lake Chubsucker were caught through seining surveys in Little Bear Creek in 2013. In 2017, Lake Chubsucker (n = 3) was detected in Prince Albert Drain, and in 2018, an individual was captured in Collop Drain; both of these represent new localities and were incidental captures. In 2019, 50 individuals were captured in Chenail Ecarté in a seine, and in 2020, two individuals were captured upstream of Chenail Ecarté (mouth of St. Clair River) by boat electrofishing (Aguiar et al. 2021).

ST. CLAIR NWA

The St. Clair Unit of the St. Clair NWA is located approximately 8.5 km south of Mitchell's Bay. The NWA is separated from Lake St. Clair by dykes and fish movement between these two systems is presumed to be infrequent (DFO 2021). It is composed of an East and a West cell. Extensive sampling was completed in the St. Clair NWA in 2003 and 2004 by boat electrofishing and fyke netting. Although Lake Chubsucker did not appear in the 2003 sampling, six individuals (ranging in size from 66–255 mm) were recorded in 2004 in the West cell. In 2016, the East cell was sampled using a variety of gear types (minnow traps, dip nets, visual observation), and 22 Lake Chubsucker were recorded (Biotactic 2016). The West cell was sampled using mini fyke nets yielding 18 individuals (DFO unpublished data). Using mini fyke nets, DFO captured six Lake Chubsucker in the East cell in 2018, nine in 2019, and five in the West cell in 2019; individuals ranged in total length from 61 mm to 215 mm (Barnucz et al. 2021a).

An additional specimen was captured in 2016 in the Bear Creek Unit (Maxwell cell) of the St. Clair NWA in a mini fyke net (DFO unpublished data); the species was not previously known from this waterbody. The Bear Creek Unit is located between the mouths of Maxwell Creek and Little Bear Creek in the lower Sydenham River, approximately 6.5 km northeast of Mitchell's Bay.

JEANNETTE'S CREEK

Jeannette's Creek is a tributary of the Thames River. Historically, two records of Lake Chubsucker exist for upper Jeannette's Creek (1963 and 1965) and were recorded approximately 20 km upstream of the confluence with the Thames River. This area has been re-sampled on numerous occasions, and the lower reaches have been regularly sampled in recent years, but none of these efforts have detected Lake Chubsucker. The site of initial capture has more recently been described as very turbid, channelized, and forming part of an agricultural drain (COSEWIC 2008). This type of habitat is no longer consistent with Lake Chubsucker preferred habitat, and the species is thought to be extirpated from this area.

POINT PELEE NATIONAL PARK[4]

Lake Chubsucker was first recorded from Point Pelee National Park (PPNP) in 1949. Since this first collection, Lake Chubsucker has been recorded from PPNP in 1968, 1969, 1972, 1979, 1983, 1993, 2003, 2016, and 2019. All Lake Chubsucker records from the park are from three ponds; Lake Pond, Redhead Pond, and Girardin Pond. A total of 25 individuals were collected from Redhead and Girardin ponds in 2003 ranging 46–247 mm TL in size (Surette 2006), suggesting that a reproducing population is likely present (COSEWIC 2008). A single Lake Chubsucker was captured in Girardin Pond in 2016 in a fyke net (T. Bortoluzzi, DFO, pers. comm.). Lake Chubsucker had not been detected in Lake Pond since 1972, despite extensive sampling in 2002 and 2003 (Surette 2006); however, a single individual was captured in 2019 (175 mm TL) in a mini fyke net as part of a study to assess population size of SARA-listed fishes in PPNP (Barnucz et al. 2021b).

RONDEAU BAY[5]

The first record of Lake Chubsucker from Rondeau Bay dates back to 1955 when 14 individuals were captured. There have been very limited known occurrences in Rondeau Bay since this date of first capture, with records from 1963, 1983, and 2005. The inner marshes of Rondeau Bay have been sampled on numerous occasions with several gear types in 2005, 2007–2009, and 2013–2020. All records, both historical and current, occur within Rondeau Bay Provincial Park. Lake Chubsucker had not been recorded in Rondeau Bay since 2005 despite extensive sampling with suitable gears (although sampling had not occurred within the provincial park boundaries). COSEWIC (2021) felt it was likely extirpated from this area. However, a single individual (227 mm TL) was detected in August 2020 by boat electrofishing (Aguiar et al. 2021), suggesting the species likely persists in very low numbers.

LONG POINT BAY

For the purposes of this population status assessment, Big Creek undyked marshes, Turkey Point marshes, and Long Point Inner Bay were grouped and will be referred to as Long Point Bay. These localities were grouped because they are directly connected to each other and movement between them is possible. Lake Chubsucker was historically recorded from Long Point Inner Bay in 1951, 1955, 1994, 1999, 2004, and 2009. More recently, the Long Point Inner Bay and Crown Marsh (and associated ponds) have been the focus of several wetland studies as well as for Asian carp surveillance work, resulting in consistent captures of Lake Chubsucker since 2012. Individuals were captured using seine nets and boat electrofishing in 2012 (n = 87), 2013 (n = 21), 2014 (n = 88), 2015 (n = 9), 2016 (n = 7), 2017 (n = 9), 2018 (n = 15), 2019 (n = 7), and 2020 (n = 2) (DFO unpublished data; Ministry of Northern Development, Mines, Natural Resources and Forestry unpublished data; Rook et al. 2016; Marson et al. 2018; Colm et al. 2018; Colm et al. 2019a,b, Colm et al. 2020; Aguiar et al. 2021). Additional records from the undyked marshes of Big Creek exist from 1955, 1979, 1982 and more recently, from 2008 when two individuals were recorded from a site approximately 2 km upstream of where the mouth of Big Creek flows into Long Point Inner Bay. The first record from Turkey Point marshes was from 1985, and Lake Chubsucker was not detected again until 2007 when 22 individuals

[4] Preliminary sampling results from DFO in summer 2021 yielded one Lake Chubsucker captured in each Redhead and Girardin ponds in Point Pelee National Park in mini fyke nets (TL 32 and 44 mm; DFO unpublished data).

[5] A Lake Chubsucker was detected in Rondeau Bay in August 2021 (Lake Chubsucker in August 2021 by Kevin Gevaert iNaturalist)

were captured. An additional 12 individuals were captured in 2009, two individuals in 2010, and 37 individuals in 2011.

LONG POINT NWA

Long Point NWA is located on the eastern portion of the large spit forming the southern boundary of Long Point Bay. This portion of the spit is characterized by several small ponds. Of the ponds that contain Lake Chubsucker, some are continuously connected to Lake Erie, others exchange water infrequently, and some are fully landlocked (D. Bernard, Canadian Wildlife Service, pers. comm.). This is considered a separate area from Long Point Bay as movement between these areas is unlikely given the distance and unsuitable, open lake habitat in between. Due to its remote location, there have been very few sampling events in this area. From these limited sampling activities, Lake Chubsucker was captured in 1953, 1975, 2005, and 2009 (represented by a single individual). Recent sampling using mini fyke nets and seines yielded 14 Lake Chubsucker in 2016, and 54 in 2017 (DFO unpublished data). Specimens ranged in size from 59–205 mm TL.

BIG CREEK NWA DYKED MARSHES

The dyked marshes of Big Creek NWA should be considered a separate area from the open wetlands of Big Creek NWA and ultimately, a separate area from Long Point Bay as movement between these areas is prevented by the presence of dykes. The dyked marshes were sampled for the first time in 2005 with a seine net, and resulted in the capture of 13 individuals. This area had not been re-sampled until 2016 when extensive mini fyke net sets and seining occurred, resulting in the capture of 165 Lake Chubsucker, 71 from the North cell and 94 from the South cell (DFO unpublished data).

BIG CREEK UPPER TRIBUTARIES

Historical Lake Chubsucker records exist for several of the tributaries in the upper reaches of the Big Creek watershed (1960, 1972, 1973, 1974, and 1979). All voucher specimens were verified to be Lake Chubsucker (E. Holm, Royal Ontario Museum, pers. comm.). Sites where these records originated include Silverthorn Creek, Stoney Creek, Lynedoch Creek, and Trout Creek. Re-sampling of all historical sites in 2008 revealed that many of them were now buried agricultural drains or are dry (COSEWIC 2008). These sites no longer provide suitable habitat for Lake Chubsucker and this species is thought to be extirpated from the upper tributaries of Big Creek. This area has not been the subject of Lake Chubsucker investigation since 2008.

LYONS CREEK

Lyons Creek is a tributary of the Niagara River. It is generally considered to be composed of highly degraded habitat and poor water quality with the exception of a clear segment approximately 2 km long that receives overflow water from the Welland Canal. Approximately half of the Lake Chubsucker records collected since 2004 were located in this clear segment of Lyons Creek. The remaining records are from the 8 km section of Lyons Creek immediately downstream. A total of five, 28, 20, 13, and five Lake Chubsucker were captured from Lyons Creek in 2004, 2008, 2009, 2010, and 2013 respectively (DFO unpublished data, Ministry of Northern Development, Mines, Natural Resources and Forestry unpublished data).

In 2012, targeted, exploratory sampling using a seine net occurred in tributaries of the Welland River (Grassy Brook and Big Forks Creek) with suitable habitat near the mouth of Lyons Creek, but no Lake Chubsucker were detected (DFO unpublished data).

TEA CREEK

Tea Creek is a small tributary to Lyons Creek. A single historical record exists for Tea Creek from 1958. This waterbody has been sampled on several occasions since 1958 and has not yielded any additional records. Most recently, targeted sampling occurred in Tea Creek in 2012 using seine nets but failed to produce any individuals (DFO unpublished data). The habitat in the vicinity of the historical record at present is not considered to be suitable for Lake Chubsucker and the species is thought to be extirpated from Tea Creek.

POPULATION ASSESSMENT

To assess the population status of Lake Chubsucker populations in Canada, each area was ranked in terms of abundance (Relative Abundance Index) and trajectory (Population Trajectory; Table 1). A population assessment was conducted during the first RPA for Lake Chubsucker (Bouvier and Mandrak 2011) and a revised Population Assessment was completed by COSEWIC during the updated species status assessment (COSEWIC 2021) considering data collected from 2010–2018; these revised results are presented below with modifications.

The Relative Abundance Index was assigned as Extirpated, Low, Medium, High or Unknown. The number of individual Lake Chubsucker caught during each sampling period was considered, along with sampling parameters such as gear, area sampled, sampling effort and whether the study was targeting Lake Chubsucker. The Relative Abundance Index is a relative parameter in that the values assigned to each population are relative to the most abundant population. L Lake was historically thought to be the most abundant population, and was used as the anchor against which other Lake Chubsucker populations were assessed in Bouvier and Mandrak (2011) and COSEWIC (2021). However, this population appears to have declined in recent years. The Old Ausable Channel has been sampled most regularly, targeting Lake Chubsucker, and has yielded relatively large catches on most occasions (except following a winterkill event in 2010), thus, populations have been assessed relative to the OAC here. Catch data from all populations sampled using different gear types were assumed to be comparable when assigning the Relative Abundance Index.

The Population Trajectory was assessed as Increasing (an increase in abundance over time), Decreasing (a decrease in abundance over time), or Stable (no change in abundance over time). The number of individuals caught over time for each population was considered. If insufficient information was available to inform the Population Trajectory, the population was listed as Unknown.

A measure of certainty has been assigned to the Relative Abundance Index and Population Trajectory rankings and is listed as 1 = quantitative analysis, 2 = Catch per unit effort (CPUE) or standardized sampling, and 3 = expert opinion.

Table 1. Relative Abundance Index and Population Trajectory of each Lake Chubsucker population in Canada. Certainty has been associated with each ranking and is listed as 1 = quantitative analysis, 2 = CPUE or standardized sampling, 3 = expert opinion. Values are revised relative to assessment in Bouvier and Mandrak (2011). Adapted from COSEWIC (2021).

Locality	Revised Relative Abundance Index	Certainty	Revised Population Trajectory	Certainty
Old Ausable Channel	Medium	2	Stable	2
L Lake	Low	1	Unknown	2
Lake St. Clair	Low	3	Unknown	3
Dyked marshes within Lake St. Clair drainage	Medium	3	Unknown	3

Locality	Revised Relative Abundance Index	Certainty	Revised Population Trajectory	Certainty
St. Clair NWA	Low	2	Unknown	3
Jeannette's Creek	Extirpated	2	-	-
Point Pelee National Park	Low	2	Unknown	2
Rondeau Bay	Low	3	Unknown	3
Long Point Bay	Low	2	Unknown	3
Long Point NWA	Low	3	Unknown	3
Big Creek (upper tributaries)	Extirpated	2	-	-
Big Creek NWA (dyked marshes)	Medium	2	Unknown	3
Lyons Creek	Low	1	Unknown	2
Tea Creek	Extirpated	2	-	-

The Relative Abundance Index and Population Trajectory values were combined in the Population Status matrix (Table 2) to determine the Population Status for each population. Population Status was subsequently ranked as Poor, Fair, Good, Unknown or Not Applicable (Table 3). Certainty assigned to each Population Status is reflective of the lowest level of certainty associated with either initial parameter (Relative Abundance Index or Population Trajectory).

Table 2. The Population Status matrix combines the Relative Abundance Index and Population Trajectory rankings to establish the Population Status for each Lake Chubsucker population in Canada.

		Population Trajectory			
		Increasing	**Stable**	**Decreasing**	**Unknown**
Relative Abundance Index	**Low**	Poor	Poor	Poor	Poor
	Medium	Fair	Fair	Poor	Poor
	High	Good	Good	Fair	Fair
	Unknown	Unknown	Unknown	Unknown	Unknown
	Extirpated	Extirpated	Extirpated	Extirpated	Extirpated

Table 3. Population Status of all Lake Chubsucker populations in Canada, resulting from an analysis of both the Relative Abundance Index and Population Trajectory; certainty assigned to each Population Status (in brackets) is reflective of the lowest level of certainty associated with either initial parameter. Values are revised relative to original assessment in Bouvier and Mandrak (2011) due to perceived declines in L Lake and its validity as the reference population. Adapted from COSEWIC (2021).

