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Information in support of a Recovery Potential Assessment of Warmouth (*Lepomis gulosus*) in Ontario

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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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ABSTRACT

The presence of Warmouth was first reported in the Canadian waters of Lake Erie in 1966. In April 1994, of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) recommended that Warmouth be designated as a species of Special Concern. Subsequently, Warmouth was listed on Schedule 1 of the *Species at Risk Act* (SARA) when the Act was proclaimed in June 2003. In May 2015, the status was re-examined and designated Endangered. The reason given for this designation was that Warmouth "has a very small distribution in Canada, occurring only within the Lake Erie drainage. It exists at a few locations and is subjected to continuing decline in habitat quality due to a complexity of ecosystem modifications to its preferred vegetated habitat, primarily from the establishment of dense beds of non-native aquatic plants and eutrophication resulting from agricultural runoff." Results of a population status assessment ranked all three populations (Rondeau Bay, Long Point Bay and Point Pelee) as poor. A threat assessment indicated that the greatest threats to Warmouth populations are aquatic vegetation removal, and natural system modifications due to the establishment of exotic plants and wetland draining for agricultural purposes. 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, which will be used to inform recovery plans. Mitigation measures and alternative activities related to the identified threats, that can be used to protect the species, are also presented. This information may be used to inform the issuing of SARA Section 73 permits.

INTRODUCTION

In April 1994, COSEWIC recommended that Warmouth (*Lepomis gulosus*) be designated as Special Concern. This status was assessed and confirmed in November 2001, and May 2005. In May 2015, Warmouth was assessed and designated Endangered due to its restricted distribution in Canada, and continuing decline of its preferred vegetated habitat. In June 2003, Warmouth was listed on Schedule 1 of the *Species at Risk Act* (SARA) when the Act was proclaimed. Warmouth is currently listed as Special Concern under the *Endangered Species Act*, 2007. A Recovery Potential Assessment (RPA) process has been 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). This document provides background information on Warmouth in Canada to inform the RPA.

BIOLOGY, ABUNDANCE, DISTRIBUTION AND LIFE HISTORY PARAMETERS

Element 1: *Summarize the biology of Warmouth*

SPECIES DESCRIPTION

Warmouth is a member of the family Centrarchidae, commonly known as sunfishes and basses (Figure 1; Page et al. 2013). Warmouth is a small-to medium-sized fish with an average length of 155 mm total length (TL) in Ontario and a world record length of 310 mm TL (Holm et al. 2010). It is characterized by having a large mouth, with the upper jaw extending back well beyond the anterior margin of the eye. The pectoral fins have a rounded margin and are moderately long. There is a patch of tiny teeth present on the tongue (Holm et al. 2010).

Warmouth has three to five dark bands radiating back from the snout and eye (Trautman 1981) and the opercular flap has a dark spot with a light yellow to dusky edge (Holm et al. 2010). The body is light yellow-olive to dark olive-green, with lighter vermiculations and dull bluish, purplish and golden reflections. Six to eleven chain-like, double bands of dark olive are present on the back and sides (Trautman 1981). The anal, caudal and dorsal fins are spotted. Breeding males have a more brilliant colour pattern with grey pelvic fins and a bright orange spot at the base of the posterior three dorsal rays (Holm et al. 2010).

Warmouth is one of 11 members of the Centrarchidae found within the Canadian Great Lakes basin (Holm et al. 2010). Warmouth can be easily distinguished from both Largemouth Bass (*Micropterus salmoides*) and Smallmouth Bass (*M. dolomieu*) by the absence of a notched dorsal fin and a deeper body shape (Holm et al. 2010). The number of spines in the anal fin differentiates Warmouth from Rock Bass (*Ambloplites rupestris*); three for Warmouth, five to seven for Rock Bass (Holm et al. 2010). Warmouth can be distinguished from both White Crappie (*Pomoxis annularis*) and Black Crappie (*P. nigromaculatus*) by the number of dorsal spines; Warmouth having 10 dorsal spines, and crappies having six to eight (Holm et al. 2010). A suite of characters including its large mouth, dark bands radiating from the eye, and presence of teeth on the tongue distinguishes Warmouth from other sunfishes in the genus *Lepomis*.

Figure 1. Warmouth, Lepomis gulosus*. Illustration by Joe Tomelleri; reproduced with permission.*

DIET

Warmouth is considered to be a food generalist and habitat specialist (Larimore 1957, Guillory 1978, Savitz 1981). Warmouth feeds in both the pelagic and benthic zones and its diet is mainly composed of crustaceans, aquatic insects, crayfishes, molluscs, and other fishes (Carlander 1969, Becker 1983, COSEWIC 2015). Composition of prey is based on the size of Warmouth and feeding location (Becker 1983). Juvenile Warmouth feed primarily on plankton and small insects, while larger Warmouth also include crayfishes, fishes, and insects in their diets (McMahon et al. 1984 and references therein). A diet analysis completed by Tumlison et al. (2007) on 133 Warmouth captured from Lake Ouachita, Arkansas, revealed that the majority of stomachs contained mayfly (Ephemeroptera) naiads and crayfishes. In warm water, Warmouth may consume 4% of its body weight in food per day (Hunt 1960). Warmouth almost always feeds in the early morning (Larimore 1957). No data is available on the diet of Ontario Warmouth.

GENETICS

There have been no genetic studies conducted in either Canada or the United States on the Warmouth. A genetic study comparing the Great Lakes populations with those in the Mississippi and Atlantic drainages, although interesting, may not be a necessity from a management point of view at present.

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

DISTRIBUTION

Warmouth is native to the Mississippi River, Atlantic and Great Lakes basins (Figure 2; NatureServe 2015). These populations are widely distributed throughout central and eastern US, from Texas to Florida in the south, and Minnesota to New York in the north (Page and Burr 2011). Introduced populations of Warmouth are known to occur in Pacific drainages in the western US (New Mexico, Arizona, Nevada, Idaho, Oregon and Washington; Page and Burr 2011, NatureServe 2015). Warmouth has also been introduced into Mexico (Page et al. 2013). Within its native range in Illinois, Warmouth has been widely introduced into impoundments

(Larimore 1957). Within the Great Lakes basin, populations are found in Illinois, Indiana, Michigan, New York, Ohio, Ontario and Wisconsin (NatureServe 2018). Although the Warmouth has an extensive distribution in the United States, it is only known in Canada from a few isolated areas in southwestern Ontario. Less than 5% of the global distribution is currently found in Canada (COSEWIC 2005).

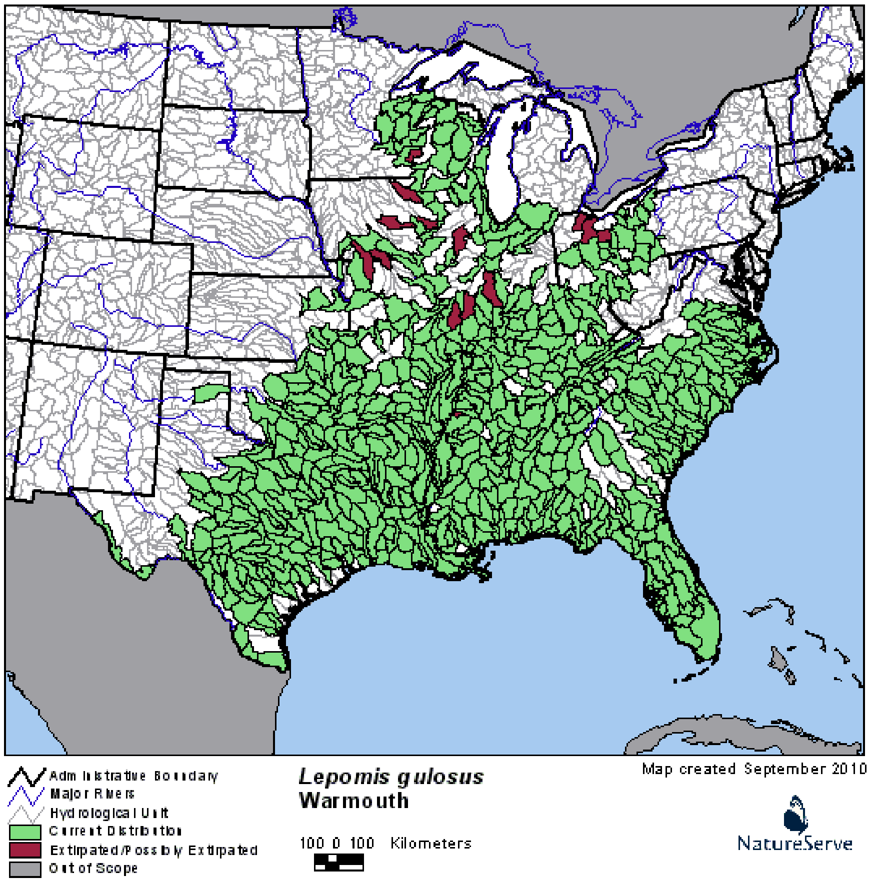

Figure 2. Global distribution of Warmouth (NatureServe 2015).

In Canada, the current and historic distribution of Warmouth is limited to three locations, all situated in the Lake Erie drainage (Figure 3). These locations include Rondeau Bay Provincial Park, Point Pelee (including Hillman Marsh), and Long Point Bay (including Big Creek Marsh, Long Point National Wildlife Area, Turkey Point, Crown Marsh, Bluff Bar, and Long Point Inner Bay; hereafter referred to as Long Point Bay). Two additional sites have been reported in the literature. The first was a YOY specimen from Cedar Creek (a tributary of Lake Erie) collected in 1994 (Leslie et al. 1999), which was later re-identified as Northern Sunfish (*L. peltastes*) (E. Holm, Royal Ontario Museum, pers. comm. *in* COSEWIC 2005). The second was reported from Duck Creek (a tributary of Lake St. Clair; Leslie and Timmins 1998); however, this voucher specimen was not recovered or verified and, therefore, is excluded from this report. Limited sampling has occurred in Duck Creek in 2001 and 2004 and Warmouth was not detected during these surveys. However, it is unlikely that Warmouth occupies this system as the habitat does not appear to be suitable (DFO unpublished data; Essex Erie Conservation Authority unpublished data). In addition, Canadian tributaries of Lake St. Clair have been extensively sampled since 2002 using suitable gear and effort for capturing Warmouth; however, none were detected. Appendix 1 details all known detections and sampling effort of Warmouth in Canada.

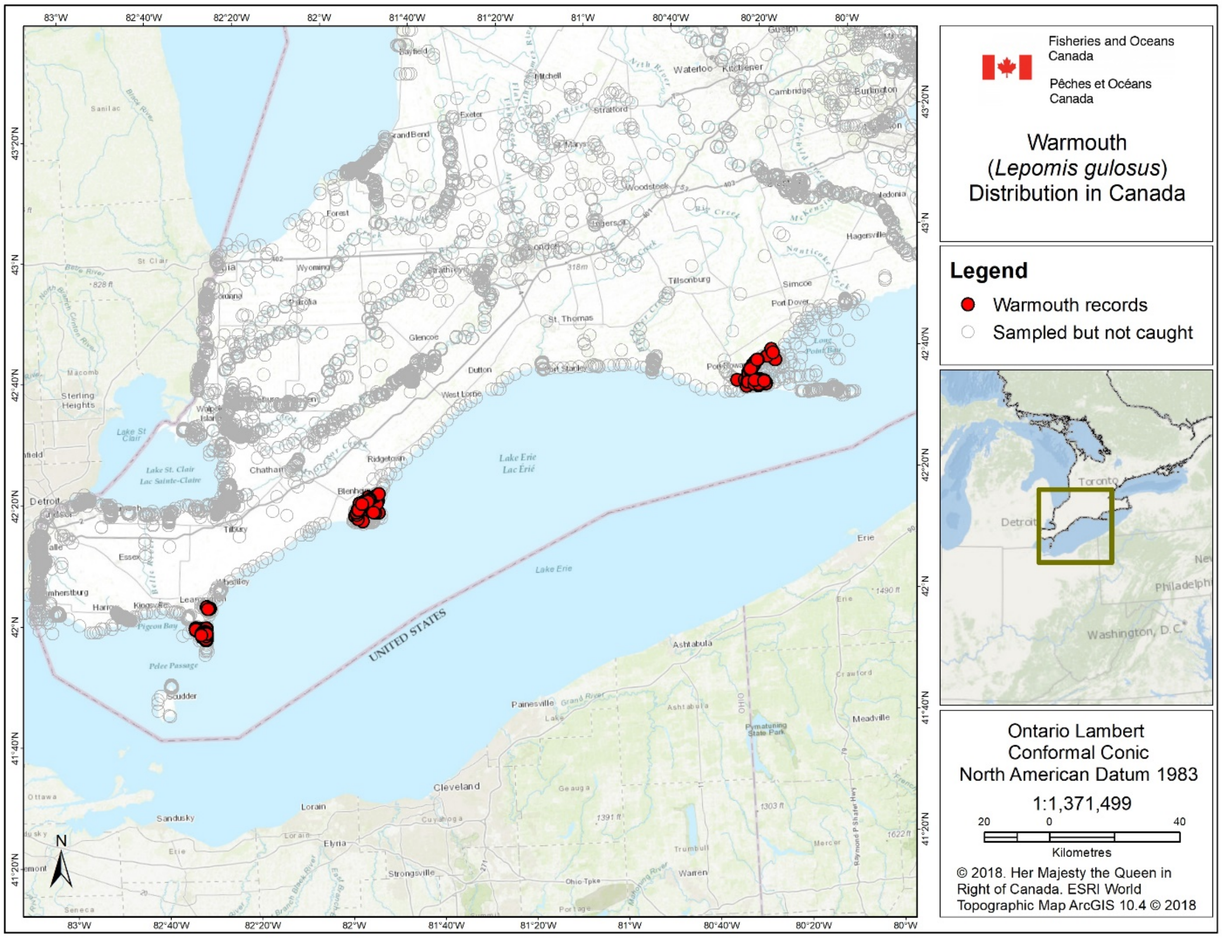

Figure 3. Distribution of Warmouth, Lepomis gulosus, in Canada.

