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RECOVERY POTENTIAL ASSESSMENT OF WARMOUTH (*LEPOMIS GULOSUS*) IN CANADA

*Warmouth (*Lepomis gulosus*). Illustration by Joe Tomelleri, reproduced with permission.*

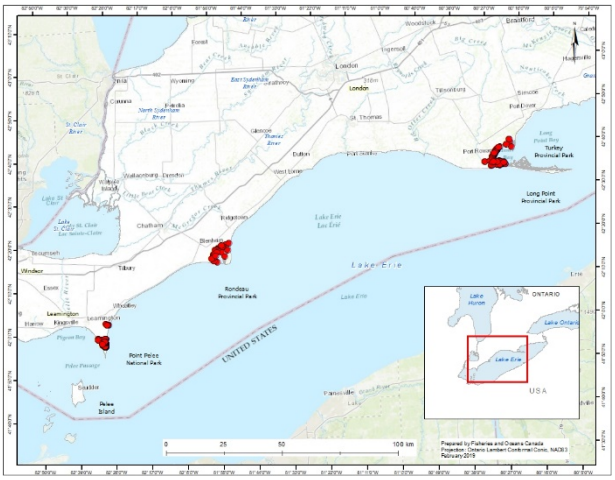

*Figure 1. Distribution of Warmouth (*Lepomis gulosus*) in Canada.*

Context:

In April 1994, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) recommended that Warmouth (Lepomis gulosus) be designated as Special Concern. This status was assessed and confirmed in November 2001 and May 2005. In June 2003, Warmouth was listed as Special Concern on Schedule 1 of the Species at Risk Act (SARA) when the Act was proclaimed. In May 2015, Warmouth was re-assessed and designated as Endangered by COSEWIC. The reason given for this designation was that "This species of sunfish has a very small distribution in Canada, occurring only within the Lake Erie drainage. It exists at 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" (COSEWIC 2015).

A species Recovery Potential Assessment (RPA) process has been developed by Fisheries and Oceans Canada (DFO) Science to provide the information and scientific advice required to meet the various requirements of the SARA, such as the authorization to carry out activities that would otherwise violate the SARA as well as the development of recovery strategies. The scientific information also serves as advice to the Minister of DFO regarding the listing of the species under SARA and is used when analyzing the socio-economic impacts of adding the species to the list as well as during subsequent consultations, where applicable. This assessment considers the scientific data available with which to assess the recovery potential of Warmouth in Canada.

This Science Advisory Report is from the December 12th, 2018 Recovery Potential Assessment – Warmouth (Lepomis gulosus). Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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Canada

SUMMARY

- In Canada, the current and historic distribution of Warmouth is limited to just three locations (Point Pelee, Rondeau Bay, and Long Point Bay) in the Lake Erie drainage (Figure 1). Results of a population status assessment ranked all three populations as Poor.
- Warmouth uses shallow (< 2 m), heavily-vegetated embayments of lakes, slow-moving streams and wetlands. Important habitat features include submergent and emergent vegetation as well as soft bottom substrates consisting of sand, silt, clay, or organic material.
- To achieve 99% probability of persistence, given a 15% chance of catastrophic decline (50% reduction in abundance) per generation, there would need to be ~ 6,000 adults for a minimum viable population (MVP) using an independent correlation structure. The minimum area required to support this population (i.e., minimum area for population viability [MAPV]) is approximately 41 ha. The effects of intra-annual correlation in vital rates were explored and were found to have a large impact on MVP estimates.
- Warmouth are most sensitive to perturbations to the adult stage. Chronic annual mortalities of greater than 24.7% to the adult stage or 13.2% to all age-classes is likely to cause population decline.
- The greatest threats to Warmouth populations are aquatic vegetation removal, wetland draining for agricultural purposes, and natural system modifications due to the establishment of invasive plants.
- For Canadian populations, knowledge gaps exist related to Warmouth life cycle, distribution, habitat needs, and population abundance. This includes uncertainty with population trajectories and age-specific mortality used in population modelling. Research is required to identify spawning and nursery grounds and to identify the spatial extent of suitable Warmouth habitat. There is also a need for causative studies to evaluate the impact of threats on Warmouth populations.

