

# **Barriers to natural recruitment of stocked Walleye (*Sander vitreus*) in the Hamilton Harbour Area of Concern**

Jonathan D. Midwood, Melanie V. Croft-White, Nicole A. Turner,  
Paul A. Bzonek, and David T. Reddick

Fisheries and Oceans Canada  
Ontario and Prairie Region  
Great Lakes Laboratory for Fisheries and Aquatic Sciences  
867 Lakeshore Road  
Burlington, ON L7S 1A1

2026

**Canadian Technical Report of  
Fisheries and Aquatic Sciences 3749**



Fisheries and Oceans  
Canada

Pêches et Océans  
Canada

**Canada**

## **Canadian Technical Report of Fisheries and Aquatic Sciences**

Technical reports contain scientific and technical information that contributes to existing knowledge but which is not normally appropriate for primary literature. Technical reports are directed primarily toward a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of Fisheries and Oceans Canada, namely, fisheries and aquatic sciences.

Technical reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in the data base *Aquatic Sciences and Fisheries Abstracts*.

Technical reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page.

Numbers 1-456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457-714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715-924 were issued as Department of Fisheries and Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

## **Rapport technique canadien des sciences halieutiques et aquatiques**

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Les rapports techniques sont destinés essentiellement à un public international et ils sont distribués à cet échelon. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques de Pêches et Océans Canada, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports techniques peuvent être cités comme des publications à part entière. Le titre exact figure au-dessus du résumé de chaque rapport. Les rapports techniques sont résumés dans la base de données *Résumés des sciences aquatiques et halieutiques*.

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre.

Les numéros 1 à 456 de cette série ont été publiés à titre de Rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457 à 714 sont parus à titre de Rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715 à 924 ont été publiés à titre de Rapports techniques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 925.

Canadian Technical Report of  
Fisheries and Aquatic Sciences 3749

2026

Barriers to natural recruitment of stocked Walleye (*Sander vitreus*) in the Hamilton  
Harbour Area of Concern

by

Jonathan D. Midwood, Melanie V. Croft-White, Nicole A. Turner, Paul A. Bzonek, and  
David T. Reddick

Fisheries and Oceans Canada  
Ontario and Prairie Region  
Great Lakes Laboratory for Fisheries and Aquatic Sciences  
867 Lakeshore Road  
Burlington, ON L7S 1A1

© His Majesty the King in Right of Canada, as represented by the Minister of the  
Department of Fisheries and Oceans, 2026

Cat. No. Fs97-6/3749E-PDF ISBN 978-0-660-97870-3 ISSN 1488-5379

<https://doi.org/10.60825/pxpq-bh40>

Correct citation for this publication:

Midwood, J.D., Croft-White, M.V., Turner, N.A., Bzonek, P.A., and Reddick, D.T. 2026.  
Barriers to natural recruitment of stocked Walleye (*Sander vitreus*) in the Hamilton  
Harbour Area of Concern. Can. Tech. Rep. Fish. Aquat. Sci. 3749: ix + 46 p.

<https://doi.org/10.60825/pxpq-bh40>

## TABLE OF CONTENTS

<b>LIST OF TABLES</b> .....	v
<b>LIST OF FIGURES</b> .....	vi
<b>ABSTRACT</b> .....	viii
<b>RÉSUMÉ</b> .....	ix
<b>INTRODUCTION</b> .....	1
<b>WHAT DO WE KNOW ABOUT WALLEYE RECRUITMENT IN OTHER SYSTEMS?</b> .....	2
<b>REALITIES OF WALLEYE RECRUITMENT IN HEALTHY ECOSYSTEMS</b> .....	2
<b>WALLEYE STOCKING</b> .....	3
<b>ABIOTIC FACTORS</b> .....	3
<b>BIOTIC FACTORS</b> .....	4
<b>KNOWLEDGE GAPS AND LIMITATIONS</b> .....	5
<b>SYNTHESIS</b> .....	5
<b>WHAT DO WE KNOW ABOUT RECRUITMENT OF STOCKED WALLEYE IN HAMILTON HARBOUR?</b> .....	6
<b>ECOLOGY</b> .....	6
<b>Spawning Adults</b> .....	6
<b>Habitat</b> .....	6
<b>Eggs</b> .....	7
<b>Larvae</b> .....	7
<b>Juveniles/YOY</b> .....	8
<b>ABIOTIC FACTORS</b> .....	8
<b>Summer Hypoxia</b> .....	8
<b>Water Temperature</b> .....	8
<b>Water Quality</b> .....	9
<b>BIOTIC FACTORS</b> .....	9
<b>Predation</b> .....	9
<b>Competition</b> .....	9
<b>SYNTHESIS</b> .....	10
<b>DISCUSSION</b> .....	11
<b>ACKNOWLEDGEMENTS</b> .....	13
<b>REFERENCES</b> .....	14

<b>TABLES AND FIGURES</b> .....	21
<b>APPENDIX A:</b> Assessment of early life phase catch from boat electrofishing and nursery habitat supply .....	27
<b>APPENDIX B:</b> Water temperature during early life growth.....	35
<b>APPENDIX C:</b> Secchi depth information .....	41
<b>APPENDIX D:</b> Boat electrofishing catch of potential predators and planktivores .....	42

## LIST OF TABLES

Table 1. Summary of potential base (fixed) and modifying (within-year) factors influencing Walleye recruitment in Hamilton Harbour (HH). .....	21
Table 2: Summary of Walleye recruitment potential at six locations in the harbour (Figure 1; sites align with those presented in Croft-White et al. 2026). For each location and category, recruitment potential was assessed as: high (✓✓), moderate (✓), low (X), and unknown (?). .....	25
Table A1: Chronology of Walleye (Bay of Quinte strain, White Lake Fish Culture Station) stocked into the Hamilton Harbour Area of Concern 1993-2022. Adults in the 1990's were directly transplanted from the Bay of Quinte. ....	29
Table A2: Boat electrofishing effort (number of transects) by year for Hamilton Harbour and the Bay of Quinte (includes upper and lower Bay of Quinte, South Bay, and Weller's Bay [2023 only]). The dashed line indicates the year (2012) when summer fingerling Walleye were successfully stocked into Hamilton Harbour. ....	30
Table A3: Summary of electrofishing effort (number of transects), catch, and catch per unit effort (CPUE) of Walleye in Hamilton Harbour (HH) and the Bay of Quinte (BoQ). Data reflect surveys completed between 2012-2023, see Table A2 for detailed yearly breakdown of effort and Figure A1 for length-based catch by year. ....	31
Table B1: Annual growing degree days (Base 0°C) for Hamilton Harbour. All values are well above the minimum requirement determined for Minnesota Lakes (Honsey et al. 2020). .....	36
Table B2: Annual warming rate (°C/day) in Hamilton Harbour measured for the whole spawning period (01 April – 15 May) and just the estimated egg incubation period (14 April – 28 April). .....	37
Table C1: Mean, standard deviation, and quantiles for Secchi depth data collected at multiple locations in Hamilton Harbour. ....	41

## LIST OF FIGURES

Figure 1: Locations of interest within the Hamilton Harbour Area of Concern. Specific areas mentioned in text that align with those presented in Croft-White et al. (2026) are noted by the blue squares.....	26
Figure A1: Catch per unit effort (CPUE; number of fish/ transect) by month for Walleye of different size groups including all (CPUE), individuals <150 (CPUE150), and individuals <215 mm (CPUE215). Data are split for capture in the Bay of Quinte (BoQ) and Hamilton Harbour (HH).....	32
Figure A2: Mid-points for boat electrofishing transects in Hamilton Harbour (yellow circles) and catch of Walleye <215 mm in total length (#/year) at these transects. Only three Walleye <150 mm were captured and their locations are marked in black. Potential nursery habitat for early and late demersal Walleye are also plotted based on information from Pratt and Fox (2001). ....	33
Figure A3: Lengths of Walleye captured in DFOs standardized fish community surveys of Hamilton Harbour, which typically occur between May and October. Red circles are captured Walleye with shading applied based on estimated age; horizontal dotted lines denoting mean lengths at age 2, 3, 4, and 5 for Walleye captured in Hamilton Harbour. Stocking events split by life stage at stocking are also shown at the bottom of the figure alongside when boat electrofishing surveys were completed. See Table A1 for specific numbers and biomass stocked during each event. N.B. sampling in 2022 was limited to just the Piers 5-7 region of the harbour with just 16 transect in August and 14 in October. ....	34
Figure B1: Hourly temperature for station 1001 (combination of observed and modelled temperatures; R. Valipour, unpublished data). The dashed line indicates the lower thermal maxima for Walleye of 27°C (Raabe et al. 2020).....	38
Figure B2: Daily cumulative growing degree days (Base 0°C) by year from Station 1001 in Hamilton Harbour. ....	39
Figure B3: Daily warming rates in Hamilton Harbour for the estimated egg incubation period (14 April [Day of Year 104] to 28 April [Day of Year 118]). For context, warming rates identified as indicative of a “good” recruitment year warming (0.22 °C/day, dashed line) and a “poor” recruitment year (0.16 °C/day, dotted line; Roseman et al. 1996) are shown. ....	40
Figure D1: Mean spring catch per unit effort for potential early life phase (eggs and larvae) predators of Walleye by location in Hamilton Harbour (data summarized for samples between 2013 and 2023).....	43
Figure D2: Mean seasonal catch per unit effort by location in Hamilton Harbour for Largemouth Bass, a common predator of early life phase and juvenile Walleye (data summarized for samples between 2013 and 2023).....	44
Figure D3: Mean spring catch per unit effort for potential plankton competitors by location in Hamilton Harbour (data summarized for samples between 2013 and 2023). ....	45

Figure D4: Mean summer catch per unit effort for potential plankton competitors by location in Hamilton Harbour (data summarized for samples between 2013 and 2023). ..... 46