Crossman et al. (1996) speculated that Warmouth may have more recently colonized Canadian waters relative to other native freshwater fish species and that this recent colonization may be a result of a period of global warming, and/or continuing range expansion following the last glaciation period (COSEWIC 2005). Alternatively, Warmouth may have been recently introduced to these systems as a result of direct human actions. Recent introductions, a few successful, have been reported in US waters (Van Meter and Trautman 1970). However, there are no American populations near the Canadian populations that would have allowed easy transfer, there is no motivation for such a transfer, and it is unlikely that it would be introduced into a protected area, such as Point Pelee National Park. It is more likely that Warmouth has been present in Canada since the last Ice Age, but had remained undetected and/or misidentified until the first record of its presence in Rondeau Bay in 1966.

If Warmouth only recently colonized its Canadian range, one would expect it to be present in other suitable habitats along the north shore of Lake Erie. These suitable habitats would have acted as colonization stepping stones to the western-most established population in Point Pelee National Park. Suitable habitat may include the River Canard, Holiday Beach/Big Creek complex and Cedar Creek in Essex County. However, Warmouth has not been detected in: River Canard (years sampled: 1980, 1985, 1990-91, 1994, 1996, 2002-04, 2009, 2012-18; various sources); Holiday Beach intensively sampled by fyke net and boat electrofisher in 2003 and 2004 (L. Bouvier unpublished data); Big Creek (tributary to Holiday Beach) sampled by hoop net and seining in 2007 (N. Mandrak unpublished data); and, Cedar Creek, a tributary to Lake Erie located between Holiday Beach and Point Pelee, sampled in 14 different years between 1941 and 2018.

In addition, connectivity between the Point Pelee National Park ponds and Lake Erie proper is regulated by a barrier beach system on the eastern perimeter of the park. In the past, the barrier beach rarely breached, with only five breach events recorded between 1922 and 1983 (Surette 2006). This would result in limited colonization opportunities for Warmouth in the time period prior to its first discovery in 1983.

A comparison of the extent of occurrence (EO; 2004–2015) to two historical periods (1994–2003 and pre-2004) indicates an increase in EO (COSEWIC 2015). EO (2004–2015; 2408.62 km²) has increased by 54.2% when compared to the previous 10 years (1994–2003; 1561.70 km²) and has increased by 47.9% when compared to all historical records (pre- 2004; 1628.36 km²). The index of area of occupancy (IAO) shows a similar trend with an increase in IAO when records from 2004–2015 are compared to both historical periods (1994–2003 and pre-2004). The most recent IAO (2004–2015; 100 km²) has increased by greater than threefold when compared to the previous 10 years (1994–2003; 32 km²) and has increased greater than twofold when compared to all historical records (pre-2004; 44 km²). It is difficult to determine the cause of the increases in both EO and IAO as consistent sampling effort and long-term trend data are currently unavailable. Increases in both metrics may be partially attributed to increased sampling efforts in areas known to be occupied by Warmouth. The paucity of historical information and the lack of consistent sampling through time make it impossible to determine population fluctuations or trends associated with Warmouth in Canada.

CURRENT STATUS

POINT PELEE

The current and historical distribution of Warmouth in Point Pelee is shown in Table A1.1 and Figure 4. Surette (2006) provides an in-depth historical account of fish sampling events that have occurred in Point Pelee from 1940 to 2003 (Table 1.1. in Surette [2006]). Sixteen sampling events in 15 different years failed to detect Warmouth in this system from 1940 to 1983 using a variety of sampling equipment, including seine nets, gill nets, minnow traps, creel surveys, and trap nets (Table A1.1). Warmouth was first detected in Lake Pond, Point Pelee National Park in 1983. This first record consisted of two individuals (G. Mouland unpublished data). Subsequently, the species was recorded from the system in low numbers in 1989, 1993, and 1997. A large-scale fish assemblage study was completed in 2002 and 2003 in which 657 Warmouth were recorded from 87 of 117 sampling events (Surette 2006). The ponds at Point Pelee were re-sampled in 2004, (n = 0), 2005 (n = 1), and 2009 (n = 6), yielding Warmouth detections at low numbers. The substantially greater abundance of Warmouth observed in 2002-2003 when compared to subsequent sampling events is likely a result of decreased sampling effort since the 2002-2003 surveys (see Appendix 1).

In 2017, 25 Warmouth were caught at Hillman Marsh (J. Ciborowski unpublished data; F. Montgomery unpublished data), representing the first detection of this species in this waterbody. Hillman Marsh can be found approximately six kilometers north. This may represent a range extension of the Point Pelee population; however, the barrier beach at Point Pelee likely prevents genetic exchange between these two areas. Historically, wetlands would have connected Point Pelee to Hillman Marsh prior to the draining of these wetlands for agricultural purposes (Parks Canada 2007). It’s possible that Warmouth have always occurred at Hillman

Marsh and have only now been identified there as there has been no direct effort to survey this species using appropriate gear at this location in the past.

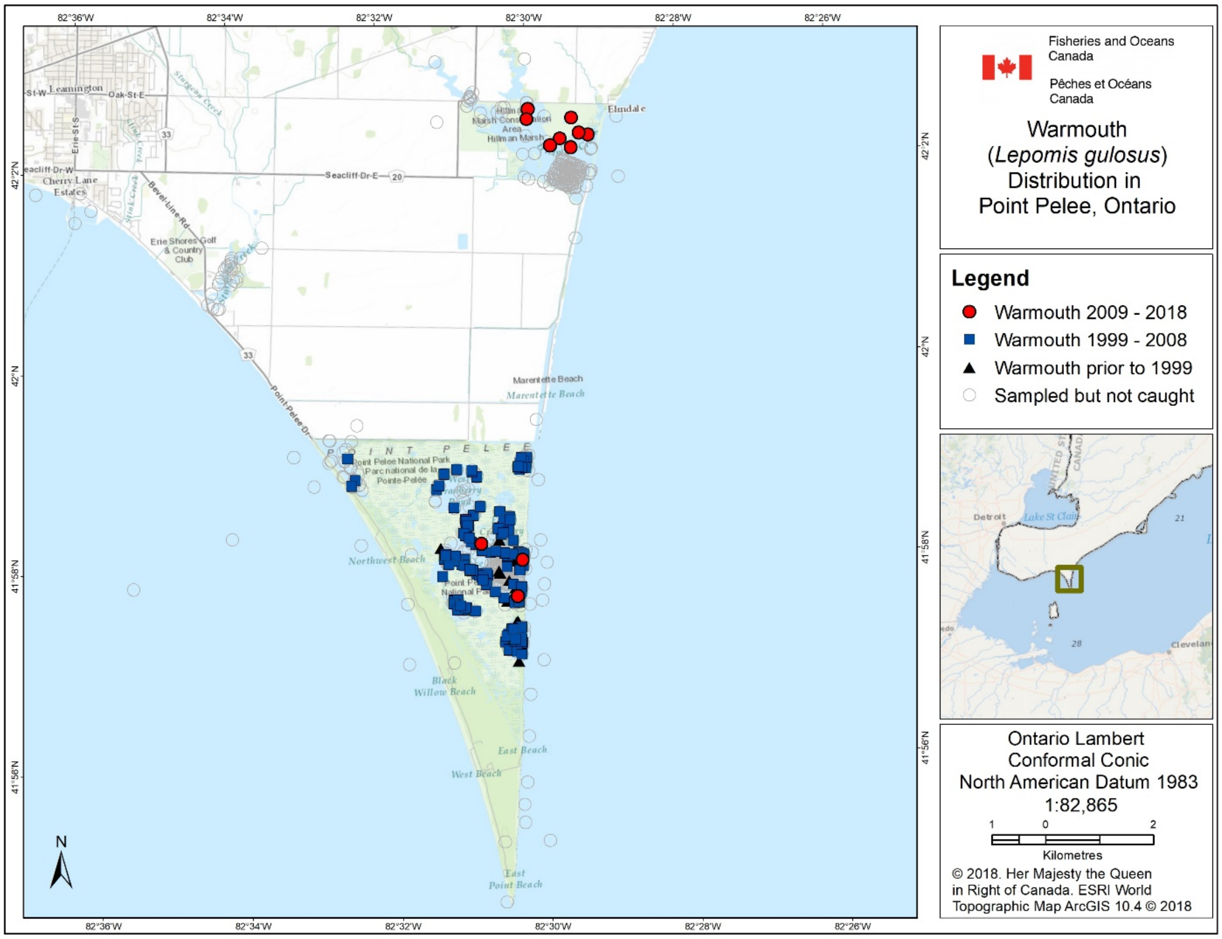

Figure 4. Distribution of Warmouth, Lepomis gulosus*, in Point Pelee National Park.*

RONDEAU BAY

The current and historical distribution of Warmouth in Rondeau Bay is shown in Table A1.2 and Figure 5. Warmouth was first recorded from Rondeau Provincial Park in 1966 (RPM F103-66; Crossman and Simpson 1984). An additional two records in 1967, and three records in 1968 (voucher ROM 34267) were recorded from Rondeau Provincial Park (Crossman and Simpson 1984). In 1999, two individuals were captured in southwest Rondeau Bay (ROM 72050). Although Warmouth has not been the focus of any studies in this system, substantial sampling with gear known to be effective at detecting Warmouth has occurred in Rondeau Bay in 2007 (128 fyke net sets), 2008 (126 fyke net sets), and 2009 (78 fyke net sets). These sampling efforts resulted in the detection of three, four, and six Warmouth, respectively (B. Glass unpublished data; M. Belore LEMU, unpublished data). One individual was captured in 2011 by C. Scott (LEMU, ROM 91723). Additional sampling in 2013 by hoop net and fyke net resulted in the capture of an additional 11 individuals (D. Marson unpublished data; N. Mandrak unpublished data). A combination of mini-fyke and hoop nets resulted in the detection of 19 individuals from 2015–2018. (Table A1.2; DFO unpublished data).

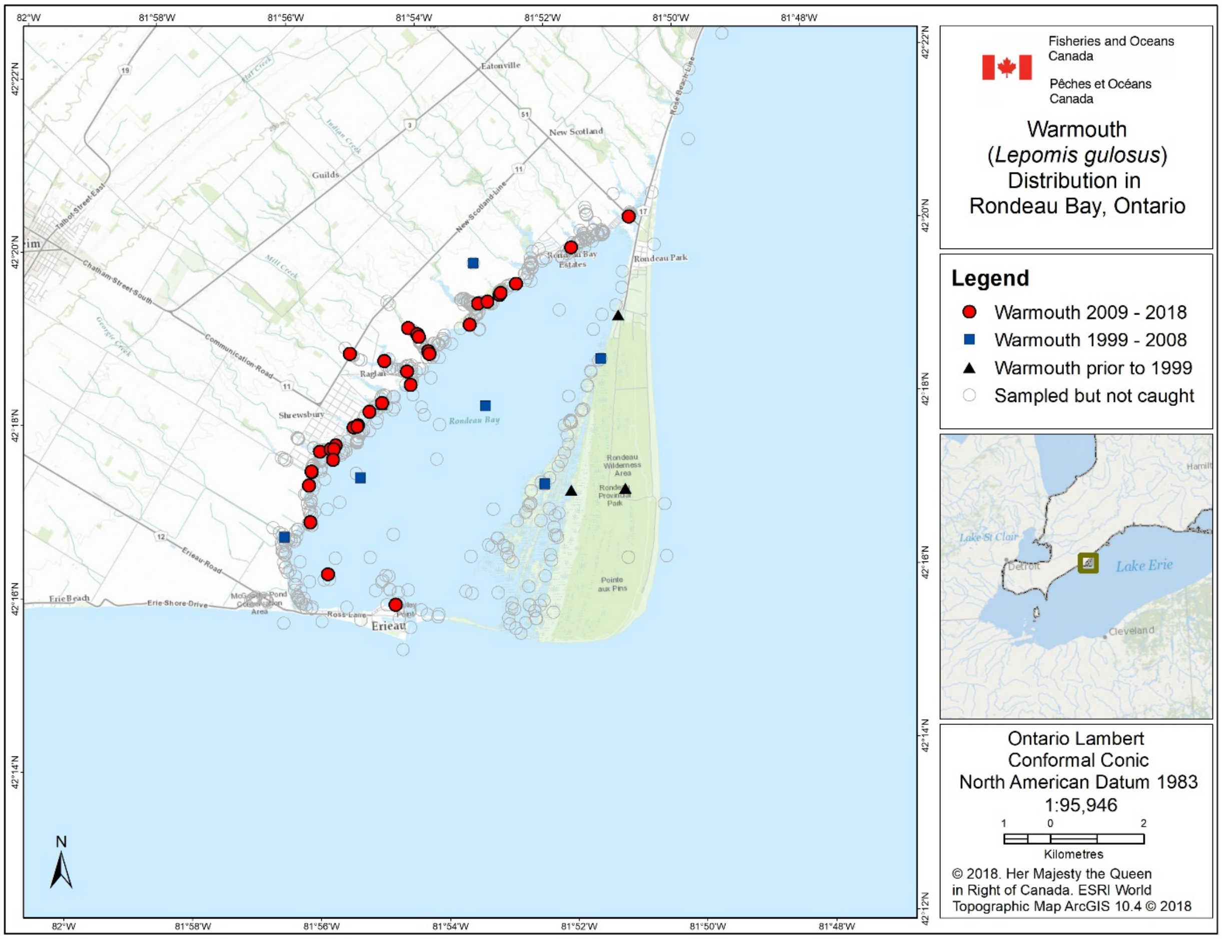

Figure 5. Distribution of Warmouth, Lepomis gulosus*, in Rondeau Bay.*

LONG POINT BAY

All known detection locations and collection efforts for Long Point Bay can be found in Table A1.3 and Figure 6. The first record of Warmouth from Long Point Bay and surrounding areas (Big Creek, Big Creek marshes and Turkey Point marshes) was recorded in 2003 when one YOY specimen was collected in the Inner Bay of Long Point (L. Bouvier unpublished data). From 2004 to 2005, 15 Warmouth were captured in Big Creek Marsh during DFO surveys. Between 2006 and 2010, 159 individuals were captured in Long Point Bay, Crown Marsh, Murray Marsh, and Turkey Point marshes. From 2011 to 2018 another 148 individuals were captured from Long Point Bay, Big Creek, Turkey Point marshes, and Crown Marsh. One individual from Crown Marsh was deposited as a voucher at the ROM (ROM 95521). A single Warmouth caught by the Canadian Wildlife Service, possibly in 2002 in Big Creek marshes, was also deposited at the ROM (ROM 89123). Monitoring data from the commercial hoop net coarse fishery along the north shore of the bay in 2009, indicated that 141 Warmouth were captured from 368 hoop net sampling events (Gislason et al. 2010). Also, four years (2011–12 and 2017–18) of bycatch data showed that 771 Warmouth were captured by commercial trap nets in the bay (OMNRF unpublished data). Warmouth appears to occupy all areas within inner Long Point Bay, including Turkey Point Marsh and Big Creek Marsh, but appears to be excluded from outer Long Point Bay. This trend is to be expected considering the lack of suitable habitat in outer Long Point Bay.