Locality	Original Population Status	Revised Population Status
Old Ausable Channel	**Fair (2)**	**Fair (2)**
L Lake	Fair (2)	Poor (2)
Lake St. Clair	Poor (3)	Poor (3)
Dyked marshes within Lake St. Clair drainage	Poor (3)	Poor (3)
St. Clair NWA	Poor (3)	Poor (3)
Jeannette's Creek	Extirpated (2)	Extirpated (2)
Point Pelee National Park	Poor (3)	Poor (3)
Rondeau Bay	Poor (3)	Poor (3)

Locality	Original Population Status	Revised Population Status
Long Point Bay	Poor (3)	Poor (3)
Long Point NWA	Poor (3)	Poor (3)
Big Creek (upper tributaries)	Extirpated (2)	Extirpated (1)
Big Creek NWA (dyked marshes)	Poor (3)	Poor (3)
Lyons Creek	Poor (2)	Poor (2)
Tea Creek	Extirpated (2)	Extirpated (2)

HABITAT AND RESIDENCE REQUIREMENTS

***Element 4:** Describe the habitat properties that Lake Chubsucker needs for successful completion of all life-history stages. Describe the function(s), feature(s), and attribute(s) of the habitat, and quantify by how much the biological function(s) that specific habitat feature(s) provides varies with the state or amount of habitat including carrying capacity limits, if any*

Lake Chubsucker is a warmwater species, with preferred summer temperature ranging 28–34 °C (Coker et al. 2001). Throughout the Canadian Lake Chubsucker range, it is found in clear, well vegetated, slow-moving or still waters (COSEWIC 2021). Areas typically inhabited by Lake Chubsucker include backwaters, wetlands, ponds, floodplain lakes, and marshes (COSEWIC 2021). Turbidity is generally very low in these areas, and the substrate is commonly composed of clay, silt, and organic debris (COSEWIC 2021). Overwinter habitat for this species is unknown. A recent study evaluating responses of imperilled species to common environmental stressors in the Great Lakes basin found that Lake Chubsucker exhibited a strong negative (non-linear) relationship with turbidity, water velocity, and dissolved oxygen, the latter likely indicating some tolerance to low dissolved oxygen, and a strong positive (non-linear) relationship with water temperature (Rodriguez et al. 2021).

SPAWNING AND NURSERY

Spawning habitat consists of shallow waters of bays, the lower reaches of tributaries, or ponds and marshes with aquatic vegetation beds, dead grass, or filamentous algae (Goodyear et al. 1982). Males clear an area in the sand, silt, or often gravel, where females deposit eggs. The eggs subsequently hatch when water temperature reaches between 22 and 29°C (Cooper 1983). Nursery habitat has been described as water 2 m in depth composed of submerged and emergent vegetation over substrate of silt, sand, or clay (Lane et al. 1996). Goodyear et al. (1982) noted adult Lake Chubsucker moving across the Long Point Inner Bay to the Crown Marsh for spawning in mid to late April. A spawning-ready female was captured in West Feed Pond in Long Point Bay Crown Marsh at the end of May 2014, suggesting that spawning occurs in constructed/restored ponds in the Crown Marsh (Rook et al. 2016).

YOUNG-OF-THE-YEAR AND JUVENILE

Young-of-the-year (YOY) preferred habitat has been described as shallow areas (0 to 2 m) containing heavy aquatic vegetation and substrates of silt, sand, and clay (Goodyear et al. 1982; Becker 1983; Lane et al. 1996). Lake Chubsucker YOY were captured from Long Point Inner Bay, and a habitat description of the capture location was provided (Leslie and Timmins 1997). This area was described as a heavily vegetated drainage ditch with water temperature between 24 and 28°C (Leslie and Timmins 1997). During the same study, additional YOY individuals were captured in approximately 10 cm of water under a layer of leaves in a roadside ditch (Leslie and Timmins 1997). YOY captured from L Lake in June 2010 (n = 28) were captured when water temperatures were between 22 and 25°C and dissolved oxygen ranged between 6.93 and 9.07 mg/L (DFO unpublished data). The substrate at all sampling locations was described as 100% organic. Vegetative cover (combination of submerged, floating and emergent) was greater than 70%, with dominant species of watershield (*Brasenia schreberi*), water lily (*Nymphaea* sp.), milfoil (*Myriophyllum sibiricum*) or *Chara* (*Chara* spp.) (DFO unpublished data).

In addition to YOY, age 1+ individuals were also recorded from Long Point, and were found in marshes associated with hairgrass (*Eleocharis* sp.), sedges (*Carex* sp.) and cattails (*Typha* sp.) (Leslie and Timmins 1997). Juveniles captured from L Lake in June 2010 were captured when water temperatures ranged from 21 to 24°C and dissolved oxygen was between 5.39 and 13.71 mg/L (DFO unpublished data). Similar to the YOY habitat description for L Lake, all individuals were captured from sites composed of 100% organic substrate. Vegetative cover at sites where juveniles were found was greater than 75%, with the dominant vegetation type at all sites being listed as *Chara* (DFO unpublished data).

ADULT

Adult Lake Chubsucker are generally found in clear, still, well-vegetated waters, such as those provided by backwaters, drainage ditches, floodplain lakes, marshes, oxbows, sloughs, or wetlands (COSEWIC 2021). Substrate in these systems is generally composed of gravel, sand, and silt mixed with organic debris (COSEWIC 2021). In Ontario, adult Lake Chubsucker are commonly found in heavily vegetated systems with very low turbidity. An aquatic vegetation survey of the St. Clair NWA (East and West cells), indicated that the most frequently occurring aquatic macrophyte genera included: *Nymphaea*, *Ceratophyllum*, *Elodea*, *Hydrocharis*, *Typha*, and *Lemna*. Lake Chubsucker captured during this study ranged in size from 61–215 mm TL, indicating that several life stages were using this habitat (Barnucz et al. 2021a). Based on all known Lake Chubsucker records in Ontario where water depth was available, Lake Chubsucker appear to occupy areas with a mean water depth of 0.89 m (range from 0.18 to 4.40 m; only two sites had depths greater than 2 m but this likely reflects sampling restrictions). Lake Chubsucker sampling from L Lake in 2010 indicated that Lake Chubsucker were found in areas where the substrate was classified as being greater than 90% organic (DFO unpublished data). It appears that throughout the range of Lake Chubsucker in Ontario, protected coastal wetlands and dyked marshes play a crucial role in the maintenance of preferred Lake Chubsucker habitat and subsequently, are of paramount importance for this species.

FUNCTIONS, FEATURES, ATTRIBUTES

A description of the functions, features, and attributes associated with the habitat of Lake Chubsucker in Canada can be found in Table 4. The habitat required for each life stage has been assigned a life-history function that corresponds to a biological requirement of Lake Chubsucker. In addition to the life-history function, a habitat feature has been assigned to each life stage. A feature is considered to be the structural component of the habitat necessary for the species. Habitat attributes have also been provided, these are measurable components describing how the habitat features support the life history function for each life stage. The habitat functions, features, and attributes outlined in Table 4 were adapted from the Critical Habitat order for Lake Chubsucker (Canada 2018), supplemented with additional, recent information to guide any future identification of critical habitat for this species.

Table 4. Summary of the essential functions, features, and attributes for each life stage of Lake Chubsucker in Canada. Habitat attributes from published literature (see Bouvier and Mandrak 2011) were used to identify critical habitat (Staton et al. 2010, Canada 2018), and those recorded during recent (2011–2020) Lake Chubsucker sampling events can be used to support further delineations of critical habitat. Current knowledge reflects mean habitat values at sites where young-of-year and juvenile (i.e., < 120 mm TL) and adult (i.e., > 120 mm TL) Lake Chubsucker were captured across Ontario (DFO unpublished data). Life stages are based on presumed age and size at maturity from the literature (see Fung and Koops 2023).

Life Stage	Function	Features	Attributes		
			Scientific Literature	Current Knowledge	Critical Habitat
Spawn to hatch	Spawning, cover, nursery	Areas that seasonally support aquatic vegetation	• 22–29°C (Cooper 1983); • Beds of submerged and emergent vegetation, dead grass, or filamentous algae (Goodyear et al. 1982); • Sand, silt, or gravel substrates where a nest may be cleared by male.	-	• Shallow waters (0–2 m) of bays, ponds, marshes, lower reaches of tributaries; • Abundant submerged aquatic vegetation; • Water temperatures of approximately 20°C from April to June.
Young-of-year, juvenile,	Feeding, cover, nursery	Areas that seasonally support aquatic vegetation	• 24–28°C (Leslie and Timmins 1997); • Slow-moving or still waters; • Shallow depths (0–2 m; Lane et al. 1996); • Heavily vegetated (> 70% cover; *Brasenia, Nymphaea, Myriophyllum, Ceratophyllum, Chara, Potamogeton, Eleocharis, Carex, Typha*) (Leslie and Timmins 1997; Barnucz et al. 2021a; DFO unpublished data); • Organic substrates, or silt, sand or clay substrates (DFO unpublished data); • Low turbidity.	• Mean water temperature of 24.55°C (range: 12.07–33.70), mean conductivity of 339.29 µs/cm (21.70–741.1), mean dissolved oxygen of 6.40 mg/L (0.98–15.38), mean turbidity of 23.81 ntu (0–486.0) (mean secchi tube depth of 0.79 m (0.16–1.18)); • Mean percent composition of substrate classes: organic (40%; range: 0–100), silt (30%; 0–100), sand (24%; 0–100), clay (12%; 0–90); • Mean percent areal cover of aquatic vegetation types: submerged (68%; range: 0–100), floating (14%; 0–50), emergent (10%; 0–70); open water (11%; 0–80).	• Calm and shallow waters (0–2 m); • Abundant aquatic vegetation; • Substrates of organic debris, sand, silt, clay; • Low turbidity.

Life Stage	Function	Features	Attributes		
			Scientific Literature	Current Knowledge	Critical Habitat
Adult	Feeding, cover	Areas that seasonally support aquatic vegetation	• warm waters, 28–34°C (Coker et al. 2001; Rodriguez et al. 2021); • Clear, low velocity, heavily vegetated waters (backwaters, drainage ditches, floodplain lakes, marshes, oxbows, sloughs, wetlands) (COSEWIC 2008; Bouvier and Mandrak 2011; Rodriguez et al. 2021).	• Mean water temperature of 22.33°C (range: 14.5–28.07), mean conductivity of 356.12 µs/cm (232.40–474.30), mean dissolved oxygen of 5.75 mg/L (0.99–11.22), mean turbidity of 5.30 ntu (0.11– 22.33) (mean secchi tube depth of 0.84 m (0.52–1.15)); • Mean percent composition of substrate classes: silt (38%; range: 0–80), organic (37%; 0–100), sand (24%; 0–100), clay (4%; 0–40); • Mean percent areal cover of aquatic vegetation types: submerged (54%; range: 0–100), emergent (19%; 0–100), floating (14%; 0–60); open water (15%; 0–85); • Mean depth of 0.89 m (range: 0.18–4.4 m).	Same as above

Element 5: *Provide information on the spatial extent of these areas in Lake Chubsucker distribution that are likely to have these habitat properties*

The spatial extent of areas that are likely to have the habitat properties outlined in Table 4 has been partially defined (Staton et al. 2010, Canada 2018). A Critical Habitat order identifies the following locations as required for the survival and recovery of Lake Chubsucker: Old Ausable Channel (from the mouth to the end at Grand Bend), L Lake (all contiguous waters and wetlands), Rondeau Bay (contiguous waters of the bay along the eastern shoreline, within the Provincial Park), Long Point Bay (all contiguous nearshore waters, wetlands, and ponds including the southern spit), and Lyons Creek (all contiguous waters and wetlands from the Welland Canal to Montrose Road) (Canada 2018). Additional areas were identified in the species' Recovery Strategy as containing suitable habitat properties as: the entirety of the West cell of the St. Clair unit of the St. Clair NWA, Girardin and Redhead ponds of Point Pelee National Park, and the northern portion of the Big Creek NWA dyked marshes (contiguous waters and wetlands) (Staton et al. 2010). Detections since the last RPA (i.e., since 2010) suggest additional areas may warrant evaluation of habitat properties for critical habitat (e.g., East cell – St. Clair Unit and Maxwell cell – Bear Creek Unit of the St. Clair NWA; Lake Pond of Point Pelee National Park, Turkey Point marsh in Long Point Bay, agricultural drains Little Bear Creek, Prince Albert and Collop in Lake St. Clair), but further spatial analysis is required.

Element 6: *Quantify the presence and extent of spatial configuration constraints, if any, such as connectivity, barriers to access, etc.*

The extent of spatial configuration constraints has not been explicitly identified. However, areas as described above under the Current Status are defined based on presumed spatial extent of each area. In some cases, barriers of various kinds (e.g., dykes, low-head dams, barrier beaches) exist where movement in or out is impossible or unlikely (i.e., dyked marshes within the Lake St. Clair drainage and Big Creek NWA, St. Clair NWA, Long Point NWA inland ponds, Point Pelee National Park ponds, L Lake, and Old Ausable Channel). Other locations may be open and connected such that movement within or between locations is hydrologically possible (i.e., Long Point Bay, Rondeau Bay, Lyons Creek, Lake St. Clair), but distances between populations are too great and/or suitable habitat does not exist making such movements risky and unlikely (COSEWIC 2021). The Niagara and Detroit rivers, although passable, likely represent barriers that Lake Chubsucker would not traverse due to high flow conditions. Recent examination of Lake Chubsucker genetic structure between Ontario populations suggests that it is unlikely that gene flow has recently occurred between the Lyons Creek population and any of the other areas examined (Hauser et al. 2019).

Element 7: *Evaluate to what extent the concept of residence applies to the species, and if so, describe the species' residence.*

Residence is defined in SARA as a, "dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding, or hibernating". Residence is interpreted by DFO as being constructed by the organism. In the context of the above narrative description of habitat requirements during YOY, juvenile and adult life stages, Lake Chubsucker do not construct residences during their life cycle.

THREATS AND LIMITING FACTORS TO SURVIVAL AND RECOVERY

Element 8: *Assess and prioritize the threats to the survival and recovery of the Lake Chubsucker*

A wide variety of threats negatively impact Lake Chubsucker across its range. Knowledge of threat impacts on Lake Chubsucker populations is limited, as there is a paucity of threat-specific cause and effect information in the literature. The greatest threat to Lake Chubsucker in Canada is the establishment of aquatic invasive species (AIS; fishes and aquatic plants) that will result in substantial changes to preferred habitat (COSEWIC 2021). European common reed is of particular concern given its ability to decrease wetted area, and its limited habitat value to fishes. The occurrence of pristine, highly vegetated systems in Ontario where Lake Chubsucker thrive is very limited, and the cumulative effects of various watercourse modifications, pollution inputs, and climate change are likely to continue to degrade these areas. Biotic impacts of invasive species are considered a lesser threat, but may further impact the species. A distinct challenge when considering the effect of the various threats on Lake Chubsucker is that, even within an area, there may be several distinct localities that are very diverse, facing pressures from different threats (e.g., Lake St. Clair – Lake St. Clair; Mitchell's Bay; Chenail Ecarté; agricultural drains Little Bear Creek, Collop Drain, Prince Albert Drain; undyked wetlands in the drainage). Threats were categorized by COSEWIC (2021) according to Salafsky et al. (2008), and descriptions are reproduced below with additions where new information existed (COSEWIC 2021). These threats have been assessed based on guidance from DFO (2014).