BACKGROUND

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 as Endangered due to its restricted distribution in Canada and continuing decline of its preferred vegetated habitat. In June 2003, Warmouth was listed as Special Concern 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*. When COSEWIC designates an aquatic species as Threatened or Endangered and the Governor in Council decides to list it, the Minister of Fisheries and Oceans Canada (DFO) is required by SARA to undertake a number of actions. Many of these actions require scientific information such as the current status of the population, the threats to its survival and recovery, and the feasibility of its recovery. This scientific advice is developed through a Recovery Potential Assessment (RPA). This allows for the consideration of peer-reviewed scientific analyses in subsequent SARA processes including permitting on harm and recovery planning. This RPA focuses on Warmouth in Canada and is a summary of the conclusions and advice from a Canadian Science Advisory Secretariat peer-review meeting that occurred on December 12th, 2018 in Burlington, Ontario. Two research documents, one providing background information on the species' biology, habitat preferences, current status, threats and mitigations and alternatives (Burridge et al. 2020), and a second on allowable harm, population-based recovery, and habitat targets (van der Lee and Koops 2020) provide an

in-depth account of the information summarized below. Proceedings that document the key discussions of the meeting are also available (DFO 2020).

ASSESSMENT

Current Species Status

In Canada, the current and historic distribution of Warmouth is limited to just three locations in the Lake Erie drainage – Point Pelee, Rondeau Bay, and Long Point Bay (Figure 1).

Point Pelee

An in-depth historical account of fish sampling events in Point Pelee from 1940 to 2003 is available in Table 1.1 of Surette (2006). Sixteen sampling events over 15 different years (1940 to 1983) failed to detect Warmouth in this system using a variety of sampling equipment including seine nets, gill nets, minnow traps, creel surveys, and trap nets. Warmouth was first detected in Lake Pond in 1983. This first record consisted of two individuals. 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. The ponds within Point Pelee National Park 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.

In 2017, 25 Warmouth were caught at Hillman Marsh, representing the first detection of this species in this waterbody. Hillman Marsh can be found approximately 6 km north of Point Pelee. 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. It is possible that Warmouth have always occurred at Hillman Marsh and have only now been identified there as there has been no targeted effort to capture this species at this location in the past.

Rondeau Bay

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 Royal Ontario Museum [ROM] 34267) were recorded from Rondeau Provincial Park. In 1999, two individuals were captured in southwest Rondeau Bay. 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. One individual was captured in 2011 by C. Scott (Ontario Ministry of Natural Resources and Forestry [OMNRF], Lake Erie Management Unit). Additional sampling in 2013 by hoop net and fyke net resulted in the capture of an additional 11 individuals. A combination of mini-fyke and hoop nets resulted in the detection of 19 individuals from 2015 to 2018 (DFO unpublished data).

Long Point Bay

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 young-of-the-year (YOY) specimen was collected in the Inner Bay of Long Point (DFO 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 multiple collectors. From 2011 to 2018 another 148 individuals were captured from Long Point Bay, Big Creek, Turkey Point marshes, and Crown Marsh from multiple collectors using a variety of fishing gear. The largest number of Warmouth recorded from Long Point Bay was the result of monitoring the commercial hoop net coarse fishery along the north shore of the bay in 2009 in which 141 Warmouth were recorded from 368 hoop net sampling events. 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 is to be expected considering the lack of suitable habitat in outer Long Point Bay.

Population Assessment

To assess the population status of Warmouth 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. 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. Certainty has been associated with the Relative Abundance Index and Population Trajectory rankings and is listed as: 1 = quantitative analysis; 2 = catch per unit effort (CPUE) or standardized sampling; 3 = expert opinion. Refer to Burridge et al. (2020) for detailed methods used for the assessment of Population Status.

Table 1. 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

Habitat Requirements

Spawning

Spawning and nursery habitat is thought to be consistent with adult habitat and is 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. 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. 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 0.77m (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). 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 affects 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. Substrates were mainly composed of organic, clay, silt, and sand, with silt and sand being the dominant substrate type across sites. At Crown Marsh, sand was the dominant substrate at 77% of sites (n = 13) at sites where Warmouth (≥ 75 mm) were captured (2015–2018; OMNRF unpublished data).

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 of nests found at depths between 61–76 cm. They were usually found along shallow sloping shorelines (Wallus and Simon 2008).