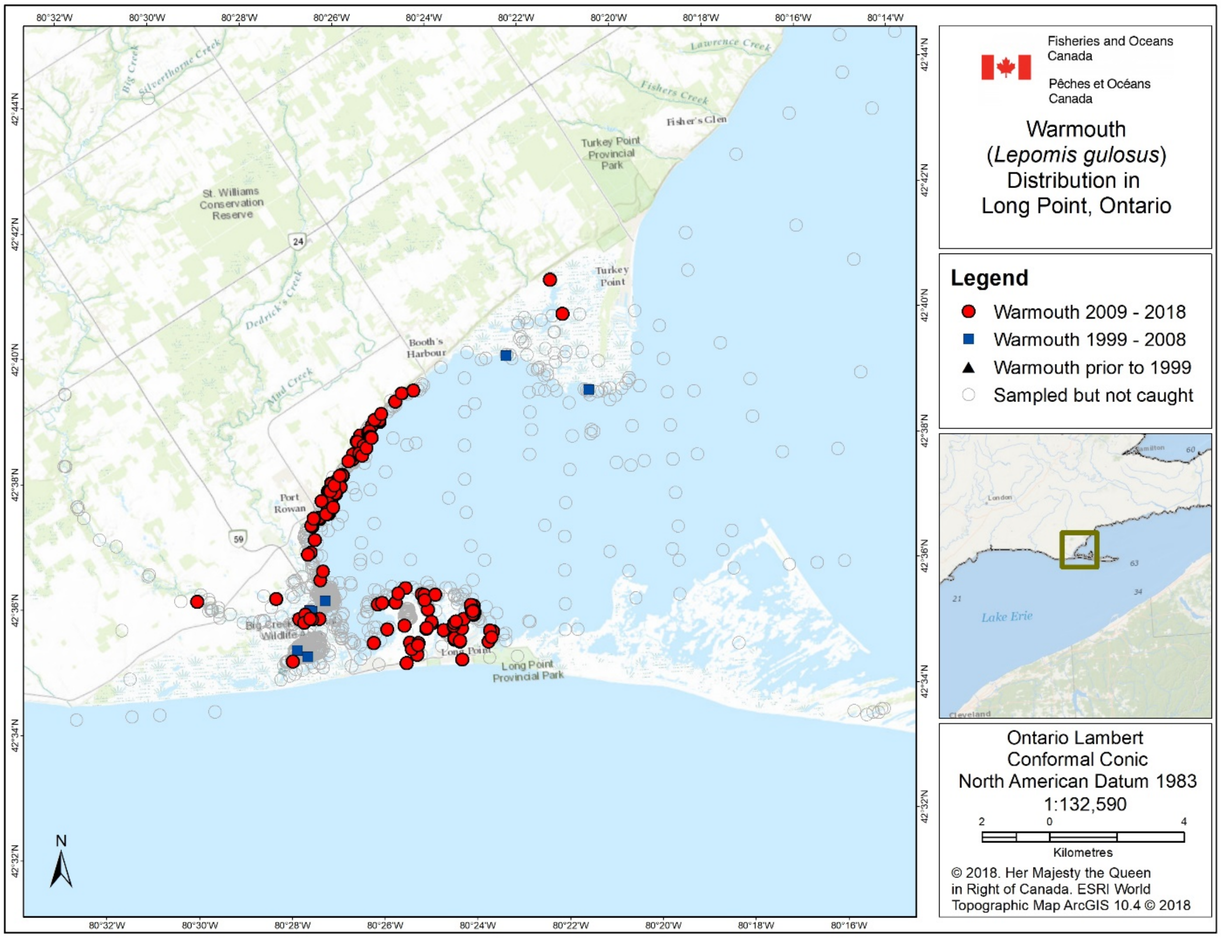

Figure 6. Distribution of Warmouth, Lepomis gulosus*, in Long Point Bay and surrounding area.*

POPULATION ASSESSMENT

To assess the Population Status of Warmouth populations in Canada, each population was ranked in terms of its abundance (Relative Abundance Index) and trajectory (Population Trajectory; Table 1).

The Relative Abundance Index was assigned as Extirpated, Low, Medium, High or Unknown. Sampling parameters considered included gear used, area sampled, sampling effort, and whether the study was targeting Warmouth. The number of individual Warmouth caught during each sampling period was then considered when assigning the Relative Abundance Index. The Relative Abundance Index is a relative parameter in that the values assigned to each population are relative to the most abundant population. In the case of Warmouth, all populations were assigned an Abundance Index relative to the Long Point Bay population. Catch-data from populations sampled using different gear types were assumed to be comparable when assigning the Relative Abundance Index.

The Population Trajectory was assessed as Decreasing, Stable, Increasing, or Unknown for each population based on the best available knowledge about the current trajectory of the population. The number of individuals caught over time for each population was considered. Trends over time were classified as Increasing (an increase in abundance over time), Decreasing (a decrease in abundance over time) and Stable (no change in abundance over time). If insufficient information was available to inform the Population Trajectory, the population was listed as Unknown.

Table 1. Relative Abundance Index and Population Trajectory of each Warmouth population in Canada. Certainty has been associated with the Relative Abundance Index and Population Trajectory rankings and is listed as: 1 = quantitative analysis; 2 = CPUE or standardized sampling; 3 = expert opinion.

Population	Relative Abundance Index	Certainty	Population Trajectory	Certainty
Point Pelee	Low	3	Unknown	3
Rondeau Bay	Medium	3	Unknown	3
Long Point Bay	Medium	3	Unknown	3

The Relative Abundance Index and Population Trajectory values were then 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).

Table 2. The Population Status Matrix combines the Relative Abundance Index and Population Trajectory rankings to establish the Population Status for each Warmouth population in Canada. The resulting Population Status has been categorized as Extirpated, Poor, Fair, Good, or Unknown.

		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 Warmouth populations in Canada, resulting from an analysis of both the Relative Abundance Index and Population Trajectory. 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).

Population	Population Status	Certainty
Point Pelee	Poor	3
Rondeau Bay	Poor	3
Long Point Bay	Poor	3

The size of the Canadian Warmouth population is currently unknown. Relatively high abundances in Long Point Bay and Rondeau Bay would indicate that these populations are well established. Few detections of Warmouth in Point Pelee National Park since 2003 suggest that abundance may be low for this population however, it may also be indicative of low search effort over the last 15 years. Additional research is necessary at all three known locations to get a better understanding of population abundance and trajectory.

Results of sampling efforts in areas known to be occupied by Warmouth over the last 10 years suggest that all populations are currently being maintained. Substantial sampling efforts in areas adjacent to historical Warmouth records have increased the known distribution of this species in both Long Point Bay, and Rondeau Bay. Decreased sampling efforts over the same time period in Point Pelee National Park may account for the decrease in the number of point occurrences in this system.

Element 3: *Estimate the current or recent life-history parameters for Warmouth.*

LIFE HISTORY PARAMETERS

Sexual maturity of Warmouth is heavily dependent on size and has been recorded at 1 and two years of age (Larimore 1957). The maximum recorded life expectancy is eight years of age (COSEWIC 2015). Due to a protracted spawning season, estimating fecundity for Warmouth presents challenges (Larimore 1957, Panek and Cofield 1978). Fecundity estimates from Illinois found that the number of ova ranged from 4,500 to 63,000 during the months of May and June (Larimore 1957). For mature individuals from South Carolina, the number of ova ranged from 798 to 34,257 (Panek and Cofield 1978). There is also a positive correlation between female total length and the number of eggs in the ovary for females in the same body of water (Larimore 1957).

Length-frequency data for 71 Warmouth captured in Long Point Bay and Rondeau Bay between 2012 and 2018 are shown in Figure 7 (DFO unpublished data). Age interpretations have yet to be determined. In the United States, Warmouth growth is found to be faster in southern compared to northern populations, a relationship that would be expected based on a longer growing season in the south (Figure 8; Stauffer et al. 2007). Average length at each scale annulus of Warmouth from the more northern states (Illinois, Iowa, and Indiana) indicates slightly slower growth than those from the more southern Tennessee. When comparing growth of Warmouth between different water-body types in the Ohio River drainage, it was shown that the type of waterbody has an effect on growth of Warmouth, with individuals in larger water bodies growing more rapidly than those from smaller bodies of water (Figure 9; Wallus and Simon 2008). There appears to be little, if any, difference in growth between males and females (Stauffer et al 2007).

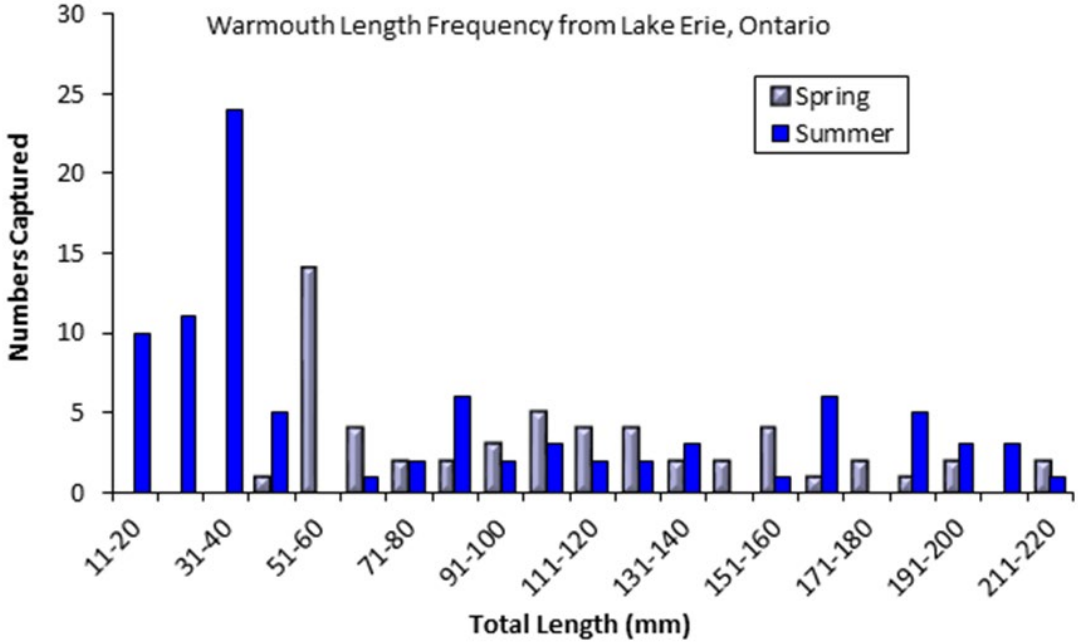

Figure 7. Length-frequency histogram for 71 Warmouth collected in Lake Erie in May/June (light bars), and July/August (dark bars) from 2012–2018 (DFO unpublished. data).