## ABSTRACT

Midwood, J.D., Croft-White, M.V., Turner, N.A., Bzonek, P.A., and Reddick, D.T. 2026. Barriers to natural recruitment of stocked Walleye (*Sander vitreus*) in the Hamilton Harbour Area of Concern. Can. Tech. Rep. Fish. Aquat. Sci. 3749: ix + 46 p. <https://doi.org/10.60825/pxpq-bh40>

Walleye (*Sander vitreus*) are an ecologically, culturally, and commercially important cool-water predator. While historically common in the Hamilton Harbour Area of Concern, naturally reproducing Walleye were largely extirpated by the 1970s. Stocking of Walleye in the early 2010s, with an objective of re-establishing a native top-predator to increase piscivore biomass, led to strong adult year classes. Here we briefly summarize the state of knowledge on factors limiting Walleye recruitment in other freshwater systems, compare these factors to the current conditions within Hamilton Harbour, and explore multiple lines of evidence to identify potential recruitment bottlenecks. Based on electrofishing, acoustic telemetry, egg collection, and habitat surveys, stocked Walleye are spawning and producing fertilized eggs in suitable habitat, but the absence of swim-up fry in larval tows<sup>16</sup> and young-of-year (YOY) in fall electrofishing surveys indicates an early life-stage recruitment bottleneck. There are few direct management actions that will likely promote Walleye recruitment in the near-term since recruitment appears limited in these early life phases due to interacting factors such as water quality, sedimentation, wind and wave transport, and predation. Fall monitoring for YOY Walleye, particularly in alternating years with stocking, is recommended as the best method for detecting natural recruitment.

## RÉSUMÉ

Midwood, J.D., Croft-White, M.V., Turner, N.A., Bzonek, P.A., and Reddick, D.T. 2026. Barriers to natural recruitment of stocked Walleye (*Sander vitreus*) in the Hamilton Harbour Area of Concern. Can. Tech. Rep. Fish. Aquat. Sci. 3749: ix + 46 p. <https://doi.org/10.60825/pxpq-bh40>

Le doré jaune (*Sander vitreus*), un prédateur qui vit dans les eaux froides, est une espèce importante sur les plans écologique, culturel et commercial. Même si cette espèce a déjà été commune dans le secteur préoccupant du port de Hamilton, les dorés jaunes se reproduisant naturellement sont en grande partie disparus depuis les années 1970. L'ensemencement de dorés jaunes au début des années 2010, dans le but de rétablir un prédateur indigène de niveau trophique supérieur pour augmenter la biomasse des piscivores, a mené à des classes d'âge fortes chez les adultes. Nous résumons ici l'état des connaissances sur les facteurs limitant le recrutement du doré jaune dans d'autres réseaux d'eau douce, comparons ces facteurs aux conditions actuelles dans le port de Hamilton, et explorons plusieurs sources de données pour déterminer les goulots d'étranglement potentiels du recrutement. D'après la pêche à l'électricité, la télémétrie acoustique, la collecte des œufs et les relevés de l'habitat, les dorés jaunes ensemencés frayent et produisent des œufs fertilisés dans un habitat convenable. Toutefois, l'absence d'alevins nageant dans les traits pour les larves et de jeunes de l'année dans les relevés par pêche à l'électricité effectués à l'automne indique un goulot d'étranglement du recrutement aux premiers stades biologiques. Il existe peu de mesures de gestion directe qui favoriseraient probablement le recrutement du doré jaune à court terme, car le recrutement semble limité dans ces premiers stades biologiques en raison de facteurs d'interaction comme la qualité de l'eau, la sédimentation, le transport par le vent et les vagues, et la prédation. La surveillance automnale des jeunes de l'année, en particulier les années sans ensemencement, est recommandée comme meilleure méthode pour détecter le recrutement naturel chez les dorés jaunes.

## INTRODUCTION

Walleye (*Sander vitreus*) are an ecologically, culturally, and commercially important cool-water predator (Bruner and DeBruyne 2021) found in freshwater systems throughout North America. Their ecology and life history have been extensively studied (Barton 2011; Bozek et al. 2011a, 2011b), with particular focus on spawning and recruitment (Raabe et al. 2020; Krabbenhoft et al. 2023).

Briefly, Walleye are spring spawners that either move into river systems or onto lentic shoals to find suitable spawning habitat (i.e., gravel and cobble substrates; Bozek et al. 2011a). Fertilized eggs survive best in well-oxygenated interstitial spaces, and for a few weeks post-emergence, Walleye larvae are at the mercy of winds and currents (Bozek et al. 2011a). Once young Walleye are free-swimming, they seek shelter in aquatic vegetation or rocky shoals to avoid predation (Pratt and Fox 2001). Growth is rapid provided adequate food is available, but there are naturally high rates of mortality for early life phases, particularly between early spring and summer, and over their first winter. Cohort survival rates during these phases are key determinants of recruitment success (Krabbenhoft et al. 2023). Walleye have been studied extensively throughout the Laurentian Great Lakes, notably in Lake Erie, where they support productive commercial and recreational fisheries (Vandergroot et al. 2010) and are actively managed to support these fisheries.

Hamilton Harbour, a large embayment (21 km<sup>2</sup>) situated at the western end of Lake Ontario, has experienced extensive anthropogenic disturbance that resulted in extensive loss and degradation of aquatic habitats and declines in the abundance and diversity of fish and wildlife populations (Midwood et al. 2024). It was listed as a Great Lakes Area of Concern in 1987 (Hamilton Harbour Remedial Action Plan (HHRAP) 1992a, 1992b), with recovery of top predators, including Walleye, as one of its recovery objectives for fish populations. Historically, Walleye were commonly found spawning in tributaries of the harbour (Dymond et al. 1929). Declines in spawning activity were evident by the early 1880s and they were no longer captured as of 1892 (Dymond et al. 1929). Whillans (1977) notes a remnant population of Walleye in the system in the 1930s, but by the 1970s there was no evidence of spawning activity. It is unclear from available records whether there was a year-round resident population of Walleye in Hamilton Harbour, or if Walleye solely used tributaries in the system for spawning, with nearshore areas acting as potential nursery habitat. Regardless, it is clear that historical conditions in Hamilton Harbour and its tributaries supported Walleye recruitment.

Walleye population recovery efforts in Hamilton Harbour started with opportunistic stocking of some adult and spring fingerling Walleye by the Ontario Ministry of Natural Resources (OMNR) throughout the 1990s (OMNR 2020; Midwood et al. 2024). More intensive stocking of summer fingerlings in 2012 led to a strong year class, and Walleye stocked in 2016, 2018, 2020, and 2022 have also been detected in subsequent sampling programs (Midwood et al. 2024; OMNR 2025). Evaluations of Walleye condition based on relative weight indicate that adults in Hamilton Harbour are comparable to those in the Bay of Quinte (Midwood et al. 2024), the source of gametes for the stocking program, and meet or exceed “desirable” relative weights as outlined in Murphy et al. (1990), suggesting there is adequate prey for adult Walleye in the harbour or adjacent areas of Lake Ontario. However, despite evidence of stocked Walleye spawning

throughout littoral areas of Hamilton Harbour (OMNR 2020; Midwood et al. 2026), natural recruitment has not been detected (Croft-White et al. 2026). The overarching objective of this report is to identify potential factors limiting the natural recruitment of stocked Walleye in Hamilton Harbour. In support of this objective, we first summarize the state of knowledge on factors limiting Walleye recruitment in other systems, using a conceptual framework of mechanisms of mortality outlined in (Krabbenhoft et al. 2023). We then review Walleye recruitment limitations in Hamilton Harbour, and finally contrast limitations presented in past works with conditions in Hamilton Harbour. We conclude this report by identifying potential management measures that may help promote natural recruitment of Walleye in both the near- and long-term.

## **WHAT DO WE KNOW ABOUT WALLEYE RECRUITMENT IN OTHER SYSTEMS?**

Numerous studies have described Walleye spawning ecology and identified or reviewed factors influencing Walleye recruitment in lentic systems (Barton 2011; Raabe et al. 2020; Krabbenhoft et al. 2023). Importantly, reviews note that factors influencing recruitment are often system-specific, such that limitations in small inland lakes may not be as relevant in larger systems like the Great Lakes (e.g., system morphometry; Krabbenhoft et al. 2023). Additionally, influencing factors are likely to interact (e.g., abiotic factors like spring warming may interact with biotic factors like zooplankton productivity), and their relative importance may vary among years (e.g., water circulation; Krabbenhoft et al. 2023). Finally, some factors vary whether they are positive or negative drivers of recruitment depending on the life stage of the Walleye (e.g., presence of Rainbow Smelt [*Osmerus mordax*], which may consume larval Walleye but are an important prey item for later life stages; Mercado-Silva et al. 2007). The result is a complex and dynamic matrix of abiotic and biotic drivers of Walleye recruitment. Here, we focus on Walleye recruitment in large lakes (e.g., Lake Erie), since Walleye can leave Hamilton Harbour for Lake Ontario. Indeed, adult Walleye have been tracked leaving the harbour in late-summer or early-fall, returning by winter (Larocque et al. 2024a), and this has been hypothesized to be linked to degraded water quality (i.e., hypolimnetic hypoxia) and warming temperatures (Brooks et al. 2025). Such movements have also been observed in Walleye in the Bay of Quinte (i.e., the donor stock for Hamilton Harbour fish), although Walleye in that area move into the main lake shortly after spawning (mid-May on average; Elliot et al. 2022).

Despite these challenges, some consistently important factors are evident, and, in the case of Hamilton Harbour, reviewing all potential drivers is helpful to identify those that may be intervention points where managers can help relieve limitations to recruitment. Krabbenhoft et al. (2023) present a conceptual framework for mechanisms of mortality affecting Walleye in their first two years of life, and that work provides a comprehensive literature review that is not duplicated herein. Instead, we highlight key abiotic and biotic factors from other systems, studies, or reviews.