THREAT CATEGORIES

Natural Systems Modifications

Agriculture

Agricultural land use is widespread in southern Ontario and is the dominant form of land cover in drainages that support Lake Chubsucker in Canada. Several agricultural practices have been attributed to the decline of Lake Chubsucker throughout the Canadian range (Bouvier and Mandrak 2011), notably increased flow of surface water leading to siltation in nearby watercourses, thereby reducing the conditions that promote the growth of aquatic macrophytes. Siltation due to agriculture is most pertinent to Lake Chubsucker populations directly adjacent to agricultural land use where flow-through effects lead to direct sediment inputs (Lake St. Clair drains, Long Point Bay, Rondeau Bay, and PPNP). Agricultural effects stemming from the modification of surface flow are reduced in dyked wetlands.

Shoreline Development and Hardening

Shoreline hardening and other forms of shoreline modification have occurred in parts of the Lake Chubsucker range in Canada, principally boating channels and other shoreline areas within Lake St. Clair, Long Point Bay, Lyons Creek, and Rondeau Bay. Hardening usually occurs through the installation of rock, metal, or other retaining structures near bankside locations to increase bank stability (i.e., protect against property loss) or for recreational purposes (maintain boat docking locations). Where hardening has occurred, the prominent effect to Lake Chubsucker habitat is the modification of water currents and sediment transport, as well as changes in the composition and availability of substrate, which may influence the availability of macrophyte cover and food. However, empirical studies of the effect of shoreline hardening on Lake Chubsucker have not occurred.

Dredging

Similar to shoreline hardening, dredging is conducted in parts of the Lake Chubsucker range in Canada. Dredging occurs mainly in canals and channels used for boating in Lake St. Clair and Long Point Bay. Although Barnucz et al. (2015) indicated that dredging is likely to pose low impacts to fish species at risk in Lake St. Clair based on a control – impact study, the study was focused on sandy river mouths, not areas likely to be inhabited by Lake Chubsucker. Where dredging occurs in proximity to Lake Chubsucker, the activity may physically disturb individuals and may also modify Lake Chubsucker habitat through changes to food supply, sedimentation, structure/cover, and macrophyte composition and availability.

Dredging recently occurred in Crown Marsh, Long Point Bay (2012–2015) as part of a large European common reed control and marsh restoration project (Rook et al. 2016). Dredging was undertaken to create new pond complexes following large-scale European common reed removal. Following their creation, the new ponds were connected with existing channels and other watercourses in Crown Marsh in areas known to support Lake Chubsucker and several other fish species at risk (Rook et al. 2016). Field sampling detected Lake Chubsucker in one of several newly created ponds (Ankney Pond); however, the long-term consequence of pond creation on the viability of Lake Chubsucker is unknown, including whether created watercourses maintain ecological function through time and (or) connectivity with the surrounding marsh. Removal of aquatic vegetation through dredging has also been proposed in Rondeau Bay (DFO 2020). Although it is unlikely to occur near the provincial park where Lake Chubsucker is known, vegetation removal via dredging would cause habitat disturbances (e.g., increased turbidity, reduced dissolved oxygen, loss of structure/cover and ecosystem function) throughout the bay, and direct physical damage to individuals is possible (DFO 2020).

Where Lake Chubsucker occupies, or has access to, agricultural farm drains (e.g., Prince Albert and Collop drains) or other watercourses subject to agricultural drainage modification (e.g., Little Bear Creek), dredging to increase watercourse drainage capacity has the potential to impact Lake Chubsucker and its habitat through changes to food supply, sedimentation, structure/cover, and macrophyte composition and availability. Montgomery et al. (2018) found that the predominant impact of dredging in agricultural drains to small-bodied fish species at risk in Southern Ontario is changes to habitat connectivity. However, the reliance of Lake Chubsucker on agricultural drains is poorly known beyond a few recent records of the species in these systems. The conversion of natural watercourses to tiled drains has been implicated as the causative factor in the loss of Lake Chubsucker from the Big Creek drainage.

Drawdown of Dyked Wetlands and Other Water Level Manipulations

Several populations of Lake Chubsucker exist in dyked wetlands in lakes St. Clair and Erie (dyked coastal marshes and St. Clair NWA in Lake St. Clair; Big Creek NWA and Turkey Point cells in Lake Erie). Wetland dykes have been in place for several decades, with dyking originally undertaken to maintain water availability in areas subject to water level reductions and associated losses of wetland plant cover and abundance. However, increasingly the management of dyked cells, including those supporting Lake Chubsucker, has involved proposed water-level drawdowns to promote regeneration of aquatic macrophytes and establish ‘hemi-marsh’ conditions required by waterfowl (ECCC 2018). The short-term consequences of water-level drawdown will be contingent on the amount and quality of refuge habitat available to Lake Chubsucker during the drawdown period, but will result in density-dependent effects (e.g., increased predation risk, reduced food supply through competition, increased risk of disease transfer due to crowding, reduced dissolved oxygen through consumption) and density-independent effects (e.g., increased temperatures, decreased dissolved oxygen from temperature effects, loss of habitat structure, fragmentation, stranding mortality) to Lake

Chubsucker (DFO 2021). Longer-term habitat changes associated with drawdown may result in regeneration of the aquatic vegetation community.

The short-term impact of water-level drawdown on habitat availability and its relationship to Lake Chubsucker abundance was modelled in the East cell of the St. Clair NWA (St. Clair Unit) (DFO 2021). The East cell is depth-limited and patchy under baseline conditions, and drawdown would result in reduced wetted area and availability of deep water refuge, and in a highly fragmented habitat likely to exacerbate density-dependent and -independent effects. The changes in habitat availability depend on the drawdown increment, but a drawdown of 0.3 m would result in a 50% loss of water volume and mean depth, and a drawdown of 0.6 m would result in a 50% loss of wetted area, a 99.96% reduction in deep water refuge, and a nearly quadrupling of isolated habitat patches. This loss of habitat would lead to a corresponding loss in fish production, with the greatest increase in the probability of Lake Chubsucker extinction at drawdown increments of 0.20–0.45 m, and a probability of extinction of 1.0 occurring at 0.45–0.75 m of drawdown, depending on presumed depth of habitat that contributes to fish community production (DFO 2021).

In addition to water-level drawdown of dyked cells, Lake Chubsucker is susceptible to water-level manipulations that may occur through the management of the Welland Canal as part of the St. Lawrence Seaway. The Lyons Creek population receives overflow water from the Welland Canal, which is pumped continuously into the headwaters of Lyons Creek. If pumping was to cease intentionally, or unintentionally due to pump malfunction or extreme water-level fluctuations in the canal system, immediate dewatering of the portion of Lyons Creek supporting Lake Chubsucker would be very likely. Dewatering would impact the availability of Lake Chubsucker habitat, and could also lead to stranding-induced mortality depending on the magnitude of water-level fluctuation.

Lastly, water-level fluctuations are common in the OAC resulting from a combination of historical and recurring human interference. Historical diversions of the OAC disconnected it from its surrounding watershed, and it now receives limited hydrologic inputs from groundwater or runoff, which causes lack of flow and stagnation (Friends of the Old Ausable Channel, 2021). Additionally, undersized culverts and failing water-control structures within the OAC further contribute to this problem, and have resulted in water-level differences among sections of the channel (K. Jean, Ausable-Bayfield Conservation Authority, and N. Mandrak, University of Toronto Scarborough, pers. comm.). Local residents also remove beaver dams, which often leads to a near dewatering of the northern portion most preferred by Lake Chubsucker (A. MacKenzie, Ontario Parks, pers. comm.). The lack of circulation and generally low water levels coupled with nutrient loading have created conditions for periods of extremely low dissolved oxygen (Ziegler et al. 2021), both daily and seasonally, and winterkills of Lake Chubsucker have been reported from this system (K. Jean, Ausable-Bayfield Conservation Authority pers. comm.). The altered hydrology and ineffective water control structures have allowed for multiple threats to interact that likely negatively affect Lake Chubsucker.

Aquatic Invasive Species (habitat related impacts)

Aquatic Invasive Species are implicated in the current and future decline of Lake Chubsucker through generalized food web changes and the loss or modification of preferred habitat. In some cases, the effects of controlling AIS, especially activities to reduce the density of European common reed and Eurasian watermilfoil (*Myriophyllum spicatum*), may negatively affect Lake Chubsucker in the short term.

Common Carp (*Cyprinus carpio*) has likely contributed to the decline of Lake Chubsucker through habitat-related effects. Common Carp is found throughout the Canadian range of Lake Chubsucker. A known ecosystem engineer, Common Carp can increase the turbidity of aquatic ecosystems by disturbing benthic sediments, thereby reducing light penetration and decreasing macrophyte abundance and diversity (Weber and Brown 2009). Common Carp may influence habitat quality of Lake Chubsucker by uprooting submerged and emergent aquatic plants, which can modify the habitat features Lake Chubsucker require for feeding, cover, and reproduction. Goldfish (*Carassius auratus*), which have become increasingly widespread and locally abundant in wetlands around the Great Lakes, may have similar impacts in terms of reducing aquatic vegetation cover and increasing turbidity (Richardson et al. 2015). In addition to habitat effects imposed by Common Carp and possibly Goldfish, habitat effects by Grass Carp (*Ctenopharyngodon idella*), a species of increasing abundance in the Lake Erie drainage (Chapman et al. 2013, Embke et al. 2016), are expected to increase in importance for Lake Chubsucker. Although reproducing populations of Grass Carp are not known to occur in Canadian waters, unless species control measures are taken, future expansion of Grass Carp into areas inhabited by Lake Chubsucker is likely (Lake St. Clair, PPNP (dependent on lake levels), Rondeau Bay, Long Point Bay, and Lyons Creek) due to the lack of migration barriers[6]. Given that Grass Carp feeds almost exclusively on aquatic vegetation (Pipalova 2002, van der Lee and Koops 2017), especially submerged macrophytes, impacts to habitat required by all life stages of Lake Chubsucker would occur should Grass Carp increase in Canadian waters (Gertzen et al. 2017). Although Rudd (*Scardinius erythrophthalmus*) is also a direct consumer of aquatic macrophytes (Kapuscinski et al. 2014), herbivory by Rudd is expected to be of lower importance than Grass Carp for the viability of Lake Chubsucker populations.

Habitat-related impacts to Lake Chubsucker due to AIS have occurred due to the establishment and expansion of European common reed and Eurasian watermilfoil. The distribution of both vascular plant species has expanded significantly within coastal and inland wetlands as a result of natural and human-mediated dispersal (Crow and Hellquist 2000, Wilcox et al. 2003, Trebitz et al. 2007, Whyte et al. 2008). European common reed is found throughout the entire Canadian range of Lake Chubsucker. The expansion of European common reed has led to substantial reductions of wetted area and a presumed reduction of preferred habitat features in many localities inhabited by Lake Chubsucker (Long Point Bay, Rondeau Bay, and Lake St. Clair). Modelling indicates that additional expansion of European common reed is expected in Long Point Bay (Jung et al. 2017), which could lead to substantial decreases in suitable habitat (by 15–100%, depending on realized colonization depth) for SARA-listed fishes (McCusker 2017). Expansion is expected to continue if control activities are not implemented or are ineffective. Eurasian watermilfoil is also found throughout most of the range of Lake Chubsucker in Canada. The dominant effect of Eurasian watermilfoil likely includes competition with native plants that Lake Chubsucker relies on for cover, feeding, and reproduction. The effect of the replacement of native plant species with Eurasian watermilfoil is unknown, but likely imposes habitat-related effects on the species, especially if Eurasian watermilfoil reaches higher densities than the native plants it replaces. A better understanding of the ecological effects of Eurasian watermilfoil on Lake Chubsucker (e.g., spawning success, food supply, provision of cover) is required.

The control of invasive macrophytes, such as European common reed and Eurasian watermilfoil, may occur through chemical control agents, burning, cutting, spraying, or other forms of physical removal from a watercourse. Mortalities and/or distress of fishes have been documented in the Long Point area (Crown Marsh, NWA, and Big Creek NWA) following glyphosate treatment for European common reed control (Reid et al. 2023). Most (85%) of the mortalities were bullhead species (*Ameiurus* spp.), Warmouth (*Lepomis gulosus*) was the only

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[6] Point Pelee National Park has a barrier beach that typically prevents movement of fishes between the wetlands and Lake Erie; however, the barrier is prone to breaches and may allow Grass Carp access to the wetlands for feeding.

SARA-listed fish for which mortalities were observed, and no catostomids were found deceased or distressed. Additional exposure and toxicology testing on Lake Chubsucker and other sensitive fishes found in the treatment area would be beneficial, as glyphosate and surfactants applied in the mixture have been shown to cause developmental, reproductive, and neurological issues as well as tissue damage in some freshwater fishes (Gill et al. 2018, Yang et al. 2021). Following mechanical removal of European common reed in L Lake, castings that were stockpiled along the banks appear to have altered flow into the system, leading to changes in habitat quality (e.g., eutrophication and hypoxic conditions; proliferation of floating macrophytes) and poor fish catches relative to previous sampling by DFO (N. Mandrak, University of Toronto Scarborough, pers. comm). Although control activities are likely to benefit Lake Chubsucker over the long term if intended reductions in invasive plants are achieved, the short-term effect on Lake Chubsucker from these activities (e.g., physical disturbance of individual Lake Chubsucker; increased sedimentation; disturbance/reduction of adjacent native wetland plants that Lake Chubsucker relies on for food and cover; bioaccumulation of chemical compounds) is poorly understood. Although an important consideration, the control of invasive macrophytes will not be considered in the threat assessment below as long-term (up to 10 years) benefits may be expected to offset short-term (1–3 year) harm within the timeframe under consideration (10 years or three generations).

Pollution

Agriculture

Surface runoff from agriculture promotes nutrient loading in certain areas inhabited by Lake Chubsucker. Nutrient loading can increase primary production, modify water clarity, and alter the availability of aquatic macrophytes that Lake Chubsucker relies on for cover and food. Nutrient loading can also decrease the availability of dissolved oxygen, thereby increasing the potential for physiological consequences to the species. The effects of nutrient loading may be reduced in dyked wetland systems, but some level of nutrient loading may occur, contingent on the frequency with which intake water is obtained from sources that experience nutrient loading. Additionally, surface runoff from agricultural fields is also likely to contain pesticides, herbicides, and metals through the field application of biosolids, which may negatively affect macrophyte growth and benthic invertebrate structure (Shafer et al. 2011).