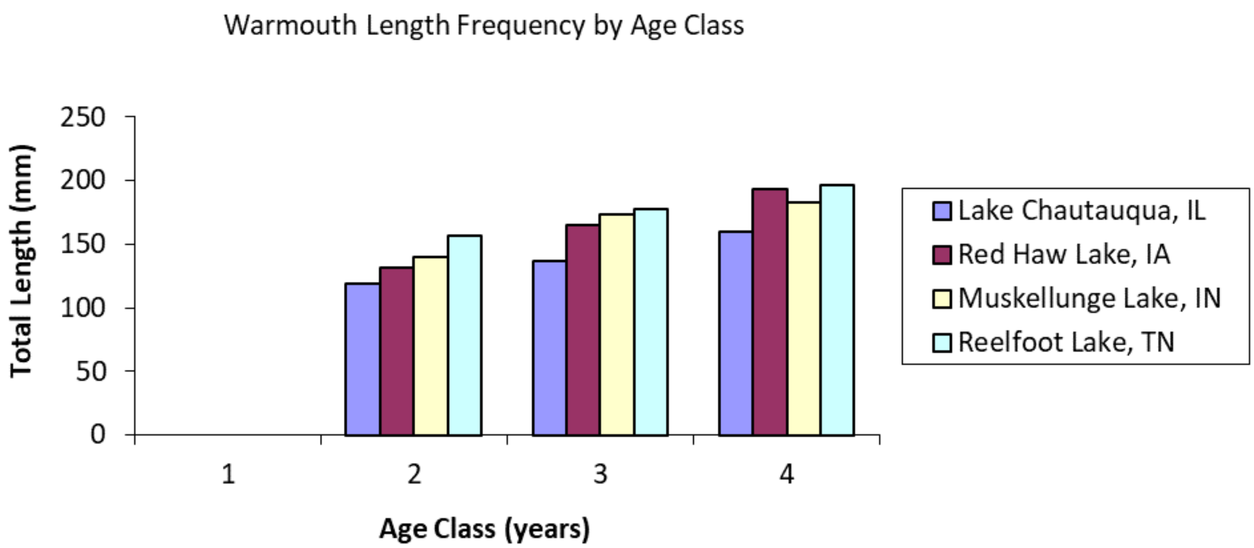

Figure 8. Age and growth data for Warmouth from several lakes in the Ohio River drainage, United States (Stauffer et al. 2007).

Figure 9. Average growth data of Warmouth from a variety of habitats in the Ohio River drainage, United States (Wallus and Simon 2008).

HABITAT AND RESIDENCE REQUIREMENTS

Element 4: *Describe the habitat properties that Warmouth 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.*

SPAWNING

Spawning and nursery habitat is thought to be consistent with adult habitat, and characterized by shallow (less than 2 m), heavily vegetated areas with both submergent and emergent vegetation (Becker 1983, Lane et al. 1996a, b). Eggs are laid in nests that are constructed and guarded by males (Larimore 1957). Nests are built near cover in shallow, protected areas over a variety of substrates (Larimore 1957, Germann et al. 1975). Warmouth nests in Georgia swamps were found near stumps, root bases, along shorelines, and in sluggish areas with emergent vegetation (Germann et al. 1975). Nests are constructed in shallow water (< 1 m depth) where rapidly falling water levels in spring may adversely affect reproduction (Larimore 1957). Optimum temperatures for spawning activity in Warmouth is 21–27 °C (Larimore 1957), which is also the optimum temperature for incubation of Largemouth Bass embryos (Coutant 1975). It is assumed that this is the optimum temperature for survival and growth of Warmouth embryos. Sudden drops in water temperature are reported to cause very significant embryo mortality resulting from fungal infection (Larimore 1957). Temperatures below 15 °C are considered poor for spawning activity of Warmouth (McMahon et al. 1984).

LARVAL AND JUVENILE

Warmouth YOY are found in shallow water with a dense cover of aquatic vegetation, roots, brush, and boulders (Larimore 1957). Survival of Warmouth YOY that hatch later in the season may be higher than that of earlier broods due to the abundance of dense stands of aquatic vegetation. Sudden temperature drops in spring can also result in embryo mortality (Larimore 1957). Surveys at Crown Marsh found that sites with YOY (individuals ≤ 75 mm) had a mean submergent vegetation cover of approximately 74% from 2015–2018 (OMNRF unpublished data). Mean depth at these sites was 66 cm with soft substrates dominating, particularly sand substrates.

Specific habitat requirements for juvenile Warmouth (age 1+ to sexual maturity) are not detailed in the literature. However, Warmouth may mature at age 1, thus requirements of juveniles are thought to be similar to those of adult Warmouth (Larimore 1957).

ADULT

Water depth, velocity, turbidity, dissolved oxygen

Warmouth generally occupies shallow waters with a large portion of individuals caught in waters less than 2 m. A comparison of depths at 75 Warmouth sites in Long Point and Rondeau bays found that mean depth was 0.77 m (DFO unpublished. data). Depth at Crown Marsh sites averaged 66 cm in areas where Warmouth (individuals > 75 mm) were caught from 2015–2018 (n = 13). Minimum and maximum gear depths for sites where Warmouth were caught was 0.22 m and 3.5 m, respectively (DFO unpublished. data). Water velocity of less than 10 cm/s is considered optimal as Warmouth is rarely seen at higher velocities (Bailey et al. 1954). Warmouth is often abundant in turbid waters characteristic of lowland lakes, backwaters and sluggish streams (Larimore 1957). Growth is slowest in highly turbid Oklahoma ponds (Jenkins et al. 1955). High turbidity reduces the growth of aquatic vegetation favoured by Warmouth (McMahon et al. 1984). Oxygen tolerance levels are unknown for Canadian populations, but Warmouth has been noted to survive in oxygen-depleted systems (down to 3.6 ppm) in Illinois waters when water temperature was 20 °C (Larimore 1957 in Becker 1983). Dissolved oxygen greater than 6 mg/l is considered excellent for Warmouth and other centrarchids (Stewart et al. 1967). Levels below 3.6 mg/l affect long-term survival and growth (Larimore 1957).

Substrate

Warmouth are often captured over fine substrates (Wallus and Simon 2008), silt, sand or mud (Larimore 1957, Edwards 1997, Eakins 2018). At Ontario locations, substrate descriptions, taken as percent composition estimates, were available from sites where Warmouth was detected from 2012–2018 (n = 76; Figures 10, 11). Substrates were composed of a combination of organic, clay, silt, sand, gravel and cobble, and boulder with the latter three being negligible. The dominant substrate type across sites was silt, followed by sand. At Crown Marsh, sand was the dominant substrate at 77% of sites (n = 13) where Warmouth > 75 mm were captured from 2015–2018 (OMNRF unpublished data). Warmouth prefer gradients at or near zero and are absent in areas where gradient is greater than 4 m/km (Larimore 1957).

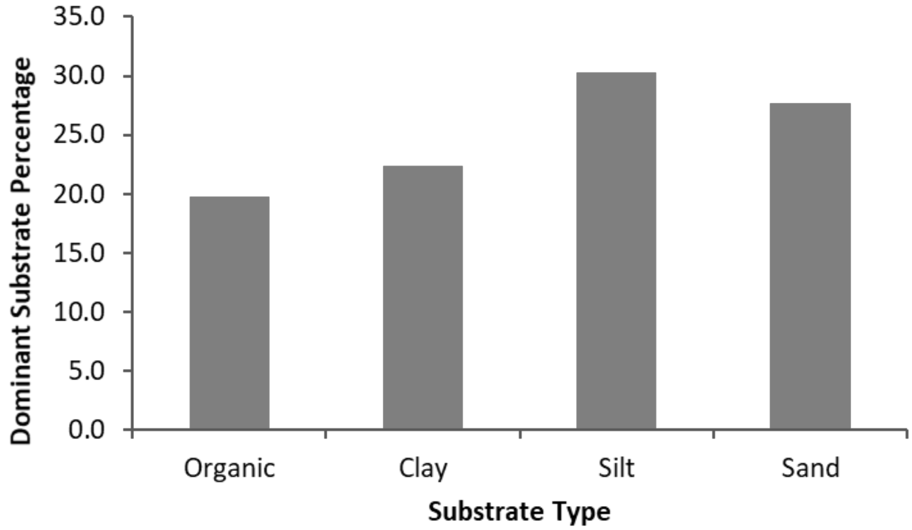

Figure 10. Dominant substrate types where Warmouth, Lepomis gulosus, was detected from 2012–2018 (n = 76 sites).

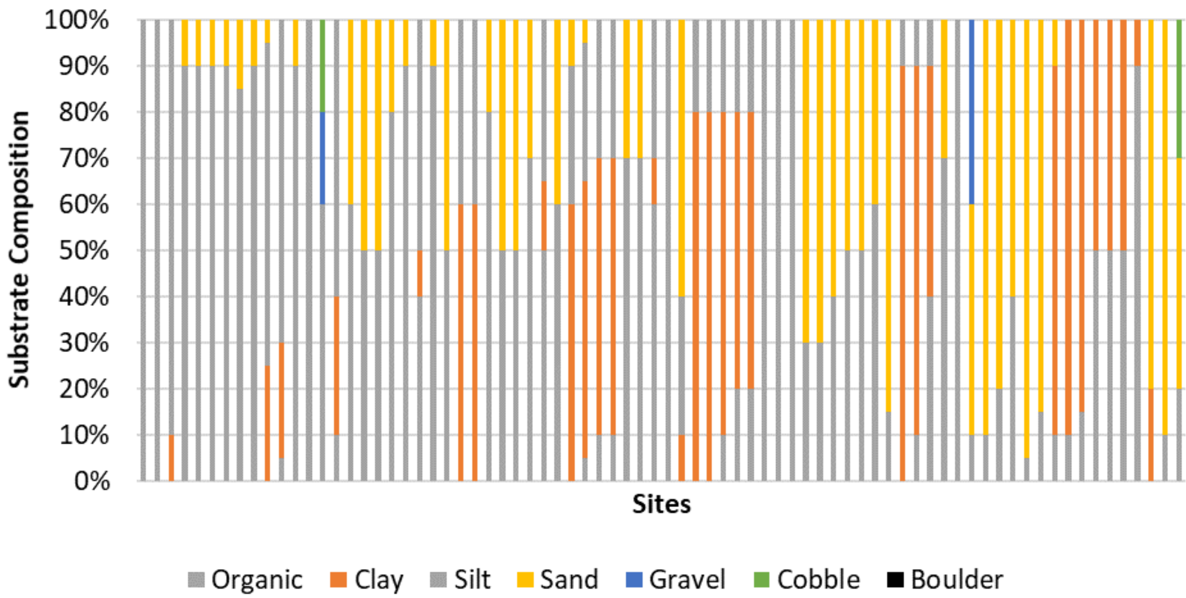

Figure 11. Substrate composition (%) at sites where Warmouth, Lepomis gulosus, was detected between 2012–2018 (n = 76 sites) throughout Rondeau Bay and Long Point Bay.

Vegetation

Warmouth is a warmwater species that prefers highly vegetated embayments of lakes, slow-moving streams and wetlands (Holm et al. 2010, Page and Burr 2011). Greater than 40% vegetation cover is considered to be excellent for Warmouth (McMahon et al. 1984). In Rondeau and Long Point bays, Warmouth was most commonly found from 2012–2018 (n = 77) in areas dominated by herbaceous shoreline vegetation. At these same sites, submergent vegetation was found to cover an average of 55% of the total area (Figure 12). Warmouth abundance falls in areas where there is a decline in aquatic vegetation due to increased turbidity and siltation (Smith 1979, Trautman 1981).

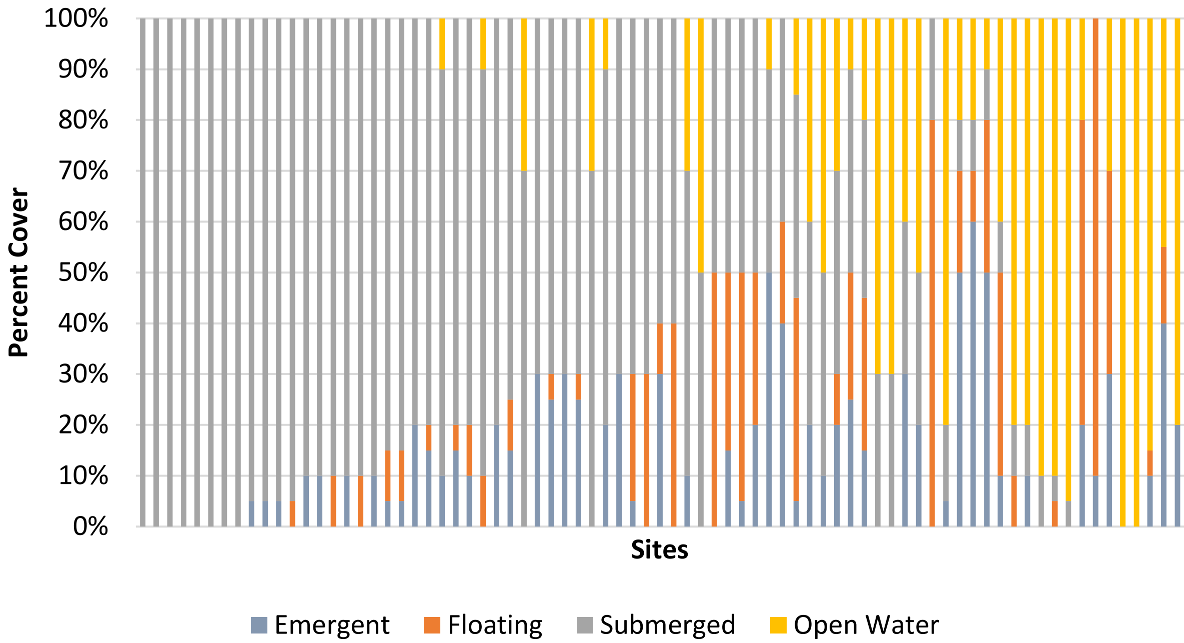

Figure 12. Aquatic vegetation as percent cover at sites where Warmouth, Lepomis gulosus, was detected between 2012-2018 (n = 76 sites) throughout Rondeau Bay and Long Point Bay.

FUNCTIONS, FEATURES AND ATTRIBUTES

A description of the functions, features, and attributes associated with Warmouth habitat can be found in Table 4. The habitat required for each life stage has been assigned a function that corresponds to a biological requirement of Warmouth. For example, individuals in the larval to juvenile life stage require habitat for nursery and spawning purposes. In addition to the habitat function, a feature has been assigned to each life stage. A feature is considered to be the structural component of the habitat necessary for the survival or recovery of the species. Habitat attributes have also been provided, describing how the features support the function for each life stage. This information is provided 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 Warmouth. Habitat attributes from published literature, and those recorded during recent Warmouth captures have been used to determine the habitat attributes required for the delineation of critical habitat.