## **REALITIES OF WALLEYE RECRUITMENT IN HEALTHY ECOSYSTEMS**

There are some important realities of Walleye recruitment that are unpredictable or uncontrollable even in systems with healthy and stable populations (Sissenwine et al. 1988). First, recruitment is variable from year to year, with strong year classes often leading to strong recruitment classes once they reach sexual maturity (Busch et al. 1975). Next, high mortality in early life phases (eggs, larvae) is to be expected (Baccante and Colby 1996; Hansen et al.

2011) and often influenced by wind, waves, and temperature conditions during incubation (Roseman et al. 1996). Sources of mortality can be generally grouped into those related to predation, starvation, and direct abiotic factors (after Krabbenhoft et al. 2023). Smaller individuals are more susceptible to predation, making rapid growth important for survival. Finally, early life recruitment bottlenecks (i.e., within the first year of life) are common across systems (Hansen et al. 2011; Tsehaye et al. 2016– in Krabbenhoft et al. 2023). These realities make it clear that, among Walleye populations, recruitment is dynamic and highly variable. The factors outlined below are thus relevant in all systems; however, it is the magnitude, duration, or spatial extent of their effect within a system like Hamilton Harbour that will influence early life phase recruitment.

## **WALLEYE STOCKING**

Walleye have been extensively stocked throughout North America (Raabe et al. 2020); however, success can be variable, and stocking strategies should be tailored to the specific system (Brooks et al. 2002; Jennings et al. 2005). The size at which Walleye are stocked is an important factor, with typically increased survival for larger sizes (e.g., small fingerlings [50 mm] generally have greater survival than fry [6-8 mm]; Brooks et al. 2002). Despite the benefits of stocking larger sizes, fry are still the most common life stage selected for stocking since they are least costly due to reduced holding and feeding (Raabe et al. 2020). Stocking density is also an important factor, with most North American programs found to use densities of 2000-5000 fry/ha or 75-150 summer fingerlings/ha (Kerr 2011). In addition to size and density, there are a range of factors related to the waterbody that will also influence stocking success, and these align closely with predictors of natural recruitment (e.g., lake size, growing degree days, and predator density; Hansen et al. 2015; Davis and Isermann 2024). Overall, stocking methods have been well studied, albeit with the primary focus on smaller in-land systems (Brooks et al. 2002; Raabe et al. 2020; Davis and Isermann 2024).

## **ABIOTIC FACTORS**

Habitat quality is a consistent indicator of recruitment success, though what constitutes 'good' quality habitat will vary by life stage (Hall et al. 1997). For shoal-spawning Walleye, spawning and incubation habitats in inland lakes are often described as occurring nearshore (<3 m from shore), in shallow water (<0.3 m), over cobble, gravel, and sometimes boulder substrates, with limited embeddedness from silt or other fines (Raabe and Bozek 2012; Zentner 2017). In the main basin of Lake Erie, spawning also occurs further offshore on rocky shoals situated at deeper depths (3-5 m; Bade et al. 2019; Kalejs et al. 2022; Izzo et al. 2023). Egg survival is limited over soft muck, silt, and detritus, intermediate on firm fine sand, and highest on gravel and rubble (Johnson 1961 – in Raabe et al. 2020). Fine sediments on spawning substrates can prevent adhesion, leading to more eggs being displaced by wave action or currents (Crane and Farrel 2013). As Walleye mature, access to cover in the form of aquatic macrophytes becomes increasingly important (Hoyle et al. 2012; Pratt and Fox 2001). Availability of suitable spawning habitat is influenced by wind and water circulation since suitable spawning habitat is often found where wave energy is sufficient to clear fine substrates, but not larger gravel or cobble materials; ice scouring can also help clear fines (Raabe et al. 2020). This hydrodynamic energy, however, can also be problematic as wind and waves can move and potentially damage Walleye eggs if too strong or if there are insufficient interstitial spaces among coarse substrates to hold them (Raabe and Bozek 2015; Zentner 2017; Raabe et al. 2020). Wind and water circulation can also affect Walleye post swim-up, as Walleye are poor swimmers at this phase,

and are readily moved by water currents, which can lead to mortality even if sufficient and suitable prey and habitat are available (Roseman et al. 1999; Fraker et al. 2015).

An often unstated assumption is that there is some base level of suitable spawning habitat available in the system, and thus a base number of eggs that can be supported to reach subsequent life stages, effectively setting a maximum recruitment potential for the system. Factors like the availability of suitable substrates and depths can therefore be considered as having a more fixed supply within a system, since they are a prerequisite requirement for a naturally reproducing population. At a minimum, these fixed conditions must be present to allow adult Walleye to find suitable spawning habitat and support a base number of fertilized eggs, thus providing a base level of potential recruitment. In contrast, many of the factors outlined in Krabbenhoft et al. (2023) act as modifiers in that their influence on within-year survival of Walleye throughout their early life phases will vary from year to year. So, while fixed habitat conditions within a system may consistently support a base level of Walleye spawning activity (e.g., number of eggs deposited), actual recruitment will fluctuate interannually depending on whether these modifying factors enhance or impede survival in early developmental stages.

An example of a 'modifying' factor is water temperature, which is consistently identified as an important driver of recruitment, with warmer spring water temperatures, faster spring warming rates, and stable warming patterns contributing positively to recruitment (Hoyle et al. 2012; Krabbenhoft et al. 2023). Warm and consistently warming water temperatures support rapid growth and development through early life phases, which in turn reduces predation pressure on young Walleye. The timing of when waters warm is also an important factor to ensure that Walleye emergence coincides with the availability of zooplankton, a critical prey item for demersal larvae (i.e., match-mismatch hypothesis; Cushing 1990).

## **BIOTIC FACTORS**

Biotic interactions can be challenging to explicitly link to Walleye recruitment since they may similarly be dynamic (i.e., influenced by within-year environmental factors), and thus challenging to measure. Indeed, Krabbenhoft et al. (2023) noted that the importance of predator-prey dynamics, including cannibalism, in Walleye recruitment were the most commonly identified factor in their survey of experts, but abiotic factors dominated their literature review. The aforementioned link between temperature and Walleye growth, as well as timing of emergence and availability of zooplankton, is a good example of this, since prey availability will directly influence Walleye growth rates but is modulated by systemic warming rates and variability.

The need for rapid growth is largely a response to predation pressure, since faster growth reduces the time larval Walleye will be adrift in the system before they can transition to freely swimming and seek shelter. Similarly, rapid growth allows Walleye to shift to piscivory more quickly, which can resolve predation pressure from some species, with Rainbow Smelt serving as a good example since they shift from a predator to prey item as Walleye grow (Mercado-Silva et al. 2007). Some specific species interactions have also been noted with Northern Pike (*Esox lucius*), Centrarchidae (Raabe et al. 2020), and Yellow Perch (*Perca flavescens*) being identified as both early-life predators and direct competitors for early life resources (Hansen et al. 1998). Several species have also been found to readily consume Walleye eggs (e.g., White Perch [*Morone americana*]; Logperch [*Percina caprodes*]; and Round Goby [*Neogobius melanostomus*]; Roseman et al. 2006), so the presence and abundance of these other fishes can be an important indicator of recruitment success within a system.

## **KNOWLEDGE GAPS AND LIMITATIONS**

While an extensively studied species, knowledge gaps for Walleye still remain. In particular, the ecology of post-hatch Walleye has received less attention, including their habitat requirements and general biology (Raabe et al. 2020). This is largely due to sampling challenges for such small fish. Work by Pratt and Fox (2001) provides useful information on the type of habitat Walleye select once they are able to actively seek shelter (i.e., shallow, nearshore areas with vegetation for cover), but prior to this, they are largely at the mercy of wind, waves, and currents. As a limitation, Krabbenhoft et al. (2023) note that the majority of information on lentic spawning Walleye comes from a limited number of extensively studied systems (e.g., Lake Erie). As such, variation in the importance and nature of drivers of recruitment is possible, but largely not available in the current literature.

## **SYNTHESIS**

The abiotic drivers listed above (e.g., spring warming rates) are thought to largely influence the growth and condition of Walleye eggs and larvae, while the biotic drivers (e.g., prey and predation) will more directly influence their survival (Krabbenhoft et al. 2023). Krabbenhoft et al. (2023) found that survival during the period between early spring and summer was a key driver of recruitment variation in Lake Erie, with spring temperature, discharge, wind and currents, and water clarity being important factors. This is consistent with several inland lakes where recruitment bottlenecks are focused in the early life phases (i.e., post-hatching to midsummer or fall; Boehm 2016; Gostiaux 2018; Raabe et al. 2020). It is therefore likely that Walleye in Hamilton Harbour face a similar early life-phase bottleneck, but this is predicated on the assumption that adults can first find suitable spawning habitat within the system.

## WHAT DO WE KNOW ABOUT RECRUITMENT OF STOCKED WALLEYE IN HAMILTON HARBOUR?

How recruitment is defined may vary depending on the management context. Krabbenhoft et al. (2023) provide a generic definition of recruitment: "...*number of fish born in a given year (cohort) that survive to the fishery or other point of interest...*". For Hamilton Harbour, since an objective of remediation efforts is to improve habitat conditions such that they can support native fish populations, including Walleye (Hamilton Harbour RAP 2018), we interpret recruitment as evidence of young-of-year (YOY) or summer fingerling Walleye captured in the system that cannot be attributed to a stocking event.

Walleye stocking efforts in Hamilton Harbour started in the 1990s with a small number of adult Walleye being transported from the Bay of Quinte (see details in OMNR 2020 and Midwood et al. 2024, Appendix D). In 2012, 100,000 summer fingerlings were released into the harbour, resulting in a strong adult year class, suggesting this was a successful stocking event (OMNR 2020; Appendix A Table A1). Swim-up fry and summer fingerling were stocked in subsequent years, with variable success, although summer fingerling survival appears higher. Year classes from 2016, 2018, 2020, and 2022 have been documented in OMNR's standardize trap net surveys (OMNR 2020; OMNR 2025). Fry and fingerlings for stocking were from a Bay of Quinte (Lake Ontario) strain reared at OMNR's White Lake Fish Culture Station.