Industrial Activity

Most of the Canadian range of Lake Chubsucker is not subject to the effects of industrial activity, in part due to the number of populations that exist within provincially or federally protected lands (e.g., NWAs, provincial parks). However, areas downstream of industrial outflows, such as the St. Clair River delta and Lyons Creek, are susceptible. No studies have been conducted to evaluate the physiological consequences of exposure of Lake Chubsucker to industrial effluent. The section of Lyons Creek inhabited by Lake Chubsucker contains elevated levels of several compounds [polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), zinc, and p,p’-DDE], particularly within the sediment. Bioaccumulation of these compounds within benthic organisms has been documented (Milani et al. 2013), which may lead to contaminant effects for Lake Chubsucker given that these organisms constitute a key prey resource.

Polycyclic aromatic hydrocarbons (PAHs), as well as the contaminant DDT and its derivatives (DDD; DDE) from historical applications for mosquito control in the 1940s through 1960s, exist in high concentrations in the sediment and soils of PPNP (Crowe and Smith 2007; Clow et al. 2017). The direct impact of these compounds on Lake Chubsucker or other marsh fauna has not been assessed.

Microplastic waste from industrial and urban sources has been found in surface waters and sediments of the lower Great Lakes, and is likely to settle out in low-energy environments, such as those inhabited by Lake Chubsucker (Castañeda et al. 2014, Driedger et al. 2015, Dean et al. 2018). Very few studies exist evaluating the impacts of microplastic waste on freshwater fishes, but benthic-feeding fishes are more likely to encounter microplastics compared to other trophic levels, particularly in urban rivers (e.g., St. Clair River) (Sanchez et al. 2014). In general, the impacts of this emerging threat are poorly understood.

Urbanization

Although agriculture is the predominant land use in areas surrounding Lake Chubsucker habitat in Ontario, some populations face threats from encroaching urbanization. Specifically, aging septic tanks leaching into groundwater or overflowing into surface waters were identified as a threat for the OAC, PPNP (upgrades to septic systems and associated infrastructure including improved nutrient capturing are planned for 2022), and likely impact areas of Long Point Bay and Rondeau Bay as well (COSEWIC 2021). Septic leaching can result in increased nitrogen and possibly phosphorus loading, leading to algal blooms and other primary production, which have resulted in heightened periods of consumption and decay during late summer and early fall. Heightened decay has been associated with seasonal patterns of hypoxia in the OAC (Ziegler et al. 2021), including an extended winter period of hypoxia driven by the interaction between biological decay and ice cover. Deceased Lake Chubsucker and other fishes have been collected during the spring melt period, indicating that winterkill due to hypoxia is likely occurring within the OAC (K. Jean, Ausable-Bayfield Conservation Authority pers. comm.). Winterkill is believed to be prominent during periods of extended ice cover; however, the relationship between ice cover, hypoxia, and mortality of Lake Chubsucker in the OAC remains poorly understood (Ziegler et al. 2021).

Although road density is generally low in most areas inhabited by Lake Chubsucker, application of road salts for winter de-icing is still a concern, and may have several direct and indirect effects on Lake Chubsucker. Increased de-icing salts have been shown to impair growth and development of salmonid eggs and larvae (Hintz and Relyea 2017, Hintz and Relyea 2019), and impact survival, feeding, and growth of leuciscid minnows (Corsi et al. 2010, Hintz et al. 2017); though impacts varied by taxa, concentration, and experimental treatments. Aquatic macrophytes may be reduced in richness and abundance, and planktonic and benthic invertebrate communities are often altered as a result of increased salinization (Richburg et al. 2001, Stoler et al. 2018, Hintz and Relyea 2017, 2019, Coldsnow and Relyea 2021).

Additionally, roadway construction or improvement projects adjacent to or within Lake Chubsucker habitat have the potential effect of reducing total Lake Chubsucker habitat area. Although mitigation and offset measures would be implemented, construction may still fragment habitat, alter flow and water level as well as sediment and nutrient dynamics, and lead to increased pollutants (e.g., road salts and other hard metals) (van Proosdij et al. 2009, Gerwing et al. 2020).

Climate Change

Climate change is expected to modify habitat resources that Lake Chubsucker relies on to carry out its life history. However, the magnitude and direction of habitat change is difficult to predict due to the potential for synergistic and antagonistic habitat effects under climate change. Therefore, like most freshwater fishes, the effect of climate change on the viability of Lake Chubsucker is poorly understood.

Recent projections for the Ontario Great Lakes basin suggest that mean annual air temperatures are likely to increase by 2.3–7.9°C, depending on the scenario, with greater warming in the winter compared to summer (McDermid et al. 2015). Precipitation is also expected to increase in the basin in winter months but summers will be drier compared to the baseline (McDermid et al. 2015). The impacts of such effects could result in dramatic changes to primary productivity, carbon storage, lake and steam hydrology, and periods of ice cover (Woodwell et al. 1995, Schindler 1998, Urquizo et al. 2000). Higher water temperatures, lower water levels, and shifts in seasonal ice cover will no doubt lead to changes in Lake Chubsucker ecology and result in invasions of new and exotic species. Overall, some fishes (e.g., warmwater species) would likely benefit, while others (e.g., coldwater species) would suffer. Northward dispersal of fish species, including invasive species, may occur, while local extinctions of native species are expected. Higher temperatures and lower water levels would also exacerbate water quality problems, which would increase fish contamination and impair fish health (Lemmen and Warren 2004).

Doka et al. (2006) completed an assessment on the projected impacts of climate change on wetland fish assemblages by ranking fish species' vulnerability to climate change. A vulnerability matrix was calculated based on species status, and thermal and habitat associations (Doka et al. 2006). Results indicated that, of the 99 fish species assessed, Lake Chubsucker was ranked as the fourth most vulnerable species. Climate change will have wide-reaching direct and indirect effects on fish species that rely on wetland (and/or shallow, well vegetated) areas for their survival and that have a limited geographic distribution (Lemmen and Warren 2004, Doka et al. 2006). The vulnerability of Lake Chubsucker to climate change was assessed by Brinker et al. (2018) as moderately vulnerable, where the species' abundance and/or range extent in Ontario is expected to decrease by 2050. Approximately 60% of its range in Ontario is expected to experience temperature increases of 2.85–3.16°C (and 40% of the range to experience an increase of 2.53–2.84°C). Anthropogenic barriers in Lake Chubsucker habitat are inhibitive such that movement out of currently occupied habitats in response to warming temperatures are likely greatly impaired. Lastly, although modelled responses to environmental stressors suggest that Lake Chubsucker may tolerate warming temperatures (Rodriguez et al. 2021), it has experienced small or slightly lower than average variation in mean seasonal temperatures across its range in Ontario over the last 50 years, suggesting it may be poorly adapted to predicted future changes in temperature (Brinker et al. 2018).

Invasive and Other Problematic Species and Genes

Direct Impacts (Competition and Predation)

Round Goby (*Neogobius melanostomus*), a small, benthic fish species native to the Ponto-Caspian region of Europe, has substantially increased its range throughout the Great Lakes basin and other areas of southern Ontario following its discovery in the Detroit River in the early 1990's (Jude et al. 1992, Kornis et al. 2012). Round Goby populations now exist in several watercourses inhabited by Lake Chubsucker (Long Point Bay, PPNP, Rondeau Bay, Lake St. Clair), with future range expansion possible to other Lake Chubsucker populations, whether by natural dispersal or human-mediated movement. Direct evidence of a negative relationship between Lake Chubsucker and Round Goby does not exist; however, Round Goby has been implicated in the decline of other small-bodied native species, assumed to be the result of direct competition for food and habitat resources, and predation on eggs and larvae (Poos et al. 2009, Kornis et al. 2012, Abbett et al. 2013). Predation by Round Goby is anticipated to influence Lake Chubsucker, though the habitat features preferred by Lake Chubsucker may reduce exposure to high-density Round Goby populations, and thus, reduce the severity of competition and predation as threat mechanisms. Rudd, a medium-sized wetland fish native to Europe, has also expanded its range into habitats occupied by Lake Chubsucker, including some sections of Lyons Creek (DFO unpublished data), Long Point Bay (Kapuscinski et al. 2012b), and Rondeau

Bay (DFO unpublished data). Future range expansion of Rudd throughout the Canadian range of Lake Chubsucker is likely, especially to connected coastal wetlands in the Lake Erie and Lake St. Clair drainages. As with Round Goby, the effect of Rudd on Lake Chubsucker is unknown. However, given shared habitat preferences (warm, still, well-vegetated wetlands) and an omnivorous feeding strategy (Kapuscinski et al. 2012a), predation and competition are likely. The establishment and ongoing range expansion of Round Goby and Rudd is also likely to cause generalized food web changes in areas where Lake Chubsucker occurs.

Problematic Native Species

Native centrarchids have been increasing in range and abundance at the expense of leuciscid minnows across Ontario, likely resulting from human mediated dispersal and climate change (Jackson and Mandrak 2002, Alofs et al. 2014, Cazelles et al. 2019). Finigan et al. (2018) reported significant increases in the abundance of centrarchids, notably Bluegill (*Lepomis macrochirus*), and declines in abundance of leuciscids in 22 eastern Ontario lakes compared to historical samples in the 1960s, and postulated that warming temperatures and changes in land use were responsible. Similar shifts in community composition favouring centrarchids have also been documented in the St. Lawrence River (Potts et al. 2021). Additionally, preliminary sampling results in L Lake suggest that centrarchids are increasing in abundance while native leuciscids and Lake Chubsucker have declined (N. Mandrak, University of Toronto Scarborough, pers. comm.). A recent study evaluating habitat value of invasive cattails and European common reed compared to native bulrushes showed that centrarchids were more abundant in stands of the invasive plants, while native bulrushes supported more leuciscids (Croft-White et al. 2021). Climate change may further increase the spread of these invasive plants, which may have additive impacts favouring centrarchids. Shifts in community composition resulting from climate change or other human influences could lead to native species, notably predatory species (e.g., *Lepomis* spp., *Micropterus* spp., *Esox lucius*), becoming problematic for Lake Chubsucker. As this threat is likely the result of cumulative effects of other threats, is emerging, and there is insufficient data to evaluate this for most Lake Chubsucker populations at this time, it is not included in the threat assessment.

Illegal Stocking

Lake Chubsucker co-occurs with predatory sportfishes, such as Black Crappie (*Pomoxis nigromaculatus*), Largemouth Bass (*Micropterus salmoides*), and Northern Pike (*Esox lucius*), throughout much of its Canadian range. However, the historical composition of fish communities supporting Lake Chubsucker in Canada is poorly understood, making it difficult to determine the ecological significance of species co-occurrence and (or) illegal stocking. Although not documented in areas inhabited by Lake Chubsucker, illegal stocking has resulted in changes to the composition and productivity of native fish communities in many parts of North America (Johnson et al. 2009). If introduced, species such as Black Crappie, Largemouth Bass, Northern Pike, and other predatory fishes may lead to the decline of Lake Chubsucker through predation and competition, which will have the greatest impact when Lake Chubsucker is ecologically naïve to the predator.

Cumulative Threat Effects

Most areas inhabited by Lake Chubsucker are characterized by small amounts of suitable habitat (e.g., ones to tens of km^2) due to restricted geographic boundaries in dyked wetland cells and other watercourses (e.g., L Lake, OAC) or underlying ecological factors (e.g., upper Lyons Creek receiving overflow water from the Welland River). The majority of inhabited localities are influenced by multiple threats (dyked cells: Common Carp, wetland plant invasions, water-level drawdown; Lyons Creek: water-level fluctuations, wetland plant invasions, contaminant effects; OAC: altered hydrology and water-level manipulations, and winterkill associated with poor nutrient controls). Although the interaction between multiple threats has not been evaluated, given the limited habitat area available to Lake Chubsucker within which multiple threats exist, it is highly likely that cumulative threat impacts on Lake Chubsucker are occurring.

THREAT ASSESSMENT

Threats were assessed following guidelines in DFO (2014). Each threat was ranked in terms of the threat Likelihood of Occurrence (LO), threat Level of Impact (LI) and Causal Certainty (CC). The Likelihood of Occurrence was assigned as Known, Likely, Unlikely, Remote or Unknown, and refers to the probability of a specific threat occurring for a given population over 10 years or 3 generations, whichever is shorter. The Level of Impact was assigned as Extreme, High, Medium, Low, or Unknown and refers to the magnitude of the impact caused by a given threat, and the level to which it affects the survival or recovery of the population (Table 5). Here, threat Level of Impact was assessed by considering both the magnitude (when likelihood of occurrence was known or likely), and the impact of threat magnitude related to area-specific factors; this allowed differences in the severity of known threats due to area-specific factors (e.g., lower degree of agriculture-related siltation in dyked wetlands compared to agricultural drains) to be incorporated. Criteria for evaluating Level of Impact consistently across threats and locations is provided (Appendix 2). The level of certainty associated with each threat was assessed and classified as: 1 = very high, 2 = high, 3 = medium, 4 = low, 5 = very low. The Population-Level Threat Occurrence (PTO), Threat Frequency (PTF) and Threat Extent (PTE) were also evaluated and assigned a status based on the definitions outlined in Table 5 (rankings in Table 6). The Likelihood of Occurrence and Level of Impact for each population were subsequently combined in the population-level Threat Risk Matrix (Table 7; rankings in Table 8). The species-level Threat Assessment in Table 9 is a roll-up of the population-level threats identified in Table 8.

Table 5. Definition and terms used to describe likelihood of occurrence (LO), level of impact (LI), causal certainty (CC), population level threat occurrence (PTO), threat frequency (PTF) and threat extent (PTE) reproduced from DFO (2014).