Functions, Features and Attributes

A description of the functions, features, and attributes associated with Warmouth habitat can be found in Table 2. 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 which describe 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 2. 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.

Life Stage	Function	Feature(s)	Habitat Attributes		
			Scientific Literature	Current Records	For Identification of Critical Habitat
Spawn to hatch (occurs in late spring)	Spawning	Nearshore, 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 in 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 total length) were found at sites with a mean depth of 66 cm (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: o Requires dense aquatic vegetation o < 2 m water depth o Fine substrates such as sand, silt and organic matter

Life Stage	Function	Feature(s)	Habitat Attributes		
			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		• Between 2012–2018 individuals were caught in water depths ranging 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 (n = 77) (DFO unpublished data); 62 percent of sites (n = 77) had submergent aquatic vegetation percent cover ≥ 35% • Crown Marsh adults were found at sites with a mean water depth of 66 cm (range: 0.3 – 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 24 % open water. Sand was the dominant substrate at 77 % (n = 13) of the sites. 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

Recovery Modelling

The analysis consisted of four parts:

1. Information on vital rates was compiled to build projection matrices incorporating variability within stochastic simulations.

With these projection matrices:

2. stochastic sensitivities of the population growth rate to changes in each vital rate were determined and used to estimate total allowable chronic harm following Vélez-Espino and Koops (2009);
3. simulation analysis was used to estimate the impact of transient harm (a one-time removal of fish of various life stages) on population growth; and,
4. population viability analysis was conducted to estimate MVP and the MAPV (i.e., the amount of suitable habitat required to support the MVP).

Allowable Harm

Allowable harm and minimum required recovery effort were assessed using a precautionary approach within a demographic framework following Vélez-Espino and Koops (2009). Recovery effort is defined as the minimum improvement in vital rate(s) that will allow a population to begin recovery. Allowable harm is defined as the maximum harm to a population (i.e., decline in vital rate[s]) that will not prevent population recovery. Modelling indicated that Warmouth populations were sensitive to perturbations to the adult stage (and age 1+). Harm affecting this portion of the life cycle should be minimized to avoid jeopardizing survival and recovery of Canadian populations. Assuming population growth rate of 1.15, chronic annual mortalities of > 24.7% to the adult stage or 13.2% all age-classes is likely to cause population decline.

Summary of Science Advice on Allowable Harm

- For the purposes of the RPA modeling, harm refers to a negative alteration to a vital rate that reduces a population growth rate.
- If a population is stable and exceeds the recovery target (MVP) then harm may be considered that does not result in a decline of the population growth rate.
- When population trajectory is declining there is no scope for allowable harm to the population.
- When population trajectory is unknown the scope for allowable harm can only be assessed once population data are collected.
- Scientific research to advance the knowledge of population data should be allowed.

Population Sensitivity

Sensitivity analysis of matrix population models determines the impact of changes to vital rates and lower level parameters on annual population growth rate (λ). Use of different correlation structures in stochastic sensitivity estimates resulted in similar elasticity values. When summed to the stage level, population growth rate was primarily sensitive to adult survival due to the length of the adult stage, except at λ_{max} when the population was more sensitive to juvenile survival. The sensitivity of λ to both survival and fecundity declined with age. See van der Lee and Koops (2020) for complete details of the model and results.

Recovery Targets

Potential recovery targets for Warmouth were identified based on demographic sustainability. Demographic sustainability is related to the concept of a MVP and was defined as the minimum adult population size that results in a desired probability of persistence over 100 years (~ 22 generations for Warmouth). In choosing recovery targets, the risks associated with extinction probability must be balanced with the costs associated with an increased target (increased recovery effort, longer time to recovery, etc.). Recovery target values were estimated for a 5% and 1% risk of extinction using simulation criteria of populations affected by a 0.1 and 0.15 catastrophe rate per generation with a quasi-extinction threshold of 50 adults. The more precautionary estimates of MVP utilize a catastrophe probability of 0.15/generation and risk of extinction of 1% over 100 years. However, the extent of intra-annual correlation among life history parameters is uncertain and adult MVP estimates ranged from 6,302 to 383,291 from variation in the level of intra-annual correlation alone.