### ECOLOGY

#### Spawning Adults

Walleye stocked into Hamilton Harbour are primarily thought to be lentic-shoal spawners, based on multiple lines of evidence. First, acoustic telemetry data show no significant movement into the harbour's tributaries (Larocque et al. 2024a, 2024b) while their nearshore presence at night suggests potential spawning activity in lentic environments (Midwood et al. 2026). Additionally, Walleye have not been observed at the Cootes Paradise Fishway, where they would be captured if attempting to access Spencer's Creek (Midwood et al. 2024). Finally, since 2016, spring boat electrofishing surveys have consistently captured spawning Walleye in shallow water (<2 m) along the shoreline of the harbour (D. T. Reddick, unpublished data). While no formal census of adult Walleye standing stock has been completed, preliminary mark-recapture estimates suggest an adult population of over 1500 individuals (range 559 – 3704; Larocque et al. 2023) within the system between 2017 and 2021. Catch rates in recent, standardized trap net surveys indicate a higher catch per unit effort (CPUE) for Walleye in Hamilton Harbour relative to the Bay of Quinte (3.56 vs 2.27, respectively; Midwood et al. 2024, Appendix D).

#### Habitat

The presence of adult Walleye in shallow nearshore areas of the harbour guided an assessment of spawning habitat conditions, with specific sampling methods designed to inform the application of an egg deposition model (Raabe and Bozek 2012). Potentially suitable spawning and egg incubation habitat, which consisted of larger aggregate material (e.g., gravel, cobble, rubble) at shallow depths (<2 m), was found at multiple locations throughout the harbour (J.D.Midwood, unpublished data).

Using conditions detailed in Pratt and Fox (2001), potential nursery habitats for early- and late-demersal Walleye were estimated and mapped (Appendix Figure A2). This showed extensive, potentially suitable nursery habitat around the margins of the harbour (with the exception of the industrialized southern shoreline), though the suitability of this habitat may be reduced during the summer by periodic upwellings of hypoxic hypolimnetic waters (Flood et al. 2021). Additionally, interannual variation in the extent and coverage of submerged aquatic vegetation driven by changes in water level and water clarity (Gardner Costa et al. 2019) may also influence the amount and distribution of suitable nursery habitat.

## **Eggs**

Gravid female and male Walleye have been found in nearshore areas of the harbour during spawning periods. Walleye eggs have similarly been detected using egg mats (20 x 40 cm horse-hair furnace filter [2.5 cm thick] on metal plates) at several locations within the harbour as part of spatially comprehensive surveys in 2024 (Croft-White et al. 2026) and during a more intensive survey of a single location over the spawning period (Midwood et al. 2026). Eyed or fertilized eggs were noted during these surveys, but their proportion was not explicitly quantified.

Sedimentation rates were evaluated as part of the 2024 egg mat surveys. Silt and organic material can reduce oxygen availability to eggs and, when present in higher density, sand deposition can similarly lead to increased egg mortality (Gatch et al. 2020). Sedimentation was found to be highest at the east end of the harbour, which coincided with the highest egg densities being found in the Southeast location (see Figure 1 for 2024 egg mat locations; Croft-White et al. 2026). Composition of sediment on mats in these areas was dominated by sand (as opposed to silt and organics elsewhere), which indicates that sedimentation and egg transport by wind and wave action may be a challenge in this area given that the wave velocity required to move eggs is lower than that required to move sand (5.0 vs 6.9 cm/s, respectively; Raabe and Bozek 2015).

## **Larvae**

An extensive survey using surface trawling (7810 m<sup>3</sup> of water filtered) was completed in 2024 with no evidence of larval Walleye recruitment (Croft-White et al. 2026). Given the size of the harbour, along with complex wind and water currents, it is possible that low densities of larval Walleye were present, but not captured in the sampling. In some transects, considerable biomass of zooplankton (critical forage for larval Walleye) was detected, suggesting that food resources were present in 2024 for larval Walleye. Even if zooplankton were limiting, larval Walleye have been found to feed on chironomid larvae (Hoxmeier et al. 2004), which are found in the sediments of Hamilton Harbour above 7 m depth (Dermott et al. 2007). More spatially limited larval trawling was completed in 2019 as part of a pilot study, with one potential larval Walleye detected at the west end of the harbour. Identification could not be confirmed, and the sample was not retained. Stocking of swim-up fry in May (i.e., same season as surface trawling, although not in the same years) has also been attempted, but efficacy is somewhat confounded since it has been largely coincident with stocking of summer fingerlings (OMNR 2020). The sole exception was in 2014, when only swim-up fry were stocked, with no clear recruitment from this event into the adult population. Such patterns are largely consistent with past studies of Walleye stocking that have observed increased survival of fingerlings compared to fry (Brooks et al. 2002).

## **Juveniles/YOY**

Prior to 2012, few Walleye were observed in the system during spring, summer, and fall standardized boat electrofishing surveys (Appendix A Figure A3). The ability of electrofishing surveys to detect within-year recruitment of Walleye has been confirmed during surveys of the Bay of Quinte where Walleye <150 mm are most often captured during the fall (September/October). Recruitment from the preceding year is also evident in the Bay of Quinte with Walleye <215 mm (Age-1; Scott and Crossman 1998) observed in late spring or early summer (May and June). Summer fingerlings are the life phase that has been observed to survive well in the harbour during summer stocking events (OMNR 2020). Successful recruitment from this life phase suggests they are able to find suitable habitat and forage opportunities within the harbour. In Hamilton Harbour, boat electrofishing surveys conducted post-stocking in 2012 captured juvenile Walleye, and this finding has been repeated during each year when stocking and boat electrofishing surveys have both occurred (Appendix A Figure A3). In the three years when boat electrofishing surveys have been conducted but stocking has not occurred (2019, 2021, 2023), no YOY Walleye (<215 mm) have been captured, suggesting a lack of natural recruitment within the system during these years. Slightly larger Walleye (215-350 mm) have been captured and were presumed to reflect survival from the preceding year's stocking event (Appendix A Figure A3). Spatially within the harbour, catch of within-year stocked Walleye is largely concentrated within three locations: sheltered areas around Bayfront Park and Pier 4 (proximate to their stocking location), nearshore areas south of the shipping canal, and nearshore areas near Willow Point (Appendix A Figure A3).

## **ABIOTIC FACTORS**

### **Summer Hypoxia**

Hypolimnetic hypoxia during the summer is a long-standing and well-documented issue in Hamilton Harbour (Polak and Haffner 1978; Hiriart-Baer et al. 2016). More recent modelling work has documented wind-induced upwellings of these hypoxic waters into nearshore areas, particularly at the western end and northeast corner of the harbour (Flood et al. 2021). Such upwellings can reduce the suitability of habitat for YOY Walleye in these locations during the summer. These modelling works used benthic and primarily offshore temperature loggers, so the extent to which these upwellings will push into shallow, nearshore areas around the margins of the harbour has not been confirmed. The rate of intrusion of these waters into nearshore areas will be an important factor. While adult Walleye have been observed to actively change their depth to avoid hypoxic waters (<3 mg/L; Brooks et al. 2022), the capacity of YOY Walleye to actively relocate is unknown, but likely limited, and could potentially put them at increased predation risk should they need to move offshore.

### **Water Temperature**

Temperature, and in particular the rate of warming during the spring, play an important role in Walleye recruitment (Roseman et al. 1996). As noted, rapid growth during early life phases are important to reduce the duration of time Walleye are exposed to predation pressure and, specifically for eggs, slower spring warming prolongs their exposure to potential risks from wind and wave action (and resulting transport), siltation, and low oxygen (Busch et al. 1975). Based on a limited surface water temperature dataset (2013-2019; see Appendix B), it was clear that warming rates in the harbour during the egg incubation period aligned with those observed for a "good" recruitment year in Lake Erie for at least two years (2013 and 2017) and were comparable or below "poor" recruitment rates in another two years (2018 and 2019; Roseman et

al. 1996). From the same dataset, exceedances of the upper lethal thermal maximum for Walleye (i.e., temperatures  $>27^{\circ}\text{C}$ ; Raabe et al. 2020) were rarely observed in surface waters, and annual growing degree days for the harbour were well above minimum values observed for inland lakes (Honsey et al. 2020; Appendix B Table B1). Finally, highly variable water temperatures, particularly in May, have been found to limit recruitment (Hansen et al. 1998), but within the harbour, variation in warming rates was low and typically positive in most years (Appendix B Figure B3). Overall, while in some years spring warming rates may limit potential recruitment, temperature conditions within the harbour seem generally favourable for Walleye.

## **Water Quality**

Previous works have identified water quality thresholds for inland lakes (Raabe et al. 2020), which, while not perfectly suited for Hamilton Harbour, can inform the overall suitability of conditions. For example, water clarity in lakes that support healthy Walleye populations (both juveniles and adults) typically fall between 1-3 m Secchi depth ( $\sim 2$  m optimal; Lester et al. 2004). Hamilton Harbour data from 2013-2018 found conditions typically within this range (mean 2.1-3.1 m), albeit with deeper Secchi depth values during some pelagic sampling events (i.e., max = 5.0 m; Appendix C). These samples, however, are largely taken in the main basin of the harbour and so likely overestimate Secchi depth values in areas where extensive algal blooms form.

As suggested in Midwood et al. (2024), the extent to which contaminants (e.g., polycyclic aromatic hydrocarbons, hormones, pesticides, pharmaceuticals and lifestyle compounds, road salt, among others) influence fish populations and recruitment in Hamilton Harbour is largely unknown. Such compounds can negatively impact reproduction, growth, development, and survival in fishes (Baker et al. 2022), but the magnitude of these effects and their influence relative to other factors in the system on natural Walleye recruitment is unknown.