Term	Definition
Likelihood of Occurrence (LO)	
Known or very likely to occur (K)	This threat has been recorded to occur 91–100%
Likely to occur (L)	There is a 51–90% chance that this threat is or will be occurring
Unlikely (UL)	There is 11–50% chance that this threat is or will be occurring
Remote (R)	There is 1–10% or less chance that this threat is or will be occurring
Unknown (U)	There are no data or prior knowledge of this threat occurring or known to occur in the future
Level of Impact (LI)	
Extreme (E)	Severe population decline (e.g., 71–100%) with the potential for extirpation
High (H)	Substantial loss of population (31–70%) or threat **would jeopardize** the survival or recovery of the population
Medium (M)	Moderate loss of population (11–30%) or threat is **likely to jeopardize** the survival or recovery of the population
Low (L)	Little change in population (1–10%) or threat is **unlikely to jeopardize** the survival or recovery of the population

Term	Definition
Unknown (U)	No prior knowledge, literature or data to guide the assessment of threat severity on population
Causal Certainty (CC)	
Very high (1)	Very strong evidence that threat is occurring and the magnitude of the impact to the population can be quantified
High (2)	Substantial evidence of a causal link between threat and population decline or jeopardy to survival or recovery
Medium (3)	There is some evidence linking the threat to population decline or jeopardy to survival or recovery
Low (4)	There is a theoretical link with limited evidence that threat is leading to a population decline or jeopardy to survival or recovery
Very low (5)	There is a plausible link with no evidence that the threat is leading to a population decline or jeopardy to survival or recovery
Population-Level Threat Occurrence (PTO)	
Historical (H)	A threat that is known to have occurred in the past and negatively impacted the population.
Current (C)	A threat that is ongoing, and is currently negatively impacting the population.
Anticipatory (A)	A threat that is anticipated to occur in the future, and will negatively impact the population.
Population-Level Threat Frequency (PTF)	
Single (S)	The threat occurs once.
Recurrent (R)	The threat occurs periodically, or repeatedly.
Continuous (C)	The threat occurs without interruption.
Population- Level Threat Extent (PTE)	
Extensive (E)	71–100% of the population is affected by the threat.
Broad (B)	31–70% of the population is affected by the threat.
Narrow (N)	11–30% of the population is affected by the threat.
Restricted (R)	1–10% of the population is affected by the threat.

Table 6. Threat Likelihood of Occurrence (LO), Level of Impact (LI), Causal Certainty (CC), Population-level Threat Occurrence (PTO), Population-level Threat Frequency (PTF), and Population-level Threat Extent of each Lake Chubsucker population in Canada. Definitions and terms used to describe the threat ratings are found in Table 5.

		Old Ausable Channel					
		LO	LI	CC	PTO	PTF	PTE
Natural Systems Modification	Agriculture[1]	R	M	5	H	R	N
	Shoreline Development and Hardening	UL	M	5	H/C	R	N
	Dredging[2]	R	M	5	H	S	R
	Drawdown of Dyked Wetlands and other Water Level Manipulations[3]	K	H	4	H	S	R
	Aquatic invasive species[4]	K	H	5	H/C/A	C	B
Pollution	Agriculture	R	M	5	H	R	N
	Industrial Activity	R	L	5	na	na	R
	Urbanization	L	M	4	H/C/A	R	B
Climate Change	Climate Change[5]	K	H	3	H/C/A	C	B
Invasive and Other Problematic Species and Genes	Competition/Predation	UL	L	4	A	C	N
	Illegal Stocking	R	M	5	A	S	B

		L Lake					
		LO	LI	CC	PTO	PTF	PTE
Natural Systems Modification	Agriculture[1]	R	M	5	H	R	N
	Shoreline Development and Hardening	UL	M	5	H/C	R	N
	Dredging[2]	R	M	5	H/C	S	R
	Drawdown of Dyked Wetlands and other Water Level Manipulations[3]	L	M	4	H	S	R
	Aquatic invasive species[4]	K	H	5	H/C/A	C	B
Pollution	Agriculture	R	M	5	H	R	N
	Industrial Activity	R	L	5	na	na	R
	Urbanization	L	M	4	H/C/A	R	B
Climate Change	Climate Change[5]	K	H	3	H/C/A	C	B
Invasive and Other Problematic Species and Genes	Competition/Predation	UL	L	4	A	C	N
	Illegal Stocking	R	M	5	A	S	B

		Lake St. Clair					
		LO	LI	CC	PTO	PTF	PTE
Natural Systems Modification	Agriculture[1]	K	H	3	H/C/A	C	B
	Shoreline Development and Hardening	K	H	4	H/C/A	R	B
	Dredging[2]	K	H	3	H/C/A	R	B
	Drawdown of Dyked Wetlands and other Water Level Manipulations[3]	R	L	5	na	na	R
	Aquatic invasive species[4]	K	H	4	H/C/A	C	B
Pollution	Agriculture	K	H	3	H/C/A	C	B
	Industrial Activity	K	M	4	H/C/A	C	N
	Urbanization	L	M	5	H/C/A	R	N
Climate Change	Climate Change[5]	K	M	3	H/C/A	C	B
Invasive and Other Problematic Species and Genes	Competition/Predation	K	L	4	H/C/A	C	N
	Illegal Stocking	UL	L	5	A	S	N

		Dyked Marshes within the Lake St. Clair drainage					
		LO	LI	CC	PTO	PTF	PTE
Natural Systems Modification	Agriculture[1]	K	M	5	H/C/A	R	B
	Shoreline Development and Hardening	R	M	5	H	S	R
	Dredging[2]	R	M	5	?	na	na
	Drawdown of Dyked Wetlands and other Water Level Manipulations[3]	L	H	3	H/C/A	R	B
	Aquatic invasive species[4]	K	H	4	H/C/A	C	B
Pollution	Agriculture	K	M	5	H/C/A	R	B
	Industrial Activity	UL	M	5	H/C/A	R	R
	Urbanization	UL	L	5	H/C/A	R	R
Climate Change	Climate Change[5]	K	H	3	H/C/A	C	B
Invasive and Other Problematic Species and Genes	Competition/Predation	UL	L	4	A	C	N
	Illegal Stocking	R	M	5	A	S	B

		St. Clair NWA					
		LO	LI	CC	PTO	PTF	PTE
Natural Systems Modification	Agriculture[1]	K	M	5	H/C/A	R	B
	Shoreline Development and Hardening	R	M	5	H	S	R
	Dredging[2]	L	H	4	H/A	S	B
	Drawdown of Dyked Wetlands and other Water Level Manipulations[3]	K	E	1	A	R	E
	Aquatic invasive species[4]	K	H	4	H/C/A	C	B
Pollution	Agriculture	K	M	5	H/C/A	R	B
	Industrial Activity	UL	L	5	na	R	R
	Urbanization	UL	L	5	H/C/A	R	R
Climate Change	Climate Change[5]	K	H	3	H/C/A	C	B
Invasive and Other Problematic Species and Genes	Competition/Predation	UL	L	4	A	C	N
	Illegal Stocking	R	M	5	A	S	B

		Point Pelee National Park					
		LO	LI	CC	PTO	PTF	PTE
Natural Systems Modification	Agriculture[1]	K	H	5	H/C/A	C	B
	Shoreline Development and Hardening	R	M	5	H	S	R
	Dredging[2]	UL	M	4	H/C/A	R	N
	Drawdown of Dyked Wetlands and other Water Level Manipulations[3]	R	M	5	na	na	na
	Aquatic invasive species[4]	K	H	4	H/C/A	C	B
Pollution	Agriculture	K	H	5	H/C/A	C	B
	Industrial Activity	K	M	4	H/C	C	N
	Urbanization	L	M	4	H/C/A	R	N
Climate Change	Climate Change[5]	K	H	3	H/C/A	C	B
Invasive and Other Problematic Species and Genes	Competition/Predation	K	L	4	H/C/A	C	N
	Illegal Stocking	R	M	5	A	S	B

		Rondeau Bay					
		LO	LI	CC	PTO	PTF	PTE
Natural Systems Modification	Agriculture[1]	K	H	5	H/C/A	C	N
	Shoreline Development and Hardening	L	M	4	H/C/A	R	N
	Dredging[2]	L	H	4	H/C/A	R	N
	Drawdown of Dyked Wetlands and other Water Level Manipulations[3]	R	L	5	na	na	na
	Aquatic invasive species[4]	K	H	4	H/C/A	C	B
Pollution	Agriculture	K	H	5	H/C/A	C	N
	Industrial Activity	UL	M	5	H/C	R	R
	Urbanization	L	M	4	H/C/A	R	R
Climate Change	Climate Change[5]	K	M	3	H/C/A	C	B
Invasive and Other Problematic Species and Genes	Competition/Predation	K	L	4	H/C/A	C	N
	Illegal Stocking	UL	L	5	A	S	N

		Long Point Bay					
		LO	LI	CC	PTO	PTF	PTE
Natural Systems Modification	Agriculture[1]	K	H	4	H/C/A	C	B
	Shoreline Development and Hardening	K	H	4	H/C/A	R	B
	Dredging[2]	K	H	4	H/C/A	R	B
	Drawdown of Dyked Wetlands and other Water Level Manipulations[3]	R	L	5	na	na	na
	Aquatic invasive species[4]	K	H	4	H/C/A	C	B
Pollution	Agriculture	K	H	4	H/C/A	C	B
	Industrial Activity	L	M	5	H/C/A	R	R
	Urbanization	K	H	4	H/C/A	R	N
Climate Change	Climate Change[5]	K	M	3	H/C/A	C	B
Invasive and Other Problematic Species and Genes	Competition/Predation	K	L	4	H/C/A	C	N
	Illegal Stocking	UL	L	5	A	S	N

		Long Point NWA					
		LO	LI	CC	PTO	PTF	PTE
Natural Systems Modification	Agriculture[1]	UL	M	5	H/C/A	R	N
	Shoreline Development and Hardening	R	M	5	H	S	R
	Dredging[2]	R	M	5	na	na	na
	Drawdown of Dyked Wetlands and other Water Level Manipulations[3]	R	M	5	na	na	na
	Aquatic invasive species[4]	K	H	4	H/C/A	C	B
Pollution	Agriculture	UL	M	5	H/C/A	R	N
	Industrial Activity	L	M	5	H/C/A	R	N
	Urbanization	UL	M	5	H/C/A	R	R
Climate Change	Climate Change[5]	K	H	3	H/C/A	C	B
Invasive and Other Problematic Species and Genes	Competition/Predation	UL	L	4	A	C	N
	Illegal Stocking	R	M	5	A	S	B

		Big Creek NWA					
		LO	LI	CC	PTO	PTF	PTE
Natural Systems Modification	Agriculture[1]	K	M	5	H/C/A	R	B
	Shoreline Development and Hardening	R	M	5	H	S	R
	Dredging[2]	K	H	5	H/C/A	R	B
	Drawdown of Dyked Wetlands and other Water Level Manipulations[3]	K	H	3	H/A	R	E
	Aquatic invasive species[4]	K	H	4	H/C/A	C	B
Pollution	Agriculture	K	M	5	H/C/A	R	B
	Industrial Activity	UL	M	5	H/C	R	R
	Urbanization	UL	L	5	H/C/A	R	R
Climate Change	Climate Change[5]	K	H	3	H/C/A	C	B
Invasive and Other Problematic Species and Genes	Competition/Predation	K	L	4	H/C/A	C	N
	Illegal Stocking	R	M	5	A	S	B

		Lyons Creek					
		LO	LI	CC	PTO	PTF	PTE
Natural Systems Modification	Agriculture[1]	K	H	4	H/C/A	C	B
	Shoreline Development and Hardening	K	M	4	H/C	S	B
	Dredging[2]	L	M	4	H	R	B
	Drawdown of Dyked Wetlands and other Water Level Manipulations[3]	K	E	3	H/C/A	C	E
	Aquatic invasive species[4]	L	M	4	A	C	B
Pollution	Agriculture	K	H	4	H/C/A	C	B
	Industrial Activity	K	M	4	H/C/A	C	N
	Urbanization	K	M	4	H/C/A	R	N
Climate Change	Climate Change[5]	K	M	3	H/C/A	C	B
Invasive and Other Problematic Species and Genes	Competition/Predation	K	L	4	C/A	C	N
	Illegal Stocking	R	L	5	A	S	N

References

[1]Agriculture: Montgomery et al. (2017)
[2]Dredging: DFO (2020), Barnucz et al. (2015), Rook et al. (2017), Montgomery et al. (2017)
[3]Drawdown of dyked wetlands and other water level manipulations: DFO (2021)
[4]Aquatic Invasive Species: Gertzen et al. (2016), Rook et al. (2016), Reid et al. (2023).
[5]Climate Change : Lemmen and Warren (2004), Doka et al. (2006), McDermid et al. (2015), Brinker et al. (2018)

Table 7. The Threat Level Matrix combines the Likelihood of Occurrence and Level of Impact rankings to establish the Threat Level for each Lake Chubsucker population in Canada. The resulting Threat Level has been categorized as low, medium, high, or unknown. Reproduced from DFO (2014).

		Level of Impact				
		Low	Medium	High	Extreme	Unknown
Likelihood of Occurrence	Known or very likely	Low	Medium	High	High	Unknown
	Likely	Low	Medium	High	High	Unknown
	Unlikely	Low	Medium	Medium	Medium	Unknown
	Remote	Low	Low	Low	Low	Unknown
	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown

Table 8. Threat Level assessment of all Lake Chubsucker populations in Canada, resulting from an analysis of both the Threat Likelihood and Threat Impact.

		OAC	L Lake	Lake St. Clair	Dyked Marshes within Lake St. Clair	St. Clair NWA	PPNP	Rondeau Bay	Long Point Bay	Long Point NWA	Big Creek NWA	Lyons Creek
Natural Systems Modification	Agriculture	Low	Low	High	Med	Med	High	High	High	Med	Med	High
	Shoreline Development and Hardening	Med	Med	High	Low	Low	Low	Med	High	Low	Low	Med
	Dredging	Low	Low	High	Low	High	Med	High	High	Low	High	Med
	Drawdown of Dyked Wetlands and other Water Level Manipulations	High	Med	Low	High	High	Low	Low	Low	Low	High	High
	Aquatic Invasive Species	High	High	High	High	High	High	High	High	High	High	Med
Pollution	Agriculture	Low	Low	High	Med	Med	High	High	High	Med	Med	High
	Industrial Activity	Low	Low	Med	Med	Low	Med	Med	Med	Med	Med	Med
	Urbanization	Med	Med	Med	Low	Low	Med	Med	High	Med	Low	Med
Climate Change	Climate Change	High	High	Med	High	High	High	Med	Med	High	High	Med
Invasive and Other Problematic Species and Genes	Competition/Predation	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
	Illegal Stocking	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low

Table 9. Species-level Threat Assessment for Lake Chubsucker in Canada, resulting from a roll-up of the population-level Threat Assessment. The species-level Threat Assessment retains the highest level of risk for any population, all categories of Threat Occurrence and Threat Frequency are retained, and the species-level Threat Extent is the mode of the population-level Threat Extent.