			Habitat Attributes		
Life Stage	**Function**	**Feature(s)**	**Scientific Literature**	**Current Records**	**For Identification of Critical Habitat**
Spawn to hatch (occurs in late spring)	Spawning	Lower levels of lake reaches, shallow (< 2 m) with heavy vegetation.	• Spawning occurs when water temperature reaches 21 °C (Holm et al. 2010); between 21–27 °C (Larimore 1957). Nests built near cover along shorelines in protected areas at a depth of 0.5–1.5 m (Larimore 1957, Carlander 1977)		• Spawning occurs when water temperature is 21–27 °C • Nesting areas near cover in shallow (0.5–1.5 m), protected areas
YOY and juvenile	Nursery Feeding Cover	Shallow water with dense aquatic vegetation.	• Require dense stands of aquatic vegetation (Larimore 1957).	• Crown Marsh YOY (≤ 75 mm TL) were found at sites with a mean depth of 0.66 m (range: 0.16 m–1.2 m) from 2015–2018. These same individuals were found in areas averaging 74% submerged vegetation, 7% emergent vegetation, 3% floating vegetation and 16% open water. Sand was the dominant substrate at 91% (n = 33) of the sites. Average Secchi tube reading at these sites was 1.16 m (OMNRF unpublished data).	• Similar to adults: ○ Requires dense aquatic vegetation. ○ < 2 m depths ○ Fine substrates such as sand, silt and organic matter

			Habitat Attributes		
Life Stage	**Function**	**Feature(s)**	**Scientific Literature**	**Current Records**	**For Identification of Critical Habitat**
Adult (from Age 1 [onset of sexual maturity])	Feeding Cover	Nearshore, shallow (< 2 m) with vegetation (> 40%)		• Between 2012–2018 individuals were caught in depths from 0.4–1.4 m. (average 0.77 m; n = 75) at Long Point and Rondeau bays (DFO unpublished data). • From 2012-2018, Warmouth used areas where aquatic vegetation percent cover was dominated by submergent vegetation. Average percent cover was 55% of the area, on average (n = 77); (DFO unpublished data). • 62% of sites (n = 77) had submergent aquatic vegetation percent cover ≥ 35% • Crown Marsh adults were found at sites with a mean depth of 66 cm (range: 0.3 m–1.05 m; n = 13) from 2015–2018. These same individuals were found in areas averaging 69% submerged vegetation, 7% emergent vegetation, 0% floating vegetation and 23.5% open water. Average Secchi tube reading at these sites was 1.18 m (OMNRF unpublished data).	• < 2 m depths • Presence of significant submergent aquatic vegetation
		Substrate	• Prefers bottoms of soft mud and muck (Larimore 1957) Fine substrates (Wallus and Simon 2008), silt, sand or mud (Larimore 1957, Edwards 1997, Eakins 2018)	• Combination of organic, sand, silt and clay (DFO unpublished data). • Sand was the dominant substrate at 77% (n = 13) of Warmouth sites at Crown Marsh from 2015–18 (OMNRF unpublished data).	• Soft bottom composed of organic, sand, silt and/or clay

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

The spatial extent of the areas that are likely to have the habitat properties outlined in Table 4 have not yet been fully defined. Future research into aquatic habitat mapping for each of the three populations would help better serve the conservation of this species moving forward. Extensive habitat mapping could help identify areas that are most important to Warmouth and identify areas that could be restored for future use by the species.

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

Currently, there is poor connectivity between the known Canadian populations of Warmouth. Each of the three known Warmouth populations are greater than 50 km apart with little suitable habitat connecting these populations. Therefore, it is likely that potential pathways of genetic exchange have been lost (COSEWIC 2015). In addition to distance, a barrier-beach system at Point Pelee may prevent opportunities for genetic exchange. It regulates connectivity between the National Park ponds and Lake Erie proper. The barrier-beach is rarely breached, with only five breach events recorded between 1922 and 1983 (Surette 2006). Further research is required to determine if the isolated nature of these populations has in fact caused genetic divergence.

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. Warmouth occupies a residence during the stage of their life cycle when males build a nest to hold the fertilized eggs and newly-hatched larvae. Warmouth males build a nest before spawning in water depths ranging from 5–152 cm deep. In Illinois, Warmouth nests were observed in water 15–152 cm deep with the majority at depths of 61–76 cm. They were usually found along shallow sloping shorelines (Wallus and Simon 2008).

THREATS AND LIMITING FACTORS TO THE SURVIVAL AND RECOVERY

Element 8: *Assess and prioritize the threats to the survival and recovery of the Warmouth.*

THREAT CATEGORIES

There are many types of threats that negatively impact Warmouth across its range. Our knowledge of threat impacts on Warmouth populations is limited to general documentation, and research from US populations, as there is a paucity of threat-specific cause and effect information currently available for Canadian populations. The greatest threats to the survival and recovery of Warmouth in Canada are thought to be related to natural system modifications that have resulted in the loss of wetlands, as well as aquatic vegetation removal for residential, recreational, and transportation purposes.

Natural system modifications

One of the greatest threats to Warmouth is the loss of its preferred habitat consisting of heavily vegetated, shallow areas. Rondeau Bay has undergone extensive modifications. Much of the wetland habitat found along the western shoreline has been lost due to ditching, diking, infilling, and hardening of shoreline for both agricultural and residential purposes (Gilbert et al. 2007). Historically, wetlands bordered the entire shore of Rondeau Bay and appeared as a large contiguous system (Gilbert and Locke 2007). The first wetland assessment of Rondeau Bay was conducted in the early 1980s and, by this time, the wetland complex on the northwest shore had been reduced to isolated patches totaling approximately 740 ha, with a further reduction in 2006 to approximately 107 ha (Gilbert et al. 2007).

A similar situation exists in the Point Pelee area where it is estimated that close to 60% of the historical wetlands that once connected Point Pelee to Hillman Marsh were drained and diked during the late 1800s to mid-1900s for agricultural purposes (Parks Canada 2007). This loss of historical wetlands has undoubtedly decreased the amount of preferred habitat available for the Warmouth population at Point Pelee.

The feeding behaviour of Common Carp (*Cyprinus carpio*) and Goldfish (*Carassius auratus*) can negatively impact aquatic systems by uprooting aquatic vegetation and increasing turbidity levels (Lougheed et al. 1998, 2004). This feeding behaviour may have significant effects on Warmouth, which is dependent on aquatic vegetation for many of its life processes.

A study at Point Pelee National Park (Sanctuary Pond) was completed in 1994 to determine the cause of elevated nutrient concentrations leading to prolific algal growth. It was determined that organic matter decomposition was an important mechanism leading to high concentrations of nutrients and that resuspension of bottom sediment, primarily by Common Carp foraging behaviour, was most likely responsible for the hypereutrophic conditions (Mayer et al. 1999).

It is also well known that exotic aquatic macrophytes can drastically alter the aquatic vegetation complex by outcompeting native plants. One such invasive plant species is the European common reed (*Phragmites australis*), which forms dense monotypic stands, outcompeting native species (Gilbert and Locke 2007) and reducing the amount of open-water habitat. Common reed is found in abundance at Rondeau Bay and Long Point Bay and is not only reducing the native floral diversity (Gilbert et al. 2007, Badzinski et al. 2008), but high density stands can reduce the amount of available habitat for Warmouth. Future suitable habitat may be drastically reduced in Long Point Bay if climate change allows the spread of common reed through the reduction of water levels (McCusker 2017a). A second invasive macrophyte that may have both positive and negative effects on Warmouth is Eurasian watermilfoil (*Myriophyllum spicatum*). Collingsworth and Kohler (2010) indicated that small juvenile sunfish preferentially selected stands of Eurasian watermilfoil when compared to American pondweed (*Elodea canadensis*) stands, suggesting that the denser Eurasian watermilfoil stands may be providing superior protection from predation. However, Eurasian watermilfoil is also known to grow into dense vegetation mats, increasing phosphorus and nitrogen inputs, increasing pH and temperature, and creating potentially unsuitable habitat for Warmouth (Gilbert et al. 2007). This negative effect may be particularly relevant to Warmouth at Point Pelee National Park and Rondeau Bay where Eurasian watermilfoil can flourish under ideal growing conditions. The submerged macrophyte community on the western and central to northern sections of Rondeau Bay tend to be dominated by Eurasian watermilfoil and coontail (*Ceratophyllum demersum*), which have been noted to reach high densities, and biomass between 500 and 1300 g·m-2 dry weight (Gilbert et al. 2007). Studies are required to elucidate the overall effect of Eurasian watermilfoil on Warmouth populations.

Dreissenid mussels are pervasive throughout the Canadian range of Warmouth. The mussels have improved water clarity in some areas of the Great Lakes (Binding et al. 2007), leading to increased growth of both native and invasive aquatic macrophytes (Higgins and Vander Zanden 2010); however, the net effect on Warmouth cannot be readily determined.

Grass Carp (*Ctenopharyngodon idella*), native to Eurasia, has recently been found to be reproducing in Maumee Bay in western Lake Erie (Chapman et al. 2013). Grass Carp is an invasive herbivore known to severely negatively impact aquatic macrophytes (Wittmann et al. 2014). It is not known if Grass Carp will expand into the Canadian range of Warmouth within the next 10 years but, if it does, it could have a significant negative impact on Warmouth habitat.

Aquatic vegetation removal

A habitat modification that requires specific attention is the removal of aquatic vegetation for residential, recreational, and transportation purposes. Warmouth is highly dependent on heavily vegetated, shallow nearshore areas for many of its life processes. Warmouth is known to use these areas throughout its life cycle as spawning and nursery grounds, as well as foraging habitat. Destruction and removal of aquatic vegetation in the nearshore area of lakes and wetland systems may have detrimental effects on the associated Warmouth population. In addition to the implications of vegetation removal, the physical act of removing aquatic vegetation may also have negative impacts on Warmouth. It has been noted that the mechanical option is preferred to chemical treatment for both habitat and aesthetic reasons, as the mechanical option reduces the oxygen demand from decaying vegetation (Gilbert et al. 2007).

The rapid spread of invasive common reed has led to removal efforts at Long Point and Rondeau Bay. In response to the significant loss of open water habitat at Long Point, various levels of government have started removing common reed stands in areas of Warmouth occurrence to help benefit breeding waterfowl (Rook et al. 2016). This removal has occurred via an integrated pest management plan that has included spraying, rolling and burning vegetation (S. Reid, Ontario Ministry of Natural Resources and Forestry, pers. comm. 2018). Limited removal has occurred at Point Pelee National Park via mechanical means. There are no records of chemical vegetation removal at Point Pelee National Park (V. McKay, Parks Canada Agency, pers. comm. in Bouvier and Mandrak 2010). The removal of common reed may benefit Warmouth in the long term by allowing native vegetation to establish and by creating more open water habitat for the species. However, there is potential for displacement and mortality during the process of vegetation removal which should be taken under consideration by managers.

Historical large-scale removals in Rondeau Bay, and more recent small-scale removals in both Rondeau Bay and Long Point Bay have occurred for the purposes of recreation and transport. The primary reason for these removals is that the presence of submerged aquatic macrophytes can become a nuisance to recreational activities when it reaches high densities (Gilbert et al. 2007). In Rondeau Bay, authorized and unauthorized chemical and mechanical vegetation removal are common place (CBC News 2016, CBC News 2018).

Pollution

Degradation of Warmouth preferred habitat may result from increases in nutrient (nitrates and phosphorus) loading. Increased nutrient loading can be the result of fertilizer releases into the waterbody, loading from sewage treatment plants, and nutrient runoff from manure piles. These increased nutrient levels can subsequently lead to the development of algal blooms and, consequently, to decreased levels of dissolved oxygen once the blooms begin to senesce (Gilbert et al. 2007). Nutrient loading has been listed as a primary threat to Long Point Bay, Point Pelee National Park, and Rondeau Bay, which are all areas currently occupied by Warmouth (Essex-Erie Recovery Team 2008).

Nutrient samples taken from Rondeau Bay tributaries during two sampling periods (June and August) in 2005 and 2006 were compared to the Provincial Water Quality Guidelines (total phosphorus should not exceed 0.03 mg/L, Ontario Ministry of the Environment and Energy

1994). Samples from all tributaries in 2005, and all tributaries but one in 2006, exceeded the guideline (Gilbert et al. 2007). These elevated nutrient levels are thought to be the primary cause of prolific algal blooms that are a common occurrence in Rondeau Bay (Gilbert et al. 2007). An algal bloom, reaching thicknesses of approximately 1 m, covering 70% (3169 ha) of the surface of Rondeau Bay was recorded in 2005 (Gilbert et al. 2007). The bloom substantially altered the dissolved oxygen concentrations, which dropped to 5 mg/L (Gilbert et al. 2007). The bloom senesced in the winter months and resulted in the deposit of a thick organic material over the northern and eastern shorelines that smothered habitat and created anoxic zones (Gilbert et al. 2007).

Increases in sediment loading and turbidity may be detrimental to Warmouth survival and recovery. Warmouth was ranked as moderately intolerant to turbidity based on its occurrence and relative abundance pattern across a wetland turbidity gradient (Trebitz et al. 2007). Increases in sediment loading and turbidity can be attributed to poor agricultural and land management practices, improper drain maintenance practices, dredging activities, and the removal of riparian vegetation (Staton et al. 2012). Indirect negative effects of increased turbidity on Warmouth may include decreases in preferred habitat through decreased water clarity, which impedes light penetration leading to decreasing macrophyte growth, and resulting in a loss of habitat.