## **BIOTIC FACTORS**

### **Predation**

Several fish species have been found to prey on Walleye during their early life phases (i.e., egg and larval), including: White Perch, Yellow Perch, Round Goby, and Logperch, among others (Roseman et al. 2006). Boat electrofishing conducted between 2013-2023 in May and June found White Perch at all six locations assessed in the harbour, with the highest catch per unit effort in the Southeast location (Appendix D Figure D1). Catch of Logperch, Yellow Perch, and Round Goby was minimal, with the exception of the west end, which had the highest catch rates for Round Goby. Largemouth Bass will readily eat juvenile Walleye and have been linked to declines in stocked Walleye (Fayram et al. 2005) and found to limit stocking success (Davis and Isermann 2024). Within Hamilton Harbour, Largemouth Bass are found proximate to all six locations, but catch is highest at the west end of the harbour (Larocque et al. 2024a; Appendix D Figure D2) and has remained relatively stable within the harbour since sampling started in 1988 (Midwood et al. 2024). Finally, cannibalism is likely an important source of predation for Walleye, with adults and juveniles targeting individuals smaller than themselves, and larval Walleye consuming similarly sized individuals (Chevalier 1973; Cuff 1980).

### **Competition**

The survival and comparable growth rates of adult stocked Walleye to Walleye in the Bay of Quinte imply they are not greatly affected by competition for resources. As noted previously, the

recovery of top predators is a core objective for Hamilton Harbour Area of Concern fish populations, and recent works have found either low catch and population sizes (e.g., Northern Pike and Smallmouth Bass; Larocque et al. 2023; Midwood et al. 2024; OMNR 2025) or restricted spatial distributions (e.g., Largemouth Bass; Larocque et al. 2024a, 2024b) for top predators that compete with Walleye in other systems. Resource competition for adult Walleye is, therefore, likely limited. Additionally, an abundance of Gizzard Shad (*Dorosoma cepedianum*) in Hamilton Harbour (Midwood et al. 2024) likely provide excellent forage opportunities for Walleye as they have high lipid contents and are a preferred prey item for Walleye in Lake Erie (Madenjian et al. 1996). In the eastern basin of Lake Ontario, summer diets for Walleye that move into the main basin of Lake Ontario are dominated by Alewife, while younger Walleye that remain in the Bay of Quinte have a more diverse diet that also includes: Yellow Perch, White Perch, Gizzard Shad, and Johnny Darter (*Etheostoma nigrum*) (Hoyle et al. 2017). Diverse forage selection and their clear ability to migrate to find suitable resources both likely act to reduce competition.

Little research has been conducted on competition as a driver for Walleye recruitment success (1.7% of studies; Krabbenhoft et al. 2023), but findings suggest that competition is tied to water temperature. Large temperature fluctuations during early development may slow growth, decreasing competition, whereas warm waters and higher growing degree days may increase competition with warmwater species. Walleye larvae select for the rarer and larger cladocerans, instead of the smaller, more abundant cyclopoid copepods (Johnston and Mathias 1994), and fry survival was highest when the density of large-bodied cladocerans and adult copepods exceeded 100 organisms/L (Peterson et al. 2006). Bowen and Currie (2017) identified a higher proportion of small-bodied zooplankton in Hamilton Harbour, suggesting high fish planktivory. In addition, the overall zooplankton biomass and density in Hamilton Harbour are among the highest in the Great Lakes (Bowen and Currie 2017), supporting planktivorous fishes such as Alewife (*Alosa pseudoharengus*) and Emerald Shiner (*Notropis atherinoides*). Although abundant, zooplankton blooms were highly variable in Hamilton Harbour during larval tows (May 2024), with large quantities captured at some locations (Croft-White et al. 2026), but very few zooplankton at the same survey location only a few days later.

Analysis of fish community data from 1988 to 2023 identified little change in the relative proportion of planktivorous fish in Hamilton Harbour, particularly when Alewife were excluded, as declines in Alewife numbers in the harbour are more of a reflection of the lake population (Midwood et al. 2024; Turner et al. 2025). Regardless, planktivorous fishes that may compete with the early life phase of Walleye are still present in the system, with higher catch per unit effort of Alewife along the north and west shores and Emerald Shiner more often captured, albeit in lower numbers than Alewife, in the west, southeast, and northeast (Appendix D Figures D3 and D4).

## **SYNTHESIS**

While all factors undoubtedly influence Walleye recruitment, there are likely some key drivers limiting recruitment in Hamilton Harbour (see Table 1), specifically: sedimentation of eggs and spawning grounds either from discharge or wind and wave action, transport of larval Walleye to suitable nursery habitat (R. Valipour, unpublished data), egg and fry predation (White Perch in particular), summer hypoxia compressing habitats, and unknown influences on growth and development from water-based contaminants (e.g., pharmaceuticals).

## DISCUSSION

Based on electrofishing, acoustic telemetry, egg deposition, and habitat data, Walleye are spawning on suitable substrate, but the absence of swim-up fry in larval tows or young-of-year in fall electrofishing surveys indicates an early life-stage recruitment bottleneck (Croft-White et al. 2026, Midwood et al. 2026). The situation in Hamilton Harbour is similar to some inland lakes with recruitment bottlenecks focused on early life phases, with failure occurring somewhere between post-hatching and midsummer or fall (Boehm 2016; Gostiaux 2018; Raabe et al. 2020). However, in those works, post-hatch larval Walleye were still captured (albeit in lower numbers), while in Hamilton Harbour, we have not detected post-hatch larvae.

Successful recruitment is dependent on a number of fixed factors like substrate composition and bathymetry, as well as modifying factors that vary by year and system, such as the rate of temperature warming, sedimentation, winds, and currents. While fixed habitat factors will still vary among systems and among years (e.g., water levels changing suitable substrate depths), modifying factors will more directly influence the magnitude of survival and ultimately, recruitment, leading to strong year-class recruitment when modifying factors are favourable. That daily, seasonal, and annual fluctuations in modifying factors (e.g., water warming rates, wind velocity/direction, and water quality) are driven by natural processes puts them beyond the scope of restoration-focused interventions. In contrast, as the baseline requirement for spawning success, fixed factors are more amenable to such efforts.

The Southeast location (see Figure 1) in the harbour had the highest rate of egg deposition, but also the highest exposure, making eggs vulnerable to both sedimentation and transport (Croft-White et al. 2026). Reducing exposure at this location could help reduce transport and sediment deposition. Artificial islands built in the Northeast corner of the harbour provide shelter and warm-water refugia for some fish species (Maynard et al. 2022) and are thus one potential means of reducing exposure. Areas behind these islands, however, are prone to sedimentation from Indian Creek and proximate to large colonies of nesting birds (i.e., Double-crested Cormorant [*Phalacrocorax auritus*]) and thus, potentially high rates of avian predation. The creation of similar structures in the Southeast corner of the harbour that reduce wave energy may increase sedimentation of silt and organic material, thereby decreasing spawning habitat quality. Walleye have also been observed aggregating further offshore at the Southeast location during the spawning season in deeper water and over less suitable (i.e., sand) substrates (Midwood et al. 2026). Aggregations further offshore were hypothesized to be linked to the comparatively higher wave energy closer to shore relative to smaller inland lakes (i.e., Raabe and Bozek 2012). Substrate enhancements at greater depths (i.e., 1-3 m) in this location could provide more suitable spawning conditions and would be less influenced by wind and wave actions and thus inadvertent transport of eggs. Such additions could be costly and would have to be weighed against potential negative effects on the spatially limited beds of submerged aquatic vegetation found at this location (Gardner Costa et al. 2019). Regardless of the approach used, detailed modelling of sediment transport dynamics at the Southeast location are essential prior to consideration of the creation of any in-water structures or addition of aggregate materials.

Historically, rocky shoals existed along the north shore of the harbour (Holmes and Whillans 1984), but have since been buried by sediment. The North location (see Figure 1), just east of Willow Point has potential for restoration as it is close to nursery habitat (west end and north shore), is less exposed to wind and wave action than the Southeast location, and currently has a hardened shoreline (concrete-filled barrels) and sandy substrate. Actions could include the addition of gravel and cobble substrates for spawning; however, similar to the Southeast location, hydrodynamic or sedimentology studies should be conducted to determine long-term retention and rates of sedimentation of any added spawning substrates.

Hamilton Harbour has adequate spawning substrates at multiple locations, sufficient depth, and ample cover for nursery habitat; however, connectivity between the preferred spawning habitat and nursery habitat is poor. The area with the highest egg deposition lies in the southeast corner of the harbour, but the nursery habitat in the west and the north shore lies upwind and upcurrent from the areas of highest egg deposition. Conversely, spawning locations in the west end, which are closer to nursery habitat, are affected by silty sediments and have low egg deposition (Croft-White et al. 2026). Any habitat-related restoration action must therefore take into account the likelihood that winds and currents can bring larval Walleye close to suitable nursery habitat. Works are currently underway to use particle tracing to evaluate movement and dispersal within the harbour at a range of potential spawning locations. Such an approach has been used to accurately predict the larval Walleye transport in Saginaw Bay, Lake Huron (Sesterhenn et al. 2014), and should similarly shed light on larval Walleye transport in Hamilton Harbour that could identify opportunities to improve habitat connectivity.