		Species-level Threat Risk	Species-level Threat Occurrence	Species-level Threat Frequency	Species-level Threat Extent
Natural Systems Modifications	Agriculture	High	H/C/A	R/C	B
	Shoreline development and hardening	High	H/C/A	S/R	R
	Dredging	High	H/C/A	S/R	B
	Drawdown of dyked wetlands and other water level manipulations	High	H/C/A	S/R/C	R/E
	Aquatic Invasive Species	High	H/C/A	C	B
Pollution	Agriculture	High	H/C/A	R/C	B
	Industrial activity	Medium	H/C/A	R/C	R
	Urbanization	High	H/C/A	R	R
Climate Change	Climate Change	High	H/C/A	C	B
Invasive and other Problematic Species and Genes	Competition/Predation	Low	H/C/A	C	N
	Illegal Stocking	Low	A	S	B

Element 9: *Identify the activities most likely to threaten (i.e., damage or destroy) the habitat properties identified in elements 4–5 and provide information on the extent and consequences of these activities*

Shallow, productive, low flow areas with organic and finer particle sediment types that support growth of aquatic macrophytes are the most important habitat properties for Lake Chubsucker, and several activities that take place in its habitat are likely to damage or destroy those properties.

- Dredging for drain/channel maintenance, or pond creation/maintenance. This is likely to remove native aquatic vegetation needed for supporting all life stages of Lake Chubsucker, will increase turbidity, and may alter sediment types important for spawning.
- Control activities for invasive plants (e.g., European common reed, cattails) through chemical applications (aerial spraying or localized spot treatments), mechanical removal, prescribed burns, or a combination of approaches. The long-term impacts of control are likely beneficial to Lake Chubsucker, but in the short term, native vegetation cover may be reduced, dissolved oxygen decreased, and shifts may occur in invertebrate communities that Lake Chubsucker feeds on.
- Water-level drawdowns in dyked wetlands to promote hemi-marsh conditions. Dyked wetlands are often already habitat-limited and further reductions of total habitat space and fragmentation of habitat will lead to short-term impacts such as increased water temperatures, decreased dissolved oxygen, loss of access to refuge areas, crowding, and risk of stranding (DFO 2021). Long-term outcomes may be beneficial to Lake Chubsucker.

- Accidental or intentional introduction of AIS. Several wetland plants from the aquarium/ornamental trade (e.g., Water Soldier (*Stratiotes aloides*), Water Lettuce (*Pistia stratiotes*), Hydrilla (*Hydrilla verticillata*)) may result in monocultures or dense stands or mats that do not offer the same habitat quality as native species and may increase hypoxic conditions during decay; and, herbivorous fishes (e.g., Grass Carp) could lead to reduced aquatic vegetation cover (Pipalova 2002).
- Shoreline development and hardening from canal creation, rural residential developments and marina construction. This can lead to altered substrate composition, loss of aquatic vegetation, altered flow and sediment transport regimes, and, in flowing systems, may result in the loss of low flow, heavily vegetated habitats used by Lake Chubsucker.
- Land use practices that result in reduced pervious surfaces and reduce the riparian buffer surrounding waterbodies (e.g., agriculture, urban development). This can lead to increased sedimentation of watercourses (reducing macrophyte growth) and increased water temperatures.

Limiting Factors

Element 10: *Assess any natural factors that will limit the survival and recovery of the Lake Chubsucker*

The primary limiting factor to Lake Chubsucker survival and recovery in Canada is the availability of suitable habitat (i.e., warm, clear, heavily-vegetated, low-flowing waters) free of anthropogenic disturbances (COSEWIC 2021). Lake Chubsucker also has a limited dispersal capability and a patchy, disjunct distribution, which prevents it from relocating to other suitable patches in response to deteriorating conditions or re-colonizing areas from which it has been extirpated. The species is at the northern end of its range in Ontario and may be limited by the prevalence of wetlands within its thermal optimum (Staton et al. 2010).

Element 11: *Discuss the potential ecological impacts of the threats identified in element 8 to the target species and other co-occurring species. List the possible benefits and disadvantages to the target species and other co-occurring species that may occur if the threats are abated. Identify existing monitoring efforts for the target species and other co-occurring species associated with each of the threats, and identify any knowledge gaps*

Agricultural land-use practices are among the biggest threats to Lake Chubsucker populations in Canada, currently and historically, having led to degradation of habitat through sedimentation, nutrient loading, increased water temperatures, and removal of vegetation, as well as loss of habitat through burying of drains, and dyking and draining of wetlands. Historical diversions of watercourses (OAC, L Lake, Lyons Creek) likely resulted in the loss, restriction, or fragmentation of former Lake Chubsucker locations. Water-level drawdowns in dyked wetlands to promote hemi-marsh conditions pose a significant short-term threat to all fishes (dependent on the degree and duration of the drawdown) through loss of habitat space, leading to density-dependent and independent effects. AIS threaten Lake Chubsucker and co-occurring species directly through predation of eggs and juveniles (e.g., Round Goby) and/or competition with adults for shared resources (e.g., Round Goby, Rudd), or indirectly by consuming or uprooting aquatic vegetation (e.g., Common Carp, Grass Carp, Rudd), or displacing native macrophytes and reducing habitat complexity and diversity (e.g., European common reed, Eurasian Milfoil).

Abatement of threats through improved agricultural practices (best management practices) and use of appropriate mitigations (e.g., sediment screens, adequate riparian buffers, strategic dredging/maintenance activities) will benefit all species occurring in Lake Chubsucker habitat. Although removal of AIS (notably European common reed) is likely to provide a benefit to Lake

Chubsucker and other wetland fishes in the long term, impacts from control efforts can directly harm fishes (Reid et al. 2023), and lead to poor water quality conditions in the short term. Lake Chubsucker co-occurs with many other SARA-listed fishes across its Canadian range, including Blackstripe Topminnow (*Fundulus notatus* SARA – Special Concern), Grass Pickerel (*Esox americanus vermiculatus,* SARA – Special Concern), Pugnose Minnow (*Opsopoeodus emiliae* SARA – Threatened), Pugnose Shiner (*Notropis anogenus* SARA – Threatened), Spotted Gar (*Lepisosteus oculatus* SARA – Endangered), and Warmouth (*Lepomis gulosus* – SARA Special Concern* pending). Most of these species have strong associations with aquatic vegetation and face similar threats to Lake Chubsucker across their ranges. Any benefit to Lake Chubsucker in reducing threats would likely benefit these SARA-listed fishes as well.

There has been limited and somewhat sporadic sampling for Lake Chubsucker in Ontario, whether targeted or incidental. There has been an increase in targeted sampling since the last RPA, but repeated, standardized monitoring is needed to quantitatively analyze population status and detect the impacts of threats or management actions. There has been on-going sampling of Long Point Bay as part of both early detection surveillance efforts for Asian carps, and as part of DFO-NDMNRF long-term monitoring projects related to effects of European common reed control on SARA-listed fishes (Rook et al. 2016, Reid et al. 2023, DFO and Ministry of Northern Development, Mines, Natural Resources and Forestry unpublished data); these projects focus on monitoring threats (e.g., AIS) or actions to abate threats (e.g., control of AIS and ensuing rehabilitation of wetlands). Early detection surveillance for Asian carps also occurs in Rondeau Bay and other locations where Lake Chubsucker could be detected if present (i.e., lower Ausable River, lower Thames River and Jeannette's Creek, Welland River near the mouth of Lyons Creek). Targeted sampling for Lake Chubsucker in the St. Clair NWA – St. Clair unit occurred in 2018 and 2019, prior to a proposed water level drawdown and may serve as a baseline for Lake Chubsucker populations and the fish community overall should a drawdown occur (Barnucz et al. 2021a, DFO 2021).

SCENARIOS FOR MITIGATION OF THREATS AND ALTERNATIVES TO ACTIVITIES

Element 16*: Develop an inventory of feasible mitigation measures and reasonable alternatives to the activities that are threats to the species and its habitat (as identified in element 8 and 10)*

Threats to species survival and recovery can be reduced by implementing mitigation measures to reduce or eliminate potential harmful effects that could result from works, undertakings, or activities (w/u/a) associated with projects in Lake Chubsucker habitat.

Within Lake Chubsucker habitat, a variety of w/u/a have occurred in the last eight years with project types including: dredging/excavation, aquatic vegetation removal, culverts, and shoreline protection. A review has been completed summarizing the types of w/u/a that have been undertaken in habitat known to be occupied by Lake Chubsucker (Table 10). The DFO Program Activity Tracking for Habitat (PATH) database was reviewed to estimate the number of w/u/a that have occurred during an eight-year period from November 2013 through June 2021 within a 1 km radius of Lake Chubsucker occurrence records in Ontario. Seventy-seven w/u/a were identified, but these likely do not represent a complete list, as some w/u/a may occur in proximity to (but outside of the searched 1 km radius) Lake Chubsucker occurrence records that may also have impacts; and, some w/u/a may not have been reported to DFO as they may have met self-assessment requirements. The review did not include areas with historical records where the species is thought to be extirpated (e.g., Big Creek upper tributaries, Jeannette's Creek, Tea Creek).

There have been eight w/u/a authorized under the *Fisheries Act* in Lake Chubsucker habitat over the timeframe evaluated. Five of these w/u/a were in Long Point and involved European common reed control, either through dredging or spraying of herbicides. Mechanical removal of European common reed and invasive cattails using machinery was also authorized in PPNP; turbidity curtains were used to reduce spread of re-suspended sediments while removing piled material. A wharf expansion project was undertaken in Little Bear Creek for habitat restoration purposes with a predicted impact of fish mortalities resulting from the project. Lastly, an authorization is expected for a water-level drawdown in the East cell of the St. Clair NWA. Most projects were deemed low risk to fishes and fish habitat and were addressed through letters of advice with standard mitigations. Without appropriate mitigations, projects or activities occurring adjacent or close to these areas could have impacted Lake Chubsucker (e.g., through increased turbidity, sedimentation, direct mortality or other physiological impacts).

The most frequent w/u/a type was dredging/excavation. Based on the assumption that historical and anticipated development pressures are likely to be similar, it is expected that similar types of w/u/a will likely occur in or near Lake Chubsucker habitat in the future. There were 24 w/u/a that occurred in Lake Chubsucker Critical Habitat in the OAC (n = 3), L Lake (n = 1), Long Point Bay (n = 19), and Lyons Creek (n = 1).

Numerous threats affecting Lake Chubsucker populations in Canada are related to habitat loss or degradation. Habitat-related threats to Lake Chubsucker have been linked to the Pathways of Effects developed by the Fish and Fish Habitat Protection Program (FFHPP; Table 10). DFO FFHPP has developed guidance on mitigation measures for 18 Pathways of Effects for the protection of aquatic species at risk in the Ontario and Prairie Region (formerly part of Central and Arctic Region) (Coker et al. 2010). This guidance should be referred to when considering mitigation and alternative strategies for habitat-related threats.

In addition to the Pathways of Effects guidance, specific advice has been developed by DFO for mitigating habitat threats specifically for Lake Chubsucker, or in specific locations where Lake Chubsucker occurs; this advice is summarized below. Additional mitigation and alternative measures for non-habitat related threats (e.g., invasive and other problematic species and genes) are also provided.

Table 10. Summary of works, undertakings and activities that have occurred during the period of November 2013 to June 2021 in areas known to be occupied by Lake Chubsucker. Threats known to be associated with these types of works, undertakings, and activities are indicated with a checkmark. The number of works, undertakings, and activities associated with each Lake Chubsucker population, as determined from the project assessment analysis, has been provided. Applicable Pathways of Effects are indicated for each threat associated with a work, undertaking, or activity: 1 – Vegetation Clearing; 2 – Grading; 3 – Excavation; 4 – Use of explosives; 5 – Use of industrial equipment; 6 – Cleaning or maintenance of bridges or other structures; 7 – Riparian planting; 8 – Streamside livestock grazing; 9 – Marine seismic surveys; 10 – Placement of material or structures in water; 11 – Dredging; 12 – Water extraction; 13 – Organic debris management; 14 – Wastewater management; 15 – Addition or removal of aquatic vegetation; 16 – Change in timing, duration and frequency of flow; 17 – Fish-passage issues; 18 – Structure removal.

Work/Undertaking/Activity	**Threats** (associated with work/undertaking/activity)				**Watercourse/Waterbody** (number of works/undertakings/activities between November 2013 - June 2021)										
-	Natural Systems Modifications	Pollution	Invasive and Other Problematic Species and Genes	Climate Change and Severe Weather	Old Ausable Channel	L Lake	Lake St. Clair	Dyked Marshes within Lake St. Clair drainage	St. Clair NWA	Point Pelee National Park	Rondeau Bay	Long Point Bay	Long Point NWA	Big Creek NWA Dyked marshes	Lyons Creek
Applicable pathways of effects for threat mitigation and project alternatives	1, 2, 3, 4, 5, 7, 9, 10, 11, 12, 13, 15, 18	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12 ,13, 14, 15, 16,18	-	-	-	-	-	-	-	-	-	-	-	-	-
Water crossings (bridges, culverts, open cut crossings)	✓	✓	-	-	-	-	4	-	3	-	-	4	-	-	2
Shoreline, streambank work (stabilization, infilling, retaining walls, riparian vegetation management)	✓	✓	-	-	1	-	3	-	1	-	-	7	-	-	-
Instream works (channel maintenance, restoration, modifications, realignments, dredging, aquatic vegetation removal)	✓	✓	-	-	-	1	15	-	8	2	3	9	-	-	1

Work/Undertaking/Activity	**Threats** (associated with work/undertaking/activity)				**Watercourse/Waterbody** (number of works/undertakings/activities between November 2013 - June 2021)										
-	Natural Systems Modifications	Pollution	Invasive and Other Problematic Species and Genes	Climate Change and Severe Weather	Old Ausable Channel	L Lake	Lake St. Clair	Dyked Marshes within Lake St. Clair drainage	St. Clair NWA	Point Pelee National Park	Rondeau Bay	Long Point Bay	Long Point NWA	Big Creek NWA Dyked marshes	Lyons Creek
Applicable pathways of effects for threat mitigation and project alternatives	1, 2, 3, 4, 5, 7, 9, 10, 11, 12, 13, 15, 18	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12 ,13, 14, 15, 16,18	-	-	-	-	-	-	-	-	-	-	-	-	-
Water management (stormwater management, water withdrawal)	✓	✓	-	-	-	-	1	-	1	-	-	-	-	-	-
Structures in water (boat launches, docks, effluent outfalls, water intakes, dams)	✓	✓	-	-	2	-	1	-	-	1	-	6	-	-	-
Invasive species introductions (accidental and intentional)	✓	-	✓	-	-	-	-	-	-	-	-	-	-	-	-

DRAWDOWN OF DYKED WETLANDS

Following a proposed water-level drawdown in the St. Clair NWA (East cell of the St. Clair Unit), DFO (2021) evaluated the impacts on Lake Chubsucker across various drawdown increments and provided several potential mitigation strategies for this system. This advice is likely applicable to other dyked wetlands; however, the impacts to Lake Chubsucker from drawdown would depend on the habitat availability (and other biotic and abiotic factors) under baseline conditions in those systems.