Siltation has been highlighted as an ongoing problem in Rondeau Bay where the presence of tile drainage has led to increased siltation, particularly relevant during storm events (Gilbert et al. 2007). It has been suggested that a reduction in sediment inputs from point and non-point sources would greatly contribute to the restoration of Rondeau Bay (Gilbert et al. 2007).

At Point Pelee National Park, altered sediment transport along the Lake Erie shoreline has increased erosion of the barrier beach, leading to increases in breaching events (Surette 2006, Parks Canada 2007). This has resulted in water quality declines, including increases in turbidity levels in the park (V. McKay, Parks Canada Agency, pers. comm. in Bouvier and Mandrak 2010)

An evident turbidity plume has been noted in Long Point Inner Bay originating from the mouth of Big Creek (Bouvier and Mandrak 2010). Although turbidity values are currently not available for this area, the extent of the turbidity plume does encompass the area of occurrence for Warmouth, and may be negatively impacting Warmouth habitat.

Human intrusions and disturbance

Incidental harm on Warmouth during implementation of scientific research is thought to be minimal. Precautionary steps are taken to ensure that there is minimal to no harm to the individuals being collected. Provincial and national park scientific collection permits are required for fish sampling in Ontario and would stipulate that all species at risk must be immediately released.

Recreational boating can impact Warmouth especially in narrow shallow canals where wakes and propellers can disturb fish and fish habitat. This activity is likely more prevalent in Long Point and Rondeau bays, the impacts of which have not been quantified.

Residential and commercial development

A distinct challenge presents itself when considering the effect of development on Warmouth at Long Point Bay as various regions within the bay are facing varying levels of development pressure. Big Creek Marsh would face very little development pressures as this is a National Wildlife Area, which is afforded protection and is managed by Canadian Wildlife Service, Environment Canada. The northwestern shore of the bay faces increasing pressures from residential developments and the construction of marinas.

There remains a very small percentage of natural forest cover (~3.3%) throughout the Rondeau Bay watershed. It is estimated that approximately 70% of the western shoreline has been reclaimed for agricultural or residential use (Gilbert and Locke 2007). Expanding land for farming or residential properties has come at the expense of the nearshore wetlands (Gilbert and Locke 2007).

Biological resource use

The use of Warmouth as a baitfish is illegal in Ontario (Ontario Ministry of Natural Resources 2018). However, as with most fisheries, the potential exists for capturing non-target fishes as bycatch during angler and commercial baitfish harvest. The degree of bycatch is dependent on the distribution and intensity of baitfish harvest in relation to the distribution of Warmouth. Bycatch of Warmouth during angler harvest of bait is currently unknown, due to uncertain angler practices (Drake and Mandrak 2014a), but commercial harvest practices have been estimated (Drake and Mandrak 2014b). Drake and Mandrak (2014b) estimated Warmouth bycatch potential from Great Lakes tributaries and determined that the probability of randomly selecting a tributary harvest site containing target baitfishes and Warmouth was P = 0.000087 (rarer than 1 out of 11000 sites). Based on a generic harvest model, estimated bycatch-effort relationships indicated that 34,246 harvest events would be necessary for a single event to have a median 95% chance of capturing Warmouth as bycatch during the pursuit of target species (Drake and Mandrak 2014b). Non-target species closely related to Warmouth predicted to be captured frequently, such as Rock Bass and Pumpkinseed (*Lepomis gibbosus*), would require only 17 events for a single event to reach the 95% threshold. The estimated capture probabilities of Warmouth were among the lowest of all species in Ontario waters. A study of the Ontario baitfish pathway (Drake 2011, Drake and Mandrak 2014a) did not document Warmouth during sampling of baitfish retailers (n = 68) or purchased fishes (a cumulative total of 16,886 fishes) in southern Ontario during August–October 2007 and February 2008 (Drake 2011, Drake and Mandrak 2014a).

Sunfishes have been targeted by recreational anglers in Ontario (Wood and Roovers 1978). However, Warmouth is not considered a ‘Sunfish’ under the Ontario Fishery Regulations, and may not be legally caught under a recreational fishing licence. Although sunfishes have a reasonably high degree of angling effort in Ontario, the restricted distribution of Warmouth and relative rarity where found indicate that recreational angling for other fish species likely has a negligible impact on Warmouth.

Incidental catch of Warmouth in commercial fishing does occur. During 2011–12 and 2017–18, a total of 771 Warmouth were captured as by-catch by commercial trap nets in Long Point Bay (OMNRF unpublished data). Unfortunately, commercial fishing effort during that four year period is unknown. However, a study was conducted in 2009 at Long Point Bay on the effects of commercial fishing on aquatic species at risk (Gislason et al. 2010). In this study, 368 commercial hoop net lifts were monitored for aquatic species at risk, and 141 Warmouth were recorded (0.38 catch per lift; Gislason et al. 2010). Unfortunately, Warmouth abundance estimates in Long Point Bay are not available; creating a challenge in determining what proportion of the population is being affected by commercial fishing practices. As a result of this study, outreach has been undertaken to make fishers aware of the species at risk that they may by-catch and must release (N. Mandrak, University of Toronto at Scarborough, pers. comm.). Increased educational outreach will decrease any potential negative effects of commercial fishing on Warmouth. In addition, the effects of the draw-seine commercial fishing industry on Warmouth at Long Point are currently unknown and require additional research.

Invasive and other problematic species and genes

Round Goby (*Neogobius melanostomus*) are pervasive throughout the Canadian range of Warmouth. The effect of this species on Warmouth is unknown. Potential egg predation by Round Goby could be problematic for Warmouth but any potential direct effects of Round Goby require further investigation.

Climate change and severe weather

Through discussion of the effects of climate change on Canadian fish populations, impacts such as increases in water and air temperatures, changes (decreases) in water levels, shortening of the duration of ice cover, increases in the frequency of extreme weather events, emergence of diseases, and shifts in predator-prey dynamics have been highlighted, all of which may negatively impact native fishes (Lemmen and Warren 2004). Aligning with the current hypothesis that Warmouth dispersal and colonization into Canadian waters may be restricted by current water temperatures (Crossman et al. 1996), an increase in water temperature, as a result of climate change, may allow for increased dispersal and colonization into novel habitats (McCusker 2017a, b). However, a study of Warmouth habitat at Point Pelee indicated that climate change may reduce water levels within the national park (McCusker 2017b). Therefore, the overall impact of climate change on Warmouth at Point Pelee is unknown. Conversely, Warmouth may be particularly sensitive to the effects of climate change due to its thermal and habitat associations, leading to negative overall effects on Warmouth populations. This is supported by an assessment on fish species vulnerability to climate change, in which Warmouth ranked second most sensitive species when compared to 98 other species assessed (Doka et al. 2006). Changes to aquatic vegetation as a result of climate change has the potential to impact Warmouth populations in Ontario. For example, common reed may spread at Long Point Bay as a result increasing water temperature and decreased water levels which has the potential to significantly reduce Warmouth habitat (McCusker 2017a). A recent paper by Brinker et al. (2018) calculated a Climate Change Vulnerability Index score for Warmouth as “Less Vulnerable”. The discrepancies between published scores pertaining to the vulnerability of Warmouth to climate change may have resulted due to differing models used to predict these changes. This highlights the uncertainty underlying any potential impacts that climate change will have on Warmouth abundance in Ontario.

THREAT ASSESSMENT

The threat assessment was completed following guidelines provided 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) on a population-by-population basis. 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). 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 (Table 6). The Likelihood of Occurrence and Level of Impact for each population were subsequently combined in the Threat Risk Matrix (Table 7) resulting in the Population-Level Threat Risk (PTR, Table 8). The Species-level Threat Assessment in Table 9 is a roll-up of 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) Information taken 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 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.
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.

Term	Definition
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 (NA)	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 (PTE) for Warmouth populations in Ontario.

	Point Pelee							Long Point Bay							Rondeau Bay						
	LO	**LI**	**CC**	**PTO**	**PTF**	**PTE**	**Ref.**	**LO**	**LI**	**CC**	**PTO**	**PTF**	**PTE**	**Ref.**	**LO**	**LI**	**CC**	**PTO**	**PTF**	**PTE**	**Ref.**
Natural system modifications	K	M	4	H,C	C	E	1, 5	K	M	4	H,C	C	E	3,4	K	H	4	H,C	C	E	2,3, 4
Aquatic vegetation removal	K	L	4	H,C	R	B	6	K	M	4	H,C	R	NA	6	K	H	4	H,C	R	NA	2
Pollution	K	L	4	H,C	C	E	6,7, 8,9	K	L	4	H,C	C	E	7,8,9	K	M	4	H,C	C	E	2,7, 8,9
Human intrusions and disturbance	K	L	4	H,C	R	R	-	K	L	4	H,C	R	R	-	K	L	4	H,C	R	R	-
Residential and commercial development	R	L	4	H	R	B	-	K	L	4	H,C	R	B	-	K	L	4	H,C	R	B	2
Biological resource use	UL	L	4	H,C	R	R	10, 11	K	L	4	H,C	R	R	10, 11	K	L	4	H,C	R	R	10,1 1
Invasive and other problematic species and genes	U	U	4	H,C	C	E	-	U	U	4	H,C	C	E	-	U	U	4	H,C	C	E	-
Climate change and severe weather	K	U	5	C, A	C	E	12	K	U	5	C,A	C	E	12	K	U	5	C,A	C	E	12

References: 1. Parks Canada (2007); 2. Gilbert et al. (2007); 3. Gilbert and Locke (2007); 4. Badzinski et al. (2008); 5. Mayer et al. (1999); 6. Bouvier and Mandrak (2010); 7. Essex-Erie Recovery Team (2008); 8. Treblitz et al. (2007); 9. Staton et al. (2012); 10. Drake and Mandrak (2014a); 11. Drake and Mandrak (2014b); 12. Doka et al. (2006)

Table 7. The Threat Level Matrix combines the Likelihood of Occurrence and Level of Impact rankings to establish the Threat Level for Warmouth populations in Ontario. The resulting Threat Level has been categorized low, medium, high or unknown.

		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 for Warmouth populations in Ontario, resulting from an analysis of both the Threat Likelihood and Threat Impact. The number in brackets refers to the level of certainty associated with the threat impact (1 = Very High; 2 = High; 3 = Medium; 4 = Low; 5 = Very Low).

Threat	**Point Pelee**	**Long Point Bay**	**Rondeau Bay**
Natural system modifications	Medium (4)	Medium (4)	High (4)
Aquatic vegetation removal	Low (4)	Medium (4)	High (4)
Pollution	Low (4)	Low (4)	Medium (4)
Human intrusions and disturbance	Low (4)	Low (4)	Low (4)
Residential and commercial development	Low (4)	Low (4)	Low (4)
Biological resource use	Low (4)	Low (4)	Low (4)
Invasive and other problematic species and genes	Unknown (4)	Unknown (4)	Unknown (4)
Climate change and severe weather	Unknown (5)	Unknown (5)	Unknown (5)

Table 9. Species-level Threat Assessment for Warmouth in Canada, resulting from a roll-up of population-level Threat Assessment. Species-level Threat Risk, Threat Occurrence (H = Historical; C = Current; A = Anticipatory), Threat Frequency (S = Single; R = Recurrent; C = Continuous), and Threat Extent (E = Extensive; B = Broad; NA= Narrow; R = Restricted).The species-level Threat Extent is calculated as the mode of population-level Threat Extent.

Threat	**Species-level Threat Risk**	**Species-level Threat Occurrence**	**Species-level Threat Frequency**	**Species-level Threat Extent**
Natural system modifications	**High (4)**	H, C	S, R, C	E
Aquatic vegetation removal	**High (4)**	H, C	C	NA

Threat	Species-level Threat Risk	Species-level Threat Occurrence	Species-level Threat Frequency	Species-level Threat Extent
Pollution	**Medium (4)**	H, C	R	E
Human intrusions and disturbance	**Low (4)**	H, C	R	R
Residential and commercial development	**Low (4)**	H, C	R	B
Biological resource use	**Low (4)**	H, C	R	R
Invasive and other problematic species and genes	**Unknown (4)**	H, C	C	E
Climate change and severe weather	**Unknown (5)**	C, A	C	E

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.*

The greatest threats to the recovery and survival of Warmouth in Canada is the removal of aquatic vegetation and natural system modifications. Aquatic vegetation removal is of particular importance for Rondeau Bay and Long Point Bay populations where authorized and unauthorized aquatic vegetation removals are known to occur. Natural system modifications include the draining of wetlands for agricultural and urban development, and changes to aquatic habitat that are occurring via invasive species such as Common Carp, common reed, and Eurasian watermilfoil. The three populations are found in areas that have seen a drastic reduction in the amount of wetland habitat since the late 1800s. These activities have resulted in the destruction of vast amounts of preferred aquatic habitat for Warmouth. Furthermore, the feeding behavior of Common Carp uproots aquatic vegetation and increases turbidity in Warmouth habitats. Changes in turbidity can also affect macrophyte growth by decreasing light penetration through the water column. The subsequent loss of aquatic vegetation can be detrimental to Warmouth as aquatic macrophytes are used throughout its lifecycle. Exotic macrophytes are also altering habitat by outcompeting native plants and reducing the amount of open water habitat. Dense monotypic stands of common reed have decreased the amount of available habitat for Warmouth and Eurasian watermilfoil grow in dense mats that can subsequently change aquatic habitats by affecting light penetration. This decreases the growth of submerged vegetation and can increase temperature, and pH leading to decreasing habitat quality for Warmouth. These three invasive species would affect a high proportion of Warmouth habitat in Canada as they are found throughout the Lake Erie drainage. Currently, pressures from agricultural and urban development are affecting large proportions of the Long Point and Rondeau populations whereas the Point Pelee population’s habitat is part of a protected national park.