From a stocking perspective, there are some potential modifications to the current strategy that may enhance survival and potentially the establishment of natural recruitment. First, Walleye currently in the system appear to exclusively spawn over nearshore shoals within the harbour, while historic Walleye populations were noted to move into tributaries for spawning (Dymond 1929). Both river and shoal spawning Walleye are observed in the donor stock in the Bay of Quinte, with no evidence for differences in genetic structure between fish that demonstrate these two distinct behaviours (Wilson and Gatt 2001). In both the 2020 and 2022 stocking events, eggs were solely sourced from Walleye spawning in the Trent River (S. Beech, pers. comm.) yet, thus far, these fish have not been detected moving into Hamilton Harbour tributaries. Walleye have been found to display spawning site fidelity (Hayden et al. 2018); therefore, directed stocking of early life phases into tributaries may help establish such homing behaviour. Conditions within the tributaries would have to be suitable for Walleye survival, with a feasibility study assessing current conditions a good first step. An alternate hypothesis for Walleye posits that spawning site selection is a learned behaviour, with younger Walleye learning where spawning areas are by following older adults (Olson et al. 1978 in Barton 2011). In a situation like Hamilton Harbour, where Walleye were extirpated, such behaviours would present a challenge since fish first stocked into the system would have self-selected spawning areas that may or may not provide suitable conditions for recruitment. Finally, the primary release point for stocked Walleye has been at Pier 4, which is one of three areas where YOY Walleye have been captured during boat electrofishing surveys. Based on telemetry and electrofishing, this area also has a high density of predators [e.g., Largemouth Bass; (Larocque et al. 2024a)] relative to other areas of the harbour, which could reduce survival of stocked individuals (although at present clear that some base level of stocked individuals still survive at this location). Shifting locations to areas with lower predator densities (e.g., north shore) or

spreading out stocking effort to multiple locations could help reduce short-term predation while also putting stocked individuals into closer proximity to suitable nursery habitat.

With ongoing efforts to improve the treatment of wastewater entering Hamilton Harbour, some of the modifying pressures related to water quality, such as summer hypoxia, algal blooms, and water-based contaminants, may be reduced. Reduced pressure may allow for greater survival of early life phases, provided challenges related to sedimentation, transport, and predation can be alleviated. These works have identified some strong candidate areas where recruitment may be possible (Table 2), notably in the nearshore areas south of the shipping canal where: 1) adult Walleye are consistently observed spawning, 2) suitable spawning and nursery habitat are present, 3) the highest density of eggs have been found, and 4) YOY Walleye have been captured (albeit during stocking years). A more comprehensive assessment of potential nursery habitats, based on capture of YOY Walleye in areas proximate to Bayfront Park and Willow Point, is also warranted to assess the suitability of habitat conditions and potential influence of summer upwellings of hypoxic waters in these areas.

There are likely few direct management actions that can promote Walleye recruitment in the near-term since recruitment seems currently limited in early life phases (egg/larval fish) due to a complex network of interacting factors that include: water quality, sedimentation, wind and wave transport, and predation. Therefore, in the near-term, we recommend monitoring for juvenile Walleye as part of DFO's standardized fish community surveys of the harbour. In particular, surveys conducted in alternating years with stocking events are ideal for identifying natural recruitment into the system. In the Bay of Quinte, the highest capture rates of individuals <150 mm (i.e., those most reflective of within-year recruitment) occurred during the fall (September/October), and so surveys that occur during this period may be the best boat electrofishing-based indicators of natural recruitment.

This review has identified a variety of research questions that could inform our understanding of Walleye recruitment limitations in Hamilton Harbour. As noted, a large unknown in the system is the influence of water quality and contaminants on the growth and development of fishes (Midwood et al. 2024). This is similarly true for Walleye and may be a compounding factor limiting early life survival. Holding fertilized Walleye eggs in harbour waters and contrasting egg survival and hatching rates would help to document the extent and magnitude of developmental issues related to water-based contaminants (e.g., PCBs, PAHs, hormones, pharmaceuticals, etc.). Similarly, an evaluation of the growth and development of hatched Walleye from the system would help determine if any water-related contaminants are causing deformities in larval Walleye.

## **ACKNOWLEDGEMENTS**

Funding for this project came from Environment and Climate Change Canada via the Great Lakes Action Plan. We are grateful for the helpful input provided by two peer reviewers.

## REFERENCES

- Baccante, D.A., and Colby, P.J. 1996. Harvest, density and reproductive characteristics of North American walleye populations. *Annales Zoologici Fennici* **33**(3–4): 601–615.
- Bade, A.P., Binder, T.R., Faust, M.D., Vandergoot, C.S., Hartman, T.J., Kraus, R.T., Krueger, C.C., and Ludsin, S.A. 2019. Sex-based differences in spawning behavior account for male-biased harvest in Lake Erie Walleye (*Sander vitreus*). *Canadian Journal of Fisheries and Aquatic Sciences* **76**(11): 2003–2012. doi:10.1139/cjfas-2018-0339.
- Baker, B.B., Haimbaugh, A.S., Sperone, F.G., Johnson, D.M., and Baker, T.R. 2022. Persistent contaminants of emerging concern in a great lakes urban-dominant watershed. *Journal of Great Lakes Research* **48**(1): 171–182. doi:10.1016/j.jglr.2021.12.001.
- Barton, B.A. 2011. Biology, management, and culture of walleye and sauger. American Fisheries Society, Bethesda, MD.
- Boehm, H.I.A. 2016. Identifying recruitment bottlenecks for age-0 Walleye *Sander vitreus* in northern Wisconsin lakes. University of Wisconsin.
- Bowen, K.L., and Currie, W.J.S. 2017. Elevated zooplankton production in a eutrophic Lake Ontario embayment: Hamilton Harbour 2002–2014. *Aquatic Ecosystem Health and Management* **20**(3): 230–241. doi:10.1080/14634988.2017.1294425.
- Bozek, M., Baccante, D., and Lester, N. 2011a. Walleye and sauger life history. *In: Biology, Management, and Culture of Walleye and Sauger*, Bethesda, Maryland: 233–301.
- Bozek, M.A., Haxton, T.J., and Raabe, J.K. 2011b. Walleye habitat: Management and research needs. *In: Biology, Management, and Culture of Walleye and Sauger*, Bethesda, Maryland: 133–197.
- Brooks, J.L., Ledee, E.J., Larocque, S.M., Cooke, S.J., Brown, E., and Midwood, J.D. 2025. The influence of thermal and hypoxia induced habitat compression on Walleye (*Sander vitreus*) movements in a temperate lake. *Movement Ecology* **13**(1).
- Brooks, J.L., Midwood, J.D., Smith, A., Cooke, S.J., Flood, B., Boston, C.M., Semecsen, P., Doka, S.E., and Wells, M.G. 2022. Internal seiches as drivers of fish depth use in lakes. *Limnology and Oceanography* **67**(5): 1040–1051. doi:10.1002/lno.12055.
- Brooks, R.C., Heidinger, R.C., Hoxmeier, R.J.H., and Wahl, D.H. 2002. Relative Survival of Three Sizes of Walleyes Stocked into Illinois Lakes. *North American Journal of Fisheries Management* **22**(3): 995–1006. doi:10.1577/1548-8675(2002)022<0995:rsotso>2.0.co;2.
- Brousseau, C.M., Randall, R.G., and Clark, M.G. 2005. Protocol for boat electrofishing in nearshore areas of the lower Great Lakes: transect and point survey methods for collecting fish and habitat data , 1988 to 2002 . Canadian Technical Report of Fisheries and Aquatic Sciences **2702**: xi + 89 p.
- Bruner, J.C., and DeBruyne, R.L. 2021. Yellow Perch, Walleye, and Sauger: aspects of ecology, management, and culture. Springer International Publishing.

- Busch, W.-D.N., Scholl, R.L., and Hartman, W.L. 1975. Environmental Factors Affecting the Strength of Walleye (*Stizostedion vitreum vitreum*) Year-Classes in Western Lake Erie, 1960–70 . *Journal of the Fisheries Research Board of Canada* **32**(10): 1733–1743. doi:10.1139/f75-207.
- Chevalier, J.R. 1973. Cannibalism as a factor in first year survival of Walleye in Oneida Lake. *Transactions of the American Fisheries Society* **4**: 739–744.
- Croft-White, M.V., Glasbergen, J. Bzonek, P.A., Fernandes, S., Reddick, D.T, Turner, N.A., Midwood, J.D., 2026. Spring egg mat and larval net tow surveys for Walleye in Hamilton Harbour. *Canadian Manuscript Report of Fisheries and Aquatic Sciences* **3310**, vi + 23 p.
- Cuff, W.R. 1980. Behavioral aspects of cannibalism in larval walleye, *Stizostedion vitreum*. *Canadian journal of zoology* **58**(8): 1504–1507. doi:10.1139/z80-207.
- Cushing, D.H. 1990. Plankton production and year-class strength in fish populations: An update of the match/mismatch hypothesis. *In Advances in Marine Biology*. doi:10.1016/S0065-2881(08)60202-3.
- Davis, R.P., and Isermann, D.A. 2024. Assessing factors related to Walleye stocking success in the Midwestern United States. *North American Journal of Fisheries Management* (May): 1008–1024. doi:10.1002/nafm.11030.
- Dermott, R., Johannsson, O., Munawar, M., Bonnell, R., Bowen, K., Burley, M., Fitzpatrick, M., Gerlofsma, J., and Niblock, H. 2007. Assessment of lower food web in Hamilton Harbour, Lake Ontario , 2002 - 2004 . *Canadian Technical Report of Fisheries and Aquatic Sciences* **2729**: 120 p.
- Dymond, J.R., Hart, J.L., and Pritchard, A.L. 1929. *The fishes of the Canadian waters of Lake Ontario*. Univ. Library.
- Engel, S., Hoff, M.H., and Newman, S.P. 2000. Walleye fry hatching, diet, growth and abundance in Escanaba Lake, Wisconsin, 1985-1992. Madison, WI.
- Fayram, A.H., Hansen, M.J., and Ehlinger, T.J. 2005. Interactions between Walleyes and Four Fish Species with Implications for Walleye Stocking. *North American Journal of Fisheries Management* **25**(4): 1321–1330. doi:10.1577/m04-203.1.
- Flood, B., Wells, M., Midwood, J.D., Brooks, J., Kuai, Y., and Li, J. 2021. Intense variability of dissolved oxygen and temperature in the internal swash zone of Hamilton Harbour, Lake Ontario. *Inland Waters* **11**(2): 162–179. doi:10.1080/20442041.2020.1843930.
- Fraker, M.E., Anderson, E.J., May, C.J., Chen, K.Y., Davis, J.J., DeVanna, K.M., DuFour, M.R., Marschall, E.A., Mayer, C.M., Miner, J.G., Pangle, K.L., Pritt, J.J., Roseman, E.F., Tyson, J.T., Zhao, Y., and Ludsin, S.A. 2015. Stock-specific advection of larval walleye (*Sander vitreus*) in western Lake Erie: Implications for larval growth, mixing, and stock discrimination. *Journal of Great Lakes Research* **41**(3): 830–845. doi:10.1016/j.jglr.2015.04.008.
- Gardner Costa, J., Tang, R.W.K., Leisti, K.E., Midwood, J.D., and Doka, S.E. 2019. Submerged aquatic vegetation survey in Hamilton Harbour, Lake Ontario, 2016. *Canadian Technical Report of Fisheries and Aquatic Sciences* **3320**: viii + 43 p.