Mitigation

- Create deep water habitat in advance of water-level drawdowns (i.e., dredge deep sections to reduce the net loss of deep water habitat during drawdown conditions).
- Dredge channels strategically to maintain connectivity between habitat patches (based on bathymetry of system). This will maximize access to deep water habitat and minimize the risk of stranding.
- Removal of predators to reduce density-dependent effects.
- Reduce the drawdown increment to maximize both the total wetted area and area of deep water habitat to serve as refuge.

DREDGING (POND CREATION/ RESTORATION)

As part of management actions for European common reed, open-water ponds were created and/or restored in Long Point Crown Marsh. Their ability to support fish species at risk, including Lake Chubsucker, and a healthy wetland fish community overall was evaluated (DFO 2017a). Several mitigations were recommended that can be applied to future pond restoration projects within Long Point Bay.

Mitigation

- Maintain a permanent channel (i.e., sufficiently deep for low water events) to ensure fishes can enter and exit the ponds as needed based on seasonal influences. This will help promote the survival of fishes and prevent the ponds from functioning as ecological traps. In the case of Lake Chubsucker where ponds may not individually meet the Minimum Area for Population Viability (MAPV), channels connecting ponds to each other and/or to the Inner Bay will ensure the total habitat space accessible to the species meets the MAPV target.
- Ponds should be constructed with a gradient with the greatest depth at the mouth of the connecting channel so fishes can exit the ponds during low water periods.
- Maintenance works in created ponds should be limited so that submerged aquatic vegetation has the ability to recolonize quickly and provide functional habitat.

DREDGING (DRAIN MAINTENANCE)

Different scenarios for conducting agricultural drain maintenance in Little Bear Creek were evaluated in terms of their predicted effect on at-risk fishes in the system (including Lake Chubsucker) and their habitat (DFO 2017b). An aquatic vegetation survey, bathymetry survey, and fluvial geomorphology survey were completed to model changes in habitat availability under the different scenarios, and mitigation measures were proposed.

Mitigation

- Dredging activities should be conducted in the centre bottom of the channel only, leaving edges intact. This preserves slow-moving, vegetated habitat preferred by Lake Chubsucker and can help maintain longitudinal connectivity between suitable habitat patches.
- If cross-sectional dredging is required, decreasing the depth of bottom dredging to 1.425 m is recommended as this will promote macrophyte regeneration within 1–2 years.

INVASIVE AND OTHER PROBLEMATIC SPECIES AND GENES

Several aquatic invasive taxa threaten Lake Chubsucker directly (through competition/ predation) and indirectly (through habitat modifications).

Mitigation

- Develop public awareness campaigns and encourage the use of existing invasive species reporting systems (e.g., Ontario Invading Species Awareness Program hotline, EDDMapS).
- Physically remove non-native species from areas known to be inhabited by Lake Chubsucker. It should be noted that special consideration is required if an aquatic vegetation removal/control program is implemented as this may also result in the loss of preferred Lake Chubsucker habitat.
- Conduct early detection surveillance or monitoring for invasive species that may negatively affect Lake Chubsucker populations directly, or negatively affect Lake Chubsucker preferred habitat.
- Develop a response plan to address potential risks, impacts, and proposed actions if monitoring detects the arrival or establishment of an exotic species.

Alternatives

- Unauthorized introductions
  - None
- Authorized introductions
  - Do not stock non-native species in areas inhabited by Lake Chubsucker.
  - Do not enhance habitat for non-native species in areas inhabited by Lake Chubsucker.
  - Follow the National Code on Introductions and Transfers of Aquatic Organisms for all aquatic organism introductions (DFO 2017c).

SOURCES OF UNCERTAINTY

There have been concerted efforts to increase knowledge of Lake Chubsucker in Canada since the initial RPA (DFO 2011); however, there remain areas of uncertainty related to population size and trends, habitat preferences (especially for early life stages), and threat mechanisms and impacts. Sources of uncertainty have been organized into research themes based on Drake et al. (2021) to create consistency across RPAs and to aid in planning and prioritization of research objectives.

POPULATION ECOLOGY

Abundance

Abundance estimates are lacking for most Lake Chubsucker populations in Canada. Population size estimates (based on allometry and community density relationships) were made for the St. Clair NWA – East cell (DFO 2021), but several uncertainties remain surrounding the analysis and resulting estimates. A population density estimate exists for L Lake and mean relative abundance estimates exist for Long Point Bay, but estimates of population size for all other populations either have not been attempted, or too few individuals were captured to make reliable inferences (Montgomery et al. 2017, Barnucz and Drake 2021). Some locations for which recent information was lacking during the first RPA, such as the St. Clair NWA, Long Point NWA, and PPNP, have all been sampled recently and individuals representing several size classes were found, indicating that reproduction is likely occurring. The capture of a single adult in Rondeau Bay in 2020 suggests the species persists there, but the status of the population is unclear. Due to a lack of repeated, standardized sampling, the trajectory of extant populations remains a knowledge gap for most populations. Addressing uncertainties around abundance for this rare species may require substantial sampling effort using conventional methods, or novel research techniques (Drake et al. 2021, Castañeda et al. 2021).

Distribution

Progress has been made on understanding the current distribution of Lake Chubsucker in Canada, but some uncertainties remain. Sampling in the last 10 years has confirmed that Lake Chubsucker remains extant at most of the historically known locations, but these limited sampling events have documented only a few individuals. To better understand the current distribution of the species, targeted, exploratory sampling was recommended in the first RPA in oxbows around the Ausable River, and tributaries of the Niagara River. This was undertaken in 2012 but these efforts did not reveal any new localities. Incidentally, Lake Chubsucker was detected at several new localities around Lake St. Clair, including: Prince Albert and Collop drains, and the Maxwell cell (Bear Creek Unit) and the East cell (St. Clair Unit) in the St. Clair NWA. This suggests the extent of the species distribution in Ontario is not fully known. Additionally, two adult Lake Chubsucker were captured in the lower Ausable River in 2018[7]. It is likely these individuals were transported (during high water events or with human assistance) from the OAC, but further sampling would be beneficial to document additional individuals (if any) and determine whether habitat is suitable for relocated individuals to survive. Despite recent sampling at historically occupied locations, no individuals were detected at Jeannette's Creek or Tea Creek, where the species is thought to be extirpated, though sampling in the upper reaches of Jeannette's Creek where historical records exist has not occurred recently.

Altogether, recent sampling efforts have contributed to a more developed understanding of population status and distribution, but robust estimates of abundance, long-term population trends, and changes in distribution through time are still lacking for most populations. These information gaps could be resolved with standardized monitoring.

[7] A third individual was detected in September 2021 (DFO unpublished data).

HABITAT

Species-habitat associations by life stage

There is still a need to identify seasonal habitat requirements for each life stage. Although it is currently assumed that individuals from all Lake Chubsucker life stages occupy the same functional habitat, this assumption should be verified through targeted sampling of early life stages (ideally across several habitat types occupied by this species), which would provide a better understanding of preferred habitat of juvenile Lake Chubsucker. Additionally, little is known of Lake Chubsucker over-wintering habitat for all life stages, particularly in areas where the species is limited in the selection of over-winter refuges (i.e., dyked wetlands, closed systems). In addition, comprehensive surveys of Lake Chubsucker habitat availability have not been conducted.

THREATS

Like most imperilled freshwater fishes in the Great Lakes – St. Lawrence River basin, research progress has been slower for threats and recovery topics for Lake Chubsucker, as more basic information on population ecology is needed before these advanced topics can be addressed (Drake et al. 2021).

Mechanism of Impact

Numerous threats have been identified for Lake Chubsucker populations in Canada, although the mechanisms of impact of these threats are currently unknown. There is a need to understand physiological tolerances (e.g., to temperature, dissolved oxygen, pollutants, sedimentation) of Lake Chubsucker at different life stages. This may provide insights on the causes of extirpation from Jeannette's Creek and Tea Creek, and identify which populations might be most vulnerable to extirpation. Additionally, this would aid in understanding the mechanisms of impact of climate change. Further information is also needed on how nutrient inputs and biological decay affect dissolved oxygen, particularly over winter. Lake Chubsucker is considered to be a pollution intolerant species, although there is a lack of evidence on the direct or indirect effects of toxic substances on Lake Chubsucker populations. This is likely to be of growing importance as European common reed expands across Ontario, and herbicide use for control increases. Increased knowledge on physiological effects and tolerances would provide an opportunity to mitigate the effects of water quality and pollution-related threats.

Probability, Extent and Magnitude of Impact

There are many uncertainties related to the probability, extent, and magnitude of impacts from various threats, and in particular, the response of Lake Chubsucker to habitat modifications. Modelling to inform the extent and magnitude of impact of water-level drawdown on Lake Chubsucker in the St. Clair NWA has been conducted, but several uncertainties remain, particularly how the duration of drawdown conditions will affect total fish abundance through density-dependent processes (DFO 2021), as well as the long-term suitability of habitat following drawdown. Additionally, understanding physiological tolerances to temperature and dissolved oxygen as described above would help better understand the ability of Lake Chubsucker to withstand density-independent effects during drawdown. In the case of AIS, the mechanisms of impact are often known (i.e., habitat- or food web-related changes, competition, predation), but the extent to which AIS will affect the survival and recovery of Lake Chubsucker, fish community production, and habitat quantity and quality is unknown.

RECOVERY

Threat Mitigation

There are several threats to Lake Chubsucker for which mitigations have been proposed, but the effectiveness of these mitigations over the short- and long-term remain poorly understood. Removal of European common reed in numerous locations, pond creation/restoration in Long Point Crown Marsh, and creation of deepwater habitat in advance of water-level drawdowns in dyked wetlands are examples of mitigations that have been implemented or proposed. These are expected to provide net benefits to Lake Chubsucker in the long-term, assuming that the intended effects are realized (i.e., that native macrophytes regenerate and European common reed shows a decline relative to pre-control densities; that restored ponds function similarly to natural ponds and do not become population sinks). Short-term impacts to Lake Chubsucker from these mitigations are also poorly understood (see threat mechanisms). There is uncertainty in the response of Lake Chubsucker to standard mitigation and offset measures typically prescribed for other projects that occur in Lake Chubsucker habitat. Additionally, mitigations to drain maintenance activities in Little Bear Creek were modelled; however, too few Lake Chubsucker were captured for models to be derived for them specifically (Montgomery et al. 2017). It is likely that much of this information is still applicable to Lake Chubsucker in that system given shared habitat preferences with the SARA-listed fishes that were available, but the effectiveness of the advice for Lake Chubsucker and the applicability of the advice for other systems warrants further investigation.

Reintroductions

Reintroductions of Lake Chubsucker into historically occupied locations were proposed as a potential recovery strategy, pending feasibility assessments (Staton et al. 2010). In a review of translocation progress for SARA-listed fishes in Canada, Lamothe et al. (2019) highlighted research needs and progress for Lake Chubsucker in advance of reintroduction attempts. The authors identified key gaps around habitat (habitat associations of all life stages, suitability of current habitat in receiving location), compatibility of source and receiving populations (i.e., genetic structure, local conditions) and resilience of source population (i.e., population size, structure, and overall condition). Early work is being undertaken in Canada on husbandry and captive-breeding of Lake Chubsucker (Lamothe et al. 2019), but experimental rearing has occurred successfully in the southern USA as a forage fish for Largemouth Bass (Shireman et al. 1978, Eberts et al. 1998). Although progress has been made on these and other information needs, no reintroductions of Lake Chubsucker have been undertaken in Canada.

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APPENDIX I

*Table A1**.** Summary of all known occurrence records of Lake Chubsucker in Canada (1949–2020). Gear: BEF = boat electrofisher; BPEF = backpack electrofisher; DP = dip net; FN = fyke net; HN = hoop net; MFN = mini fyke net; MN = minnow trap; RN = roll nets; SN = seine net; UNK = unknown; VO = visual observation. The table has been modified from COSEWIC (2008), and updated with occurrences recorded since last status report (reproduced from COSEWIC (2021) with updates from 2019 and 2020).*

Area	Locality	Year of survey	Lake Chubsucker targeted	Gear	Number captured	Source	Effort or CPUE data available
Ausable River	Old Ausable Channel	2018	No	BEF	2	Colm et al. 2019b	Yes
Old Ausable Channel	Old Ausable Channel	1982	No	UNK	≥ 2 (n = 11; COSEWIC 2008)	Canadian Distribution Database (RMC42234, RMC42227)	No
Old Ausable Channel	Old Ausable Channel	1997	No	UNK	≥ 2 (n = 7; COSEWIC 2008)	Canadian Distribution Database (ROM71020, ROM71029)	No
Old Ausable Channel	Old Ausable Channel	2001	No	UNK	≥ 1	ROM72661	No
Old Ausable Channel	Old Ausable Channel	2002	No	SN; BEF; HN	13	DFO unpublished data	Yes
Old Ausable Channel	Old Ausable Channel	2004	No	BPEF; SN	53	DFO unpublished data	Yes
Old Ausable Channel	Old Ausable Channel	2005	No	SN	39	DFO unpublished data	Yes
Old Ausable Channel	Old Ausable Channel	2009	No	BEF; SN	28	DFO unpublished data, Ausable Bayfield Conservation Authority	Yes
Old Ausable Channel	Old Ausable Channel	2010	Yes	SN	1	DFO unpublished data	Yes
Old Ausable Channel	Old Ausable Channel	2010	No	NA*fish collected from overwinter fish kill	68	Ausable Bayfield Conservation Authority	No
Old Ausable Channel	Old Ausable Channel	2012	Yes	SN	51	DFO unpublished data	Yes
Old Ausable Channel	Old Ausable Channel	2015	No	UNK	23	DFO unpublished data	Yes
L Lake	L Lake	2007	No	BEF; SN	≥ 18	DFO unpublished data, Ausable 2007 IRF Fish Survey	Yes
L Lake	L Lake	2010	Yes	SN	215	DFO unpublished data, Ministry of Northern Development, Mines, Natural Resources and Forestry (Reid) unpublished data	Yes
L Lake	L Lake	2018	Yes	SN	39	DFO unpublished data	Yes
Lake St. Clair	Lake St. Clair	1949	No	UNK	2	COSEWIC (2008)	No
Lake St. Clair	Lake St. Clair	1952	No	UNK	≥ 3	Canadian Distribution Database (RMC15686, RMC15685, RMC15684)	No
Lake St. Clair	Lake St. Clair	1979	No	UNK	1	Canadian Distribution Database (RMC35782)	No