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

Warmouth is found in only three locations in Canada and has limited dispersal ability (COSEWIC 2015). The distance (> 50 km) between these three populations suggests that they may be genetically isolated from each other. Lack of continuous optimal habitat between these populations make it unlikely that individuals from one population could act as rescue for another. This makes Warmouth particularly vulnerable to large-scale catastrophes.

> **Element 11:** Discuss the potential ecological impacts of the threats identified in element 8 to Warmouth 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.

Aquatic vegetation removal and natural system modifications as a result of agricultural development are the greatest threats to Warmouth in Canada. Coastal wetland habitat has been greatly reduced through dyking, and infilling for the purposes of urbanization and agriculture. In addition to the reduction of coastal wetland habitat, degradation also occurs via exotics such as Common Carp and common reed. In Ontario, Warmouth co-occurs with other SARA-listed species such as Spotted Gar (*Lepisosteus oculatus*), Pugnose Shiner (*Notropis anogenus)*, and Lake Chubsucker (*Erimyzon sucetta).* If this threat is abated, there will be positive impacts to Warmouth as well as these other co-occurring species at risk. Increasing wetland habitat quality by decreasing turbidity, and allowing for growth of native aquatic macrophytes will help support Warmouth populations and other SARA-listed fishes.

Warmouth is a poorly monitored species in Canada as there is no directed monitoring effort. The majority of records are incidentally caught in fish community sampling, other field studies or in commercial fishery bycatch in the three areas where Warmouth are found.

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 or undertakings associated with projects, or activities in Warmouth habitat.

Within Warmouth habitat, a variety of works, undertakings, and activities have occurred in the last five years with project types including: aquatic vegetation removal; shoreline and streambank works (e.g., stabilization); and the placement of structures in water (e.g., boat launches and docks). A review has been completed summarizing the types of work, activity, or projects that have been undertaken in habitat known to be occupied by Warmouth (Table 10). The DFO Program Activity Tracking for Habitat (PATH) database, has been reviewed to estimate the number of projects that have occurred during a five-year period from 2013 through 2018. Thirty six (36) projects were identified in Warmouth habitat, but these likely do not represent a complete list of projects or activities that have occurred in these areas (Table 10). Some projects occurring in proximity but not in the area of habitat may also have impacts, but were not included. Some projects may not have been reported to DFO as they may have met self-assessment requirements and were not required to be reported. A number of projects may also have been completed utilizing Best Management Practices (BMP) as DFO had produced a BMP document for Long Point that identified that projects such as dredging existing boating channels could take place as long as certain measures were followed.

The only projects authorized under Canada’s Fisheries Act were for spraying to control phragmites in both Rondeau and Long Point. Most projects were deemed low risk to fishes and fish habitat and were addressed through letters of advice with standard mitigation. Eight projects were triaged out as mitigation was in place or there was no in-water work (e.g., shoreline stabilization on the bank with no in-water footprint). Without appropriate mitigation, projects or activities occurring adjacent or close to these areas could have impacted Warmouth (e.g., increased turbidity or sedimentation from upstream channel works).

The most frequent project type was for aquatic vegetation removal and shoreline stabilization. Based on the assumption that historical and anticipated development pressures are likely to be similar, it is expected that similar types of projects will likely occur in or near Warmouth habitat in the future. The primary project proponents were adjacent landowners and cottagers.

There are a number of dredging projects currently proposed which would likely impact Warmouth, but these areas are also in areas currently identified as critical habitat for Spotted Gar. The measures that may be used to protect critical habitat should therefore be protective for Warmouth. It should also be mentioned that there have been some unauthorized dredging projects that have taken place which likely impacted Warmouth habitat.

It should also be mentioned that one of the significant activities taking place in these areas is recreational boating and fishing and future increases in activity could potentially impact Warmouth.

Numerous threats affecting Warmouth populations are related to habitat loss or degradation. Habitat-related threats to Warmouth have been linked to the Pathways of Effects developed by DFO Fish Habitat Management (FHM) (Table 10). DFO FHM has developed guidance on mitigation measures for 19 Pathways of Effects for the protection of aquatic species at risk in the Central and Arctic Region (Coker et al. 2010). This guidance should be referred to when considering mitigation and alternative strategies for habitat-related threats. Additional mitigation and alternative measures, specific to Warmouth, related to invasive species and incidental harvest are listed below.

Table 10. Summary of works, projects and activities that have occurred during the period of November 2013 to November 2018 in areas known to be occupied by Warmouth. Threats known to be associated with these types of works, projects, and activities have been indicated by a checkmark. The number of works, projects, and activities associated with each Warmouth population, as determined from the project assessment analysis, has been provided. Applicable Pathways of Effects have been indicated for each threat associated with a work, project 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/Project/Activity	**Threats** (associated with work/project/activity)								**Watercourse / Waterbody** (number of works/projects/activities between November 2013– November 2018)			
	Natural system modifications	**Aquatic vegetation removal**	**Pollution**	**Residential & commercial development**	**Human intrusions and disturbance**	**Biological resource use**	**Invasive and other problematic species and genes**	**Climate change and severe weather**	**Point Pelee National Park**	**Rondeau Bay**	**Long Point Bay**	**Hillman Marsh**
Applicable pathways of effects for threat mitigation and project alternatives	1, 2, 3, 4, 5, 7, 9, 10, 11, 12, 13, 15, 18	1, 3, 5, 11, 15	1, 2, 3, 4, 5, 6, 7, 8, 19, 11, 12 ,13, 14, 15, 16,18	1, 2, 3, 4, 5 ,6, 10, 11, 12, 14, 15								
Water crossings (bridges, culverts, open-cut crossings)	✓		✓	✓					1	2	1	
Shoreline, streambank work (stabilization, infilling, retaining walls, riparian vegetation management)	✓		✓	✓						6	2	

Work/Project/Activity	Threats (associated with work/project/activity)								Watercourse / Waterbody (number of works/projects/activities between November 2013– November 2018)			
	Natural system modifications	Aquatic vegetation removal	Pollution	Residential & commercial development	Human intrusions and disturbance	Biological resource use	Invasive and other problematic species and genes	Climate change and severe weather	Point Pelee National Park	Rondeau Bay	Long Point Bay	Hillman Marsh
Applicable pathways of effects for threat mitigation and project alternatives	1, 2, 3, 4, 5, 7, 9, 10, 11, 12, 13, 15, 18	1, 3, 5, 11, 15	1, 2, 3, 4, 5, 6, 7, 8, 19, 11, 12 ,13, 14, 15, 16,18	1, 2, 3, 4, 5 ,6, 10, 11, 12, 14, 15								
In-stream works (channel maintenance, restoration, modifications, realignments, dredging, aquatic vegetation removal)	✓	✓	✓	✓						8	6	3
Water management (stormwater management, water withdrawal)			✓	✓								
Structures in water (boat launches, docks, effluent outfalls, water intakes, dams)	✓		✓	✓						4	4	
Baitfishing						✓						
Invasive species introductions (accidental and intentional)							✓					

Human intrusion and disturbance

As discussed in the Threats and Limiting Factors section, there is thought to be minimal disturbance during implementation of scientific research. Provincial and national park scientific collection permits are required for fish sampling in Ontario and would stipulate that all species at risk must be immediately released.

Mitigation

- Use of non-lethal sampling methods. Ensure that personnel are able to identify Warmouth in the field in order to minimize stress.
- Improve co-ordination of sampling to reduce duplication of sampling at sites.

Alternatives

- Consider allowable-harm recommendations when collection for scientific purposes is necessary.

Biological resource use

Although the use of Warmouth as baitfish is illegal, the potential exists for capturing non-target fishes as bycatch during angler and commercial baitfish harvest.

Mitigation

- Provide information and education to commercial and bait harvesters, and recreational anglers on Warmouth to raise awareness. This should include education on the use of baitfish alternatives when fishing as well as voluntary avoidance of Warmouth-occupied areas.
- Immediate release of Warmouth if incidentally caught as defined under the Ontario Recreational Fishing Regulations (Ontario Ministry of Natural Resources 2018).
- Introduction of timing windows so commercial and recreational fishing do not occur during Warmouth spawning season.
- Education through mandatory training on species at risk for commercial harvesters.

Alternatives

- Seasonal or zonal restrictions applied to harvesting/fishing during warmouth spawning season.
- Restrict gear type used to catch baitfish to minimize the probability of Warmouth capture.
- Prohibition on the commercial and recreational fishing industry in areas where Warmouth is known to exist.

Invasive and other problematic species and genes

As discussed in the Threats and Limiting Factors section, Round Goby and dreissenid mussels are pervasive in the Canadian range of Warmouth. Common Carp, and Asian carp species, such as the Grass Carp (*Ctenopharyngodon idella*) could also have negative effects on Warmouth populations.

Mitigation

- Monitor for invasive species that may negatively affect Warmouth populations directly, or negatively affect Warmouth preferred habitat.
- Develop a plan to address potential risks, impacts, and proposed actions if monitoring detects the arrival or establishment of an invasive species.
- Establish “Safe Harbours” in areas known to have suitable Warmouth habitat. Safe Harbours work to minimize the impact or prevent the introduction of invasive species through best management practices.
- Implement a rapid response plan if invasive species are detected to eradicate or control them.
- Introduction of a public awareness campaign and encourage the use of existing invasive species systems.

Alternatives

- Unauthorized introductions
- There are no alternatives for unauthorized introduction because unauthorized introductions should not occur.
- Authorized introductions
- Use only native species.
- Do not carry out introduction where Warmouth is known to exist.
- Follow the National Code on Introductions and Transfers of Aquatic Organisms for all aquatic organism introductions (DFO 2017).

Element 17: *Develop an inventory of activities that could increase the productivity or survivorship parameters (as identified in elements 3 and 15).*

The mitigation measures outlined above are consistent with the goal of increasing survivorship, by reducing threats to the species directly (e.g., invasive species, bait harvest) or indirectly by improving habitat quality (e.g., reducing threats of natural system modification).

Element 18: *If current habitat supply may be insufficient to achieve recovery targets (see element 14), provide advice on the feasibility of restoring the habitat to higher values. Advice must be provided in the context of all available options for achieving abundance and distribution targets.*

The feasibility of rehabilitating or restoring degraded habitat features due to wetland habitat loss, aquatic vegetation removal, and pollution in the watersheds that are occupied by Warmouth has not been assessed. However, actions to reduce vegetation removal, and agricultural and municipal pollution inputs are likely to result in increased quantity and quality of habitat.

SOURCES OF UNCERTAINTY

Few studies have been conducted on Warmouth in the past, likely due to several factors including low abundance, disjunct and small distribution, and its relatively recent discovery in Canada. It is considered to be Ontario’s rarest sunfish (Holm et al. 2010). Warmouth remains a poorly monitored species, and is not generally the focus of search efforts when it has been detected. The species is subjected to continuing decline in habitat quality due to a complexity of ecosystem modifications. Its preferred vegetated habitat is being replaced by dense beds of non-native aquatic plants, and eutrophication is occurring as a result of agricultural runoff. Knowledge gaps exist surrounding its life cycle, habitat needs, and population abundance. Additional data on the abundance and distribution of the species are needed to determine the current population status and trends. Further studies on the Warmouth are essential to the successful implementation of recovery strategies.

The spatial extent of suitable Warmouth habitat requires additional research. These areas should be the focus of future targeted sampling efforts for this species. There is also a need to refine habitat requirements for each life stage. There is very little information available for habitat requirements for most life stages (spawn to hatch, YOY, juvenile), necessitating the inference of these requirements from the adult life stage. Larval surveys are needed to identify both spawning and nursery grounds.

Numerous threats have been identified for Warmouth populations in Ontario. There is a need for more causative studies to evaluate the impact of each threat on the remaining three Warmouth populations. There is a need to determine threshold levels for water quality parameters (e.g., nutrients, turbidity) and to determine physiological parameter limits including temperature, pH, dissolved oxygen, and pollution tolerance.