Minimum Area for Population Viability (MAPV)

MAPV values were estimated for MVP simulations using a quasi-extinction threshold of 50 adult fish, a 0.1 or 0.15/generation probability of catastrophe, and a risk of extinction of 5 or 1% over 100 years assuming three levels of intra-annual correlation among age-specific parameters. MAPVs ranged from approximately 41 to 2,477 ha of Warmouth exclusive habitat (assuming shared habitat among all age classes) depending on the correlation structure used when assuming a 99% probability of persistence and a 15% chance of catastrophic decline. Previous RPA analysis for fish species at risk used an independent correlation structure when estimating MVP and MAPV.

Threats

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 as well as changes to aquatic habitat that are occurring via invasive species such as Common Carp (*Cyprinus carpio*), Common Reed (*Phragmites australis*), and Eurasian watermilfoil (*Myriophyllum spicatum*). 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 affected 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.

Threat Level Assessment

To assess the Threat Level of Warmouth populations in Ontario, each threat was ranked in terms of the Threat Likelihood of Occurrence, Threat Level of Impact, and Causal Certainty on a population-by-population basis. Terms used to describe population level threat categories are described in Table 3.Threats were rolled-up to create a species-level threat assessment in Table 4.

Table 3. Definition and terms used to describe Population Level Threat Occurrence (PTO), Threat Frequency (PTF), and Threat Extent (PTE) information taken from DFO (2014).

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)	31–71% 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 4. Species-level Threat Assessment for Warmouth in Canada resulting from a roll-up of Population-Level Threat Assessment (In Burridge et al. 2020). 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. Values in parentheses represent the highest certainty rating associated with the threat impact for populations (see Table 8 in Burridge et al. 2020)

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
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

Mitigations and Alternatives

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. For full details of this review, see Burridge et al. (2020).

The most frequent project type was related to 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 that would likely impact Warmouth but these areas are also currently identified as critical habitat for Spotted Gar (*Lepisosteus oculatus)*. 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.

Recreational activities in areas known to be occupied by Warmouth include recreational boating and fishing. Increases in these activities could also potentially negatively 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 and Fish Habitat Protection Program (Table 5). DFO has developed guidance on mitigation measures for 18 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.

Human intrusion and disturbance

As discussed in Burridge et al. (2020), there is thought to be minimal disturbance during implementation of scientific research. Further sampling of Warmouth to address population parameters is a research need that is discussed in the recovery modelling section of this document. 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 non-lethal sampling methods. Ensure that personnel are sufficiently trained to identify Warmouth in the field to minimize stress on the fish when captured.
- 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 as well as 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* (OMNRF 2019).
- 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 (*Neogobius melanostomus*) 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).

Table 5. 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, 9, 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	
In-stream works **(**channel maintenance, restoration, modifications, realignments, dredging, aquatic vegetation removal)	✓	✓	✓	✓						8	6	3

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, 9, 11, 12, 13, 14, 15, 16, 18	1, 2, 3, 4, 5, 6, 10, 11, 12, 14, 15								
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)							✓					

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.

LIST OF MEETING PARTICIPANTS

Name	Organization/Affiliation
Sara Eddy	DFO - Fisheries Protection Program
Lisa Wren	DFO - Fisheries Protection Program
Karla Zubrycki	DFO - Policy and Economics
Dave Andrews	DFO - Science
Jason Barnucz	DFO - Science
Lynn Bouvier (Chair)	DFO - Science
Andrew Drake	DFO - Science
Marten Koops	DFO - Science
Adam van der Lee	DFO - Science
Jofina Victor	DFO - Science
Dave Balint	DFO - Species at Risk Program
Amy Boyko	DFO - Species at Risk Program
Vicki McKay	Lower Thames Valley Conservation Authority
Chelsea May	Ontario Ministry of Natural Resources and Forestry
Scott Reid	Ontario Ministry of Natural Resources and Forestry

Name	Organization/Affiliation
Tara Bortoluzzi	Parks Canada - Point Pelee National Park
Tarra Degazio	Parks Canada - Point Pelee National Park
Nicholas Mandrak	University of Toronto, Scarborough

SOURCES OF INFORMATION

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Center for Science Advice (CSA)
Central and Arctic Region
Fisheries and Oceans Canada
501 University Crescent, Winnipeg, Manitoba, R3T 2N6

Telephone: (204) 983-5232
E-Mail: csas-sccs@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

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