- Gatch, A.J., Koenigbauer, S.T., Roseman, E.F., and Höök, T.O. 2020. The Effect of Sediment Cover and Female Characteristics on the Hatching Success of Walleye. *North American Journal of Fisheries Management* **40**(1): 293–302. doi:10.1002/nafm.10407.
- Gostiaux, J.C. 2018. Expanded assessment of recruitment bottlenecks for Age-0 Walleye *Sander vitreus* in northern Wisconsin. University of Wisconsin.
- Hall, L.S., Krausman, P.R., Morrison, M.L., Hall, L.S., Krausman, P.R., and Morrison, M.L. 1997. The habitat concept and a plea for standard terminology. *Wildlife Society Bulletin* **25**(1): 173–182.
- Hamilton Harbour Remedial Action Plan (HHRAP). 1992a. Remedial action plan for Hamilton Harbour stage 1 second edition: environmental conditions and problem definition. Canada Ontario Agreement: Prepared for Ontario Ministry of Environment and Environment Canada. Ottawa, Canada.
- Hamilton Harbour Remedial Action Plan (HHRAP). 1992b. Remedial Action Plan for Hamilton Harbour Stage 2, Volume 2 – Main Report: Goals, Options and Recommendations. Canada Ontario Agreement: Prepared for the Ontario Ministry of the Environment and Environment Canada.
- Hansen, G.J.A., Carpenter, S.R., Gaeta, J.W., Hennessy, J.M., and Vander Zanden, M.J. Vander. 2015. Predicting walleye recruitment as a tool for prioritizing management actions. *Canadian Journal of Fisheries and Aquatic Sciences* **72**(5): 661–672. doi:10.1139/cjfas-2014-0513.
- Hansen, M.J., Bozek, M.A., Newby, J.R., Newman, S.P., and Staggs, M.D. 1998. Factors Affecting Recruitment of Walleyes in Escanaba Lake, Wisconsin, 1958–1996. *North American Journal of Fisheries Management* **18**(4): 764–774. doi:10.1577/1548-8675(1998)018<0764:farowi>2.0.co;2.
- Hansen, M.J., Fayram, A.H., and Newman, S.P. 2011. Natural mortality in relation to age and fishing mortality on walleyes in Escanaba Lake, Wisconsin, during 1956–2009. *North American Journal of Fisheries Management* **31**(3): 506–514. doi:10.1080/02755947.2011.593929.
- Hayden, T.A., Binder, T.R., Holbrook, C.M., Vandergoot, C.S., Fielder, D.G., Cooke, S.J., Dettmers, J.M., and Krueger, C.C. 2018. Spawning site fidelity and apparent annual survival of walleye (*Sander vitreus*) differ between a Lake Huron and Lake Erie tributary. *Ecology of Freshwater Fish* **27**: 339–349. doi:10.1111/eff.12350.
- Hiriart-Baer, V.P., Boyd, D., Long, T., Charlton, M.N., and Milne, J.E. 2016. Hamilton Harbour over the last 25 years: Insights from a long-term comprehensive water quality monitoring program. *Aquatic Ecosystem Health & Management* **19**(2): 124–133. doi:10.1080/14634988.2016.1169686.
- Holmes, J.A., and Whillans, T.H. 1984. Historical review of Hamilton Harbour fisheries. *Canadian Technical Report of Fisheries and Aquatic Sciences* **1257**: 65 p.
- Honsey, A.E., Feiner, Z.S., and Hansen, G.J.A. 2020. Drivers of walleye recruitment in Minnesota's large lakes. *Canadian Journal of Fisheries and Aquatic Sciences* **77**(12): 1921–1933. doi:10.1139/cjfas-2019-0453.

- Hoxmeier, R.J.H., Wahl, D.H., Hooe, M.L., and Pierce, C.L. 2004. Growth and Survival of Larval Walleyes in Response to Prey Availability. *Transactions of the American Fisheries Society* **133**(1): 45–54. doi:10.1577/t01-082.
- Hoyle, J.A., Bowlby, J.N., Brousseau, C.M., Johnson, T.B., Morrison, B.J., and Randall, R.G. 2012. Fish community structure in the Bay of Quinte, Lake Ontario: The influence of nutrient levels and invasive species. *Aquatic Ecosystem Health and Management* **15**(4): 370–384. doi:10.1080/14634988.2012.727732.
- Izzo, L.K., Dembkowski, D., Hayden, T., Binder, T., Vandergoot, C., Hogler, S., Donofrio, M., Zorn, T., Krueger, C.C., and Isermann, D. 2023. Spawning Locations, Movements, and Potential for Stock Mixing of Walleye in Green Bay, Lake Michigan. *North American Journal of Fisheries Management* **43**(3): 695–714. doi:10.1002/nafm.10883.
- Jennings, M.J., Kampa, J.M., Hatzenbeler, G.R., and Emmons, E.E. 2005. Evaluation of Supplemental Walleye Stocking in Northern Wisconsin Lakes. *North American Journal of Fisheries Management* **25**(3): 1171–1178. doi:10.1577/m04-218.1.
- Johnston, T.A., and Mathias, J.A. 1994. Feeding ecology of Walleye, *Stizostedion vitreum*, larvae: effects of body size, zooplankton abundance, and zooplankton community composition. *Canadian Journal of Fisheries and Aquatic Sciences* **51**: 2077–2089.
- Kalejs, N.I., Zischke, M.T., Beugly, J.S., Collingsworth, P.D., Roseman, E.F., Hunter, R.D., Fielder, D.G., and Höök, T.O. 2022. An evaluation of fish spawning on degraded and remnant reefs in Saginaw Bay, Lake Huron. *Journal of Great Lakes Research* **48**(2): 593–605. doi:10.1016/j.jglr.2022.01.010.
- Kerr, S.J. 2011. Stocking and marking: lessons learned over the past century. *Biology, Management, and Culture of Walleye and Sauger*. American Fisheries Society, Bethesda, Maryland, 423-449.
- Krabbenhoft, C.A., Ludsin, S.A., Marschall, E.A., Budnik, R.R., Almeida, L.Z., Cahill, C.L., Embke, H.S., Feiner, Z.S., Schmalz, P.J., Thorstensen, M.J., Weber, M.J., Wuellner, M.R., and Hansen, G.J.A. 2023. Synthesizing Professional Opinion and Published Science to Build a Conceptual Model of Walleye Recruitment. *Fisheries* **48**(4): 141–156. doi:10.1002/fsh.10884.
- Larocque, S.M., Boston, C.M., Brooks, J.L., Jacob, W., Cooke, S.J., Doka, S.E., and Midwood, J.D. 2024a. Telemetry-derived seasonal fish-habitat associations and spatial use in the Hamilton Harbour Area of Concern in western Lake Ontario. *Canadian Technical Report of Fisheries and Aquatic Sciences* **3593**: vii + 193 p.
- Larocque, S.M., Bzonek, P.A., Brownscombe, J.W., Martin, G.K., Brooks, J.L., Boston, C.M., Doka, S.E., Cooke, S.J., and Midwood, J.D. 2024b. Application of telemetry-based fish habitat models to predict spatial habitat availability and inform ecological restoration. *Journal of Fish Biology* **106**(5): 1601–1618. doi:10.1111/jfb.15899.
- Larocque, S.M., Piczak, M.L., Turner, N.A., Jennifer, E., Boston, C.M., and Midwood, J.D. 2023. Mark-recapture population estimates of piscivores in the Hamilton Harbour Area of Concern. *Canadian Technical Report of Fisheries and Aquatic Sciences* **3506**: vii + 31 p.