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APPENDIX 1

Table A1.1. Summary of historical and current fish sampling effort within the known distribution of Warmouth in Point Pelee. Gray cells represent sampling events that have failed to detect Warmouth, Lepomis gulosus. *n = Number captured; UK = Unknown.*

Waterbody	n	Year	Sampling effort	Reference
Point Pelee	0	1913–1982	-15 different years in this time period	Canadian Museum of Nature, Royal Ontario Museum (ROM) Point Pelee National Park
			-mostly completed by seine	(PPNP) staff [see Surette (2006) for complete details]
Point Pelee	2	1983	-hoop net set (< 24 h x 39 sets)	G. Mouland, PPNP, unpublished data (received from J. Keitel, PPNP)
Point Pelee	UK (> 1)	1989	-seine net (5 days) -creel survey (unknown effort)	E. Holm and D. Boehm (ROM unpublished data) K. Janoki and G. Mouland, PPNP (Surette 2006)
Point Pelee	0	1992	-creel survey (unknown effort)	T. Linke (Surette 2006)
Point Pelee	11	1993	-trap net (48 h set x 3 sites x 2 events) -seine (10 m x 5 hauls)	Dibble et al. (1995)
Point Pelee	UK (> 1)	1997	-seine (2 days) -plastic trap (5 days) -boat electrofisher (4.3 h)	E. Holm, D. Boehm and M. Ciuk (ROM unpublished data)
Hillman Marsh	0	2002	-Bag Seine; 1/4" mesh; Length, 8.5 metres; 9 sites; 1 haul per site	DFO unpublished data
Hillman Marsh	0	2002	-14' Efishing Boat (LOWE), 5.0 Kw, single boom; 1 site; 3363 seconds	DFO unpublished data
Point Pelee	0	2002	-boat electrofisher (4 sites)	N. Mandrak, DFO, unpublished data
Point Pelee	0	2002	-hoop net (24 h sets x 5 sites) -trap net (24 h sets x 3 sites)	N. Mandrak, DFO, unpublished data
Point Pelee	657	2002–2003	-seine (55 events) -minnow trap (80 events) -Windermere trap (80 events) -trap net (28 events) -hoop net (342 events)	Surette (2006)
Point Pelee	1	2003	-boat electrofisher (100 m x 18 sites) -fyke net (24 h set x 8 sites)	L. Bouvier, DFO, unpublished data
Point Pelee	0	2004	-boat electrofisher (100 m x 18 sites x 2 events) -fyke net (24 h set x 8 sites x 2 events)	L. Bouvier, DFO, unpublished data
Point Pelee	1	2005	-3 paired fyke nets (2 large and 1 small x 2 sites)	Razavi (2006)
Point Pelee	6	2009	-fyke net (24 h set x 16 sets)	B. Glass, U. Windsor, unpublished data
Hillman Marsh	0	2011	-fyke net (effort unknown)	J. Ciborowski, U. Windsor, unpublished data
Hillman Marsh	0	2016	-fyke net (24 h set x 1 set)	J. Ciborowski, U. Windsor, unpublished data
Point Pelee	0	2016	-fyke net (20 h set)	Tara Bortoluzzi, Parks Canada, unpublished data
Hillman Marsh	1	2017	-fyke net (24 h set)	J. Ciborowski, U. Windsor, unpublished data
Hillman Marsh	24	2017	-mini fyke net(1/8" ace mesh, 1/8" ace mesh 2'x15' lead, 2' hoops, 2'x4' box; ~2544 h total set time) -bag seine (1/8" bag mesh, 1/8" wing mesh, length – 10 m; 78 hauls)	F. Montgomery, University of Toronto, unpublished data

Table A1.2. Summary of historical and current fish sampling effort within the known distribution of Warmouth in Rondeau Bay. Gray cells represent sampling events that have failed to detect Warmouth, Lepomis gulosus. n = Number captured; UK = Unknown.

Waterbody	n	Year	Sampling effort	Reference
Rondeau Bay	0	1921–1965	-14 different years	CMN & ROM (ROM, unpublished data)
Rondeau Bay	1	1966	-unknown effort	Crossman and Simpson (1984)
Rondeau Bay	2	1967	-unknown effort	Crossman and Simpson (1984)
Rondeau Bay	5	1968	-unknown effort	Crossman and Simpson (1984)
Rondeau Bay	2	1999	-unknown effort	ROM, unpublished data
Rondeau Bay	0	2002	-boat electrofisher (10 sites; Unknown effort)	N. Mandrak, DFO, unpublished data
Rondeau Bay	0	2004	-boat electrofisher (> 1000 s/500 m site x 10 sites) -hoop net (24 h set x 28 sites)	N. Mandrak, DFO, unpublished data
Rondeau Bay	2	2005	-hoop net (24 h set x 24 sites)	N. Mandrak, DFO, unpublished data
Rondeau Bay	0	2005	-bag seine (1 haul x 3 sites; 2 hauls x 5 sites; 3 hauls x 14 sites) -boat seine (1 haul x 5 sites)	N. Mandrak, DFO, unpublished data
Rondeau Bay	3	2007	-fyke net (24 h set x 128 sets)	B. Glass, U. Windsor, unpublished data
Rondeau Bay	4	2008	-fyke net (24 h set x 126 sets)	B. Glass, U. Windsor, unpublished data
Rondeau Bay	5	2009	-fyke net (24 h set x 78 sets)	B. Glass, U. Windsor, unpublished data
Rondeau Bay	1	2009	-fyke net (unknown effort)	M. Belore, OMNR, LEMU, unpublished data
Rondeau Bay	1	2011	-unknown gear and effort	C. Scott, OMNR, LEMU, unpublished data
Rondeau Bay	1	2013	-hoop net (24 h sets x 21 sites)	N. Mandrak, DFO, unpublished data
Rondeau Bay	0	2013	-bag seine (1 haul x 36 sites) -quatrefoil light trap (24 h sets x 21 sites) -pelagic trawl (100 m x 1 pass x 14 sites; 100 m x 3 passes x 1 site)	N. Mandrak, DFO, unpublished data
Rondeau Bay	9	2013	-mini fyke net (24 h sets x 14 sites)	D. Marson, DFO, unpublished data
Rondeau Bay	0	2013	-boat electrofisher (4 x 100 m x 11 sites)	D. Marson, DFO, unpublished data
Mill Creek	1	2013	-fyke net (4 sites); unknown effort	J. Ciborowski, U. Windsor, unpublished data
Rondeau Bay	4	2015	-hoop net (24 h sets x 3 sites -fyke net (24 h set)	DFO unpublished data
Rondeau Bay	9	2016	-mini fyke net (1/8" mesh, two 2'x4' box, two 2' hoops, 2'x25' lead, 2'x15' wings, 3" winker opening x 116.2 h total set time)	DFO unpublished data
Flat Creek, Indian Creek, McGeachy Pond, McLeans Drain,Mill Creek, Rondeau Bay	0	2016	-mini fyke net (1/8" mesh, two 2'x4' box, two 2' hoops, 2'x25' lead, 2'x15' wings, 3" winker opening; 971.2 h set total)	DFO unpublished data

Waterbody	n	Year	Sampling effort	Reference
Rondeau Bay	0	2017	-trammel net (10' deep, 200 yds length, 4" bar mesh, 18" outer walls; 254 min total set time?) -trap net (241.8 h set) -tied-down gill net (4" bar; 12' tied down to 10' - 200 yards length; 157 min) -mini fyke net (1/8" ace mesh, 1/8" ace mesh 2'x15' lead, 2'hoops, 2'x4' box; 291.9 h total set time) -boat electrofisher (24 ft. 7.5 GPP; dual boom; 13755 s)	DFO unpublished data
Hobblethwaite Drain Wetland	0	2017	-fyke net (24 h set); unknown number of sets	J. Ciborowski, U. Windsor, unpublished data
Rondeau Bay	4	2017	-mini fyke net (1/8" ace mesh, 1/8" ace mesh 2'x15' lead, 2' hoops, 2'x4' box, 2 sets; 48.09 h total) -boat electrofisher (24 ft., 7.5 GPP; dual boom; 1200 s)	DFO unpublished data
Rondeau Bay	2	2018	-bag seine (1/8" bag mesh, 1/8" wing mesh, Length - 10m; 3 hauls) -boat electrofisher (24 ft., 7.5 GPP; dual boom; 600 seconds)	DFO unpublished data

Table A1.3. Summary of historical and current fish sampling effort within the known distribution of Warmouth in Long Point Bay. Gray cells represent sampling events that have failed to detect Warmouth, Lepomis gulosus. *n = Number captured; UK = Unknown.*

Waterbody	n	Year	Sampling effort	Reference
Long Point Bay	0	1982–2018	-2,217 trawls at 16 sites; 6.1-m modified Biloxi bottom trawl; 10 minute tows was the unit of measure	OMNRF unpublished data
Long Point Bay	1	2003	-boat electrofisher (50 m x 18 sites x 2 events) -fyke net (24 h set x 4 sites x 2 events)	L. Bouvier, DFO, unpublished data
Long Point Bay	0	2004	-boat electrofisher (50 m x 18 sites x 2 events) -fyke net (24 h set x 4 sites x 2 events)	L. Bouvier, DFO, unpublished data
Long Point Bay	0	2004	-boat electrofisher [< 1000 s (1 pass) x 47 sites; > 1000 s (2 passes) x 10 sites)]	N. Mandrak, DFO, unpublished data
Big Creek Marsh	4	2004	-boat electrofisher (50 m x 15 sites x 2 events) -fyke net (24 h set x 4 sites x 2 events)	L. Bouvier, DFO, unpublished data
Big Creek Marsh	0	2005	-seine (2 hauls x 1 site)	N. Mandrak, DFO, unpublished data
Long Point Bay	0	2005	-hoop net (24 h sets x 24 sites)	N. Mandrak, DFO, unpublished data
Big Creek Marsh	11	2005	-hoop net (24 h set x 26 sites)	N. Mandrak, DFO, unpublished data
Long Point Bay	0	2007	-hoop net (24 h sets x 58 sites) -seine (1 haul x 2 sites; 2 hauls x 9 sites; 3 hauls x 3 sites; 4 hauls x 1 site)	N. Mandrak, DFO, unpublished data
Long Point Bay	1	2007	-seine (33 sites)	K. Oldenburg, OMNR Lake Erie Management Unit (LEMU), unpublished data
Long Point Bay	1	2007	-boat electrofisher (524-3860 s x 9 sites)	N. Mandrak, DFO, unpublished data
Big Creek	0	2008	-boat electrofisher (422-843 s x 10 sites); boat seine (1 haul x 3 sites; 3 hauls x 6 sites; 4 hauls x 1 site); bag seine (3 hauls x 1 site)	N. Mandrak, DFO, unpublished data
Crown Marsh	0	2008	-minnow traps (24 h x 9 sites) -seine (3 sites)	K. Oldenburg, OMNR LEMU, unpublished data

Waterbody	n	Year	Sampling effort	Reference
Cedar Creek	0	2008	-seine (3 sites)	K. Oldenburg, OMNR LEMU, unpublished data
Turkey Point	0	2009	-minnow trap (24 h x 12 sites); -fyke net (22 sites)	K. Oldenburg, OMNR LEMU, unpublished data
Bluff Bar	0	2009	-electrofisher (4 sites)	K. Oldenburg, OMNR LEMU, unpublished data
Long Point Bay	141	2009	-hoop net (24 h set x 368 events)	Gislason et al. (2010)
Crown Marsh	4	2009	-electrofisher (5 sites)	K. Oldenburg, OMNR LEMU, unpublished data
Turkey Point	1	2009	-electrofisher (8 sites)	K. Oldenburg, OMNR LEMU, unpublished data
Long Point Bay	10	2010	-fyke net (24 h set x 129 sets)	B. Glass, U. Windsor, unpublished data
Murray Marsh	1	2010	-hoop net (24 h set x 23 sets)	J. Wilson, Long Point Conservation Authority (LPCA), unpublished data
Big Creek	7	2011	Unknown effort	J. Wilson, LPCA, unpublished data
Turkey Point Marsh	1	2011	Unknown effort	J. Wilson, LPCA, unpublished data
Long Point Bay	35	2012	-hoop net (24 h set x 47 sites)	N. Mandrak, DFO, unpublished data
Long Point Bay	11	2012	-bag seine (5 hauls x 60 sites x 2 events)	N. Mandrak, DFO, unpublished data
Long Point Bay	0	2013	-bag seine (5 hauls X 34 sites)	N. Mandrak, DFO, unpublished data
Long Point Bay	0	2013	-bag seine (3 hauls X 1 site) -boat electrofisher (1000 m x 2 sites; 800 m x 1 site; 400 m x 6 sites; 200 m x 2 sites) -trammel net (0.5-0.75 h x 3 sites)	D. Marson, DFO, unpublished data
Long Point Bay	3	2013	-bag seine (5 hauls x 60 sites x 2 events)	N. Mandrak, DFO, unpublished data
Long Point Bay	3	2013	-mini fyke net (24 h sets X 18 sites)	D. Marson, DFO, unpublished data
Long Point Bay	3	2014	-mini fyke net (17 h set); trap net (24 h set)	DFO unpublished data
Crowne Marsh	3	2014	-bag seine (5 hauls)	DFO unpublished data
Long Point Bay	6	2015	-trap net (20 h sets X 3 sites)	DFO unpublished data
Big Creek NWA	50	2016	-bag seine (1/8" bag mesh, 1/8" wing mesh, Length – 10 m; 48 hauls) -mini fyke net (1/8" mesh, two 2'x4' box, two 2' hoops, 2'x25' lead, 2'x15' wings, 3" winker opening; 622.2 h total)	DFO unpublished data
Long Point Bay	6	2016	-unknown gear and effort	MNRF, unpublished data
Long Point Bay	1	2016	-boat electrofisher (21 ft., 7.5 GPP, dual boom; 14200 s)	DFO unpublished data
Long Point Bay	0	2016	-mini fyke net (1/8" ace mesh, 1/8" ace mesh 2'x15' lead, 2' hoops, 2'x4' box; 197.6 h)	DFO unpublished data
Long Point Bay	0	2016	-trap net (163.8 h)	DFO unpublished data
Long Point Bay	0	2016	-trammel net (14' deep, 200 yds length, 4" bar mesh, 18" outer walls; 128 min)	DFO unpublished data
Long Point Bay	17	2017	-bag seine (1/8" bag mesh, 3/16" wing mesh, Length - 10m - 30ft; 34 hauls at 7 sites; 701 hauls)	MNRF unpublished data

Waterbody	n	Year	Sampling effort	Reference
Big Creek	0	2017	-unknown gear and effort	S. Robertson, DFO, unpublished data
Long Point Bay	0	2017	-boat electrofisher (21 ft., 7.5 GPP, dual boom; 12615 s) -mini fyke net (1/8" ace mesh, 1/8" ace mesh 2'x15' lead, 2' hoops, 2'x4' box; 432 h) -bag seine (1/4" bag mesh, 1/4" wing mesh, Length – 10 m; 3 hauls) -tied-down gill net (4" bar; 12' tied down to 10' - 200 yards length; 122 min) -trap net (285 h) -trammel net (14' deep: 200 yds length; 4" bar mesh; 18" outer walls; 63 min)	DFO unpublished data
Long Point Bay	2	2018	-boat electrofisher (24', dual boom; 600 seconds)	DFO unpublished data