Area	Locality	Year of survey	Lake Chubsucker targeted	Gear	Number captured	Source	Effort or CPUE data available
Lake St. Clair	Various	1999	No	UNK	≥ 13 (n = 117; COSEWIC 2008)	ROM (Various records)	No
Lake St. Clair	Various	2001	No	UNK	≥ 4 (n = 10; COSEWIC 2008)	Canadian Distribution Database	No
Lake St. Clair	Various	2002	No	UNK	≥ 1	ROM74023	No
Lake St. Clair	Little Bear Creak	2013	No	SN	2	DFO unpublished data	Yes
Lake St. Clair	Prince Albert Drain	2017	No	UNK	3	SAR Permit Database (16-HCAA-01491)	No
Lake St. Clair	Collop Drain	2018	No	SN	1	SAR Permit Database (18-PCAA-00005)	No
Lake St. Clair	Chenail Ecarté	2019	No	SN	50	DFO unpublished data	No
Lake St. Clair	St. Clair River	2020	No	BEF	2	Aguiar et al. 2021	Yes
St. Clair National Wildlife Area (dyked wetland)	West cell	2004	No	BEF; HN	6	Bouvier (2006)	Yes
St. Clair National Wildlife Area (dyked wetland)	West cell	2016	No	MFN	18	DFO unpublished data, University of Toronto Scarborough (Montgomery) unpublished data	Yes
St. Clair National Wildlife Area (dyked wetland)	East cell	2016	No	MT; DN; VO	≥ 22	Biotactic unpublished report	Yes
St. Clair National Wildlife Area (dyked wetland)	Maxwell cell	2016	No	MFN	1	University of Toronto Scarborough (Montgomery) unpublished data	
St. Clair National Wildlife Area (dyked wetland)	East cell	2018	Yes	MFN	6	Barnucz et al. 2021a	Yes
St. Clair National Wildlife Area (dyked wetland)	East cell	2019	Yes	MFN	9	Barnucz et al. 2021a	Yes
St. Clair National Wildlife Area (dyked wetland)	West cell	2019	Yes	MFN	5	Barnucz et al. 2021a	Yes
Jeannette's Creek	-	1963	No	UNK	≥ 1	Canadian Distribution Database (CMNFI 67-0112.3)	No
Jeannette's Creek	-	1965	No	UNK	≥ 1	Canadian Distribution Database (CMNFI 67-0112)	No
Point Pelee National Park	-	1949	No	UNK	7	Canadian Distribution Database (RMC15373)	No

Area	Locality	Year of survey	Lake Chubsucker targeted	Gear	Number captured	Source	Effort or CPUE data available
Point Pelee National Park	-	1968	No	UNK	≥ 2	Canadian Distribution Database (CMNI 78-0027; CMNI 68-0316)	No
Point Pelee National Park	-	1969	No	UNK	≥ 1	-	No
Point Pelee National Park	-	1972	No	UNK	≥ 1	Canadian Distribution Database (CMNI 72-0067)	No
Point Pelee National Park	-	1979	No	UNK	> 1	Essex Region (1101)	No
Point Pelee National Park	-	1983	No	UNK	≥ 1	Canadian Distribution Database (RMC43383)	No
Point Pelee National Park	-	1993	No	UNK	≥ 1	Dibble et al. 1995	No
Point Pelee National Park	-	2003	No	HN; SN	25	Surette 2006	Yes
Point Pelee National Park	Girardin Pond	2016	No	FN	1	T. Bortoluzzi, DFO, pers. comm.	No
Point Pelee National Park	Lake Pond	2019	Yes	MFN	1	Barnucz et al. 2021b	Yes
Rondeau Bay	Rondeau Bay	1955	No	UNK	14	Canadian Distribution Database (Various ROM ID numbers)	No
Rondeau Bay	Rondeau Bay	1963	No	UNK	≥ 3	Canadian Distribution Database (Various ROM ID numbers)	No
Rondeau Bay	Rondeau Bay	1983	No	UNK	≥ 1 (n = 12; COSEWIC 2008)	Canadian Distribution Database (RMC43412)	No
Rondeau Bay	Rondeau Bay	2005	No	SN	1	SAR Permit Database (SECT 05 SCI 003)	No
Rondeau Bay	Rondeau Bay	2020	No	BEF	1	Aguiar et al. 2021	Yes
Long Point Bay	Inner Bay	1951	No	UNK	5	COSEWIC 2008	No
Long Point Bay	Big Creek Inner Bay	1955	No	UNK	7	Canadian Distribution Database (RMC18081, RMC18080)	No
Long Point Bay	Big Creek	1979	No	HN	2	MacLean 1979	No
Long Point Bay	Big Creek	1982	No	RN	4	Dewey 1982	No
Long Point Bay	Turkey Point Marsh	1985	No	UNK	1	COSEWIC 2008	No
Long Point Bay	Crown Marsh	1994	No	BEF	≥ 8	Great Lakes Laboratory for Fisheries and Aquatic Sciences Electrofishing	No
Long Point Bay	Inner Bay	1999	No	UNK	≥ 1	Canadian Distribution Database (RMC71965)	No
Long Point Bay	Crown Marsh	2004	No	BEF	1	DFO unpublished data	Yes
Long Point Bay	Turkey Point Marsh	2007	No	BEF	22	DFO unpublished data	Yes
Long Point Bay	Big Creek	2008	No	HN	2	DFO unpublished data	Yes

Area	Locality	Year of survey	Lake Chubsucker targeted	Gear	Number captured	Source	Effort or CPUE data available
Long Point Bay	Crown Marsh Turkey Point Marsh	2009	No	UNK	≥ 12	SAR Permit Database (SECT 08 SCI 028)	No
Long Point Bay	Turkey Point Marsh	2010	No	SN; HN	2	SAR Permit Database (SECT 73 SARA C&A 10-019)	No
Long Point Bay	Turkey Point Marsh	2011	No	UNK	37	SAR Permit Database (SECT 73 SARA C&A 11-029)	No
Long Point Bay	Crown Marsh	2012	Yes	SN	87	DFO unpublished data, Rook et al. 2016	Yes
Long Point Bay	Crown Marsh	2013	Yes	SN	21	DFO unpublished data, Rook et al. 2016	Yes
Long Point Bay	Crown Marsh	2014	Yes	SN	88	DFO unpublished data, Rook et al. 2016	Yes
Long Point Bay	Crown Marsh Inner Bay	2015	No	BEF	9	Marson et al. 2018, SAR Permit Database (15-PCAA-00010)	Yes
Long Point Bay	Crown Marsh	2016	Yes	BEF; SN	7	Colm et al. 2018, S. Reid (Ministry of Northern Development, Mines, Natural Resources and Forestry)	Yes
Long Point Bay	Crown Marsh	2017	Yes/No	BEF; SN	9	Colm et al. 2019a, SAR Permit Database (15-PCAA-00011)	Yes
Long Point Bay	Crown Marsh Inner Bay	2018	Yes/No	BEF/SN	15	Colm et al. 2019b, SAR Permit Database (18-PCAA-00024)	Yes
Long Point Bay	Inner Bay	2019	No	BEF/SN	7	Colm et al. 2020, SAR Permit Database (19-PCAA-00022)	Yes
Long Point Bay	Inner Bay	2020	No	BEF	2	Aguiar et al. 2021	Yes
Long Point NWA	Long Point NWA	1953	No	UNK	> 1	Essex Region	No
Long Point NWA	Long Point NWA	1975	No	UNK	≥ 2 (n = 177; COSEWIC 2008)	Canadian Distribution Database (RMC36575, RMC0568CS)	No
Long Point NWA	Long Point NWA	2005	No	HN	1	DFO unpublished data	Yes
Long Point NWA	Long Point NWA	2009	No	UNK	≥ 1	SAR Permit Database (SECT 08 SCI 028)	No

Area	Locality	Year of survey	Lake Chubsucker targeted	Gear	Number captured	Source	Effort or CPUE data available
Long Point NWA	Long Point NWA	2016	No	FN; MFN; SN	14	DFO unpublished data, University of Toronto Scarborough (Montgomery) unpublished data	Yes
Long Point NWA	Long Point NWA	2017	No	MFN; SN; FN	54	SAR Permit Database (17-PCAA-00010)	Yes
Big Creek NWA (dyked marshes)	Big Creek NWA (dyked marshes)	2005	No	HN; BEF	13	DFO unpublished data	Yes
Big Creek NWA (dyked marshes)	Big Creek NWA (dyked marshes)	2016	No	MFN; SN	165	DFO unpublished data, UTSC (Montgomery) unpublished data	Yes
Big Creek Upper Tributaries	-	1960	No	UNK	≥ 1	Canadian Distribution Database (CMNI 60-0526A)	No
Big Creek Upper Tributaries	Silverthorn Creek	1972	No	UNK	≥ 1	Canadian Distribution Database (RMC28646)	No
Big Creek Upper Tributaries	Stoney Creek	1973	No	UNK	≥ 2	Canadian Distribution Database (OMNRS84, RMC30319)	No
Big Creek Upper Tributaries	Lynedoch Creek	1974	No	UNK	≥ 1	Canadian Distribution Database (RMC30875)	No
Big Creek Upper Tributaries	Trout Creek	1979	No	UNK	≥ 2	Canadian Distribution Database (CMNI 79-1175; CMNI 79-1176)	No
Lyons Creek	Lyons Creek	2004	No	BEF	5	DFO unpublished data	Yes
Lyons Creek	Lyons Creek	2008	No	BEF	28	A. Yagi ((Ministry of Northern Development, Mines, Natural Resources and Forestry)	No
Lyons Creek	Lyons Creek	2009	No	BEF	20	A. Yagi ((Ministry of Northern Development, Mines, Natural Resources and Forestry)	No
Lyons Creek	Lyons Creek	2010	Yes	SN	13	DFO unpublished data; (Ministry of Northern Development, Mines, Natural Resources and Forestry (Reid) unpublished data	Yes
Lyons Creek	Lyons Creek	2013	Yes	SN	5	SAR Permit Database (SARA C&A 13-014)	Yes
Tea Creek	Tea Creek	1958	No	UNK	≥ 1 (n = 4; COSEWIC 2008)	Canadian Distribution Database (RMC19732)	No

APPENDIX II

Table A2. Considerations for evaluating the threat Level of Impact in the threat assessment for Lake Chubsucker in Canada. The magnitude (level of exposure or intensity) of the threat may vary across locations based on landscape-level features, degree of human interference, or invasion status. Additionally, the habitat type may influence how a threat is received in a particular location, as some waterbody types may buffer against impacts. Two Level of Impact scores (Low, Medium, High, Unknown) were assigned to each population for each threat, and the median score (or highest score if values were adjacent) was retained.

	Threat	Level of exposure/magnitude/intensity	Location/habitat type effects
Natural Systems Modification	Agriculture	Proportion of adjacent land surface that is agricultural (i.e., expected 'concentration' of sediments).	Dyked wetlands likely have a low chance of receiving inputs, closed systems a medium chance, and open systems a higher chance.
	Shoreline Development and Hardening	Proportion of surrounding shoreline that is/could be hardened/developed	Impacts likely medium in open areas and wetlands, and high in flowing systems (due to loss of low flow, highly vegetated refuge habitats).
	Dredging	Proportion of the habitat that is dredged and how frequently it occurs (i.e., maintenance dredging for shipping canals likely occurs much more frequently than pond creation/maintenance following *Phragmites* control)	Impacts likely medium in flowing systems, and high in open areas and wetlands (as turbid conditions and low dissolved oxygen are likely to persist for longer).
	Drawdown of Dyked Wetlands and other Water Level Manipulations	Proposed drawdown increment (as a proportion of Normal Operating Level/ baseline conditions)	Impacts likely low in open areas and flowing habitats (where water is replenished naturally), high in closed systems with no water control structures, and extreme in dyked wetlands and Lyons Creek (relies on constant input from the Welland Canal).

	Threat	Level of exposure/magnitude/intensity	Location/habitat type effects
	Aquatic invasive species	If only one of Eurasian Watermilfoil or *Phragmites*, score as medium. If any combination of two or more habitat-modifying AIS, score as high. Do not consider impacts from *Phragmites* control; long-term benefits and short-term consequences likely balance out over 10 year timeframe.	Impacts likely medium in open systems, and high in closed systems (as there is no ability to move elsewhere in response to habitat changes).
Pollution	Agriculture	Proportion of adjacent land that is agricultural (i.e. expected concentration of nutrients/pesticides).	Dyked wetlands likely have a low chance of receiving inputs, closed systems a medium chance, and open systems a higher chance.
	Industrial Activity	If no specific contaminants are known, score as low. If specific contaminants are known (e.g., in Point Pelee, Lyons Creek, Lake St. Clair), score as medium.	Impacts likely low in flowing systems (where pollutants will flush eventually), low in off-line systems (e.g., OAC and L Lake), medium in low-energy environments (where pollutants are likely to settle out).
	Urbanization	Due to most populations being found in agricultural areas, score as low. Where ageing septic tanks have been identified (e.g., OAC, L Lake, Rondeau Bay, Point Pelee), score as medium. Due to causeway construction (and also ageing septic tanks identified), Long Point Bay and Long Point NWA, score as high.	Dyked wetlands likely have a low chance of receiving inputs, closed systems a medium chance, and open systems a higher chance.
Climate Change	-	Due to the relatively small range of Lake Chubsucker in Ontario, it is likely that all populations will experience similar levels of warming, changes in climate moisture, seasonal timing, etc. No separate score given.	Impacts likely medium in open areas (fish have the ability to move in response to changing conditions), and high in isolated habitats.

	Threat	Level of exposure/magnitude/intensity	Location/habitat type effects
Invasive and Other Problematic Species and Genes	Competition/Predation	Impacts from Round Goby and Rudd expected to be low, regardless of invasion status.	Low for all habitat types (competition and predation likely to be less severe than habitat-related impacts of AIS).
	Illegal Stocking	Exposure likely similar across locations - most populations are not close to urban centers where releases are more likely; similar number of individuals would likely be stocked, should this occur.	Impacts likely low in open areas (ability to move, even if stocked species' density is high at times), medium in isolated systems (stronger density-dependent effects and fewer refuge/ predator avoidance possibilities).