- Leis, A.L., and Fox, M.G. 1996. Feeding, growth, and habitat associations of young-off-year walleye (*Stizostedion vitreum*) in a river affected by a mine tailings spill. *Canadian Journal of Fisheries and Aquatic Sciences* **53**(11): 2408–2417. doi:10.1139/f96-203.
- Lester, N.P., Dextrase, A.J., Kushneriuk, R.S., Rawson, M.R., and Ryan, P.A. 2004. Light and Temperature: Key Factors Affecting Walleye Abundance and Production. *Transactions of the American Fisheries Society* **133**(3): 588–605. doi:10.1577/t02-111.1.
- Madenjian, C.P., Tyson, J.T., Knight, R.L., Kershner, M.W., and Hansen, M.J. 1996. First-year growth, recruitment, and maturity of Walleyes in western Lake Erie. *Transactions of the American Fisheries Society* **125**(6): 821–830.
- Maynard, D., Boston, C.M., and Midwood, J.D. 2022. Fish community structure varies by location and presence of artificial islands: a case study in Hamilton Harbour, Lake Ontario. *Environmental Biology of Fishes* **105**: 1557–1573. doi:10.1007/s10641-022-01348-z.
- Mercado-Silva, N., Sass, G.G., Roth, B.M., Gilbert, S., and Vander Zanden, M.J. 2007. Impact of rainbow smelt (*Osmerus mordax*) invasion on walleye (*Sander vitreus*) recruitment in Wisconsin lakes. *Canadian Journal of Fisheries and Aquatic Sciences* **64**(11): 1543–1550. doi:10.1139/F07-112.
- Midwood, J.D., Balshine, S., Beech, S., Boston, C.M., Brown, E., Budgell, E., Croft-White, M. V., Gardner Costa, J., Larocque, S.M., Mehdi, H., Rebalka, A., Reddick, D., Turner, N.A., Theysmeyer, T., and Vanden Byllaardt, J. 2024. Assessment of the fish populations beneficial use impairment in the Hamilton Harbour Area of Concern. *Canadian Technical Report of Fisheries and Aquatic Sciences* **3628**: xxi + 315 p.
- Midwood, J.D., Brooks, J.L., Bzonek, P., Cooke, S.J., Croft-White, M., Reddick, D.T., Turner, N., Larocque, S., Hasler, C.T. 2026. Fine-scale behaviour of Walleye (*Sander vitreus*) on a spawning shoal in Hamilton Harbour, Ontario. *Journal of Great Lakes Research*, **102728**. doi: 10.1016/j.jglr.2025.102728.
- Murphy, B.R., Brown, M.L., and Springer, T.A. 1990. Evaluation of the relative Weight (Wr) index, with new applications to Walleye. *North American Journal of Fisheries Management* **10**(1): 85-97.
- Ontario Ministry of Natural Resources (OMNR). 2020. Lake Ontario Fish Communities and Fisheries: 2019 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources, Picton, Ontario, Canada.
- Ontario Ministry of Natural Resources (OMNR). 2025. Lake Ontario Fish Communities and Fisheries: 2024 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources, Picton, Ontario, Canada.
- Peterson, D.L., Peterson, J., and Carline, R.F. 2006. Effects of zooplankton density on survival of stocked walleye fry in five Pennsylvania reservoirs. *Journal of Freshwater Ecology* **21**(1): 121–129. doi:10.1080/02705060.2006.9664104.
- Polak, J., and Haffner, G.D. 1978. Oxygen depletion of Hamilton Harbour. *Water Research* **12**(4): 205–215. doi:10.1016/0043-1354(78)90088-X.

- Pratt, T.C., and Fox, M.G. 2001. Biotic influences on habitat selection by young-of-year walleye (*Stizostedion vitreum*) in the demersal stage. *Canadian Journal of Fisheries and Aquatic Sciences* **58**(6): 1058–1069. doi:10.1139/cjfas-58-6-1058.
- Raabe, J.K., and Bozek, M.A. 2012. Quantity, structure, and habitat selection of natural spawning reefs by walleyes in a north temperate lake: A multiscale analysis. *Transactions of the American Fisheries Society* **141**(4): 1097–1108. doi:10.1080/00028487.2012.679017.
- Raabe, J.K., and Bozek, M.A. 2015. Influence of wind, wave, and water level dynamics on walleye eggs in a north temperate lake. *Canadian Journal of Fisheries and Aquatic Sciences* **72**(4): 570–581. doi:10.1139/cjfas-2014-0320.
- Raabe, J.K., VanDeHey, J.A., Zentner, D.L., Cross, T.K., and Sass, G.G. 2020. Walleye inland lake habitat: considerations for successful natural recruitment and stocking in North Central North America. *Lake and Reservoir Management* **36**(4): 335–359. doi:10.1080/10402381.2019.1697771.
- Roseman, E.F., Taylor, W.W., Hayes, D.B., Haas, R.C., Davies, D.H., and Mackey, S.D. 1999. Influence of physical processes on the early life history of Walleye (*Stizostedion vitreum*) in western Lake Erie. *In Ecosystem Approaches for Fisheries Management*. University of Alaska Sea Grant. doi:10.4027/eafm.1999.
- Roseman, E.F., Taylor, W.W., Hayes, D.B., Haas, R.C., Knight, R.L., and Paxton, K.O. 1996. Walleye egg deposition and survival on reefs in Western Lake Erie (USA). *Annales Zoologici Fennici* **33**(3–4): 341–351.
- Roseman, E.F., Taylor, W.W., Hayes, D.B., Jones, A.L., and Francis, J.T. 2006. Predation on walleye eggs by fish on reefs in western Lake Erie. *Journal of Great Lakes Research* **32**(3): 415–423. doi:10.3394/0380-1330(2006)32[415:POWEBF]2.0.CO;2.
- Scott, W.B., and Crossman, E.J. 1998. *Freshwater Fishes of Canada*. Oakville, Ontario.
- Sesterhenn, T.M., Roswell, C.R., Stein, S.R., Klaver, P., Verhamme, E., Pothoven, S.A., and Höök, T.O. 2014. Modeling the implications of multiple hatching sites for larval dynamics in the resurgent Saginaw Bay walleye population. *Journal of Great Lakes Research* **40**(S1): 113–122. doi:10.1016/j.jglr.2013.09.022.
- Sissenwine, M.P., Fogarty, M.J., and Overholtz, W.J. 1988. Some fisheries management implications of recruitment variability. *In fish Population Dynamics*, 2nd Edition. *Edited by* J.A. Gulland. Wiley, Chichester, UK. pp. 129–152.
- Tsehay, I., Roth, B.M., and Sass, G.G. 2016. Exploring optimal walleye exploitation rates for northern Wisconsin ceded territory lakes using a hierarchical bayesian age-structured model. *Canadian Journal of Fisheries and Aquatic Sciences* **73**(9): 1413–1433. doi:10.1139/cjfas-2015-0191.
- Turner, N.A., Croft-White, M. V., Boston, C.M., and Midwood, J.D. 2025. A temporal comparison of nearshore fish communities in Hamilton Harbour and the Bay of Quinte Areas of Concern (1988 -2021). *Journal of Great Lakes Research*, **102609**. doi:10.1016/j.jglr.2025.102609

- Vandergroot, C.S., Cook, A.H., and Thomas, M.V. 2010. Status of walleye in western Lake Erie, 1985-2006. *In* Status of Walleye in the Great Lakes: Proceedings of the 2006 Symposium, Technical. *Edited by* E. Roseman, P. Kocovsky, and C. Vandergoot. Great Lakes Fishery Commission. p. 232.
- Whillans, T.H. 1977. Fish community transformation in three bays within the lower Great Lakes. University of Toronto, Department of Geography.
- Wilson, C.C. and Gatt, M., 2001. Genetic structure of spawning walleye (*Stizostedion vitreum*) populations in and near the Bay of Quinte, Lake Ontario. 10 p. Part III. Special Studies. In Lake Ontario Fish Communities and Fisheries: 2000 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources, Picton, ON.
- Zentner, D.L. 2017. Modeling wind, water movement, and physical habitat in Minnesota Lakes and associated influences on Walleye spawning habitat. University of Wisconsin.

## TABLES AND FIGURES

**Table 1.** Summary of potential base (fixed) and modifying (within-year) factors influencing Walleye recruitment in Hamilton Harbour (HH).

Base	Factor	Situation In Systems with Naturally Recruiting Populations			Overall Situation In HH
		Eggs	Non-Swimming Fry	Swimming Fry	
<i>("fixed")</i>	<i>Suitable substrate</i>	Holds/protects eggs Allows for sufficient oxygen Reduces smothering	N/A	N/A	Suitable substrate was found in multiple locations
	<i>Suitable depth</i>	Shallow waters warm more quickly/ retain heat Protect from wind/wave action Limit UV effects in clear water	N/A	Shallow waters warm more quickly/ retain heat Protect from wind/wave action	Suitable depths are present
	<i>Suitable cover</i>	N/A	N/A	Protect from predation Foraging opportunities	Suitable cover (SAV) found at multiple locations
	<i>Predation</i>	Reduces number of eggs	Reduces number of fry	Reduces number of fry	High numbers of predators, but their abundance will fluctuate (see predator abundance below)
<b>Modifiers</b>	<i>Spring warming rate</i>	Influence growth rates Slower development increases predation risk	Influence growth rates Slower development increases predation risk	Influence growth rates Slower development increases predation risk	Variable, but suitable conditions observed

Base	Factor	Situation In Systems with Naturally Recruiting Populations			Overall Situation In HH
		Eggs	Non-Swimming Fry	Swimming Fry	
<i>(within year)</i>	<i>Growing degree days</i>	Influence growth rates Slower development increases predation risk	Influence growth rates Slower development increases predation risk More rapid warming may result in mismatch with prey emergence, but also increases number larger prey Increased competition with warmwater fishes for prey	Influence growth rates Slower development increases predation risk	Variable, but suitable conditions observed
	<i>Temperature Variability</i>	Irregular warming reduces egg density Temperature extremes can exceed tolerances	Temperature extremes can exceed tolerances Influence prey availability	Temperature extremes can exceed tolerances	Variable, but suitable conditions observed
	<i>Discharge</i>	Sedimentation buries eggs Transport eggs away from suitable habitat	Sedimentation causes gill damage/suffocation Transport fry away from suitable habitat	Sedimentation causes gill damage/suffocation	Extensive sedimentation observed at some egg deposition locations (including peak location)*

Base	Factor	Situation In Systems with Naturally Recruiting Populations			Overall Situation In HH
		Eggs	Non-Swimming Fry	Swimming Fry	
	<i>Winds and currents</i>	Sedimentation buries eggs Transport eggs away from suitable habitat	Transport fry away from suitable habitat*		Extensive sedimentation observed at some egg deposition locations (including peak location)
	<i>Prey base</i>	N/A	Critical first feeding on zooplankton Availability can be influenced by other within-year factors (e.g., temperature)	Availability can be influenced by other within-year factors (e.g., temperature)	Works underway- egg/larvae transport Abundant zooplankton in the system Lower overall CPUE of native fishes may limit foraging opportunities (but stocked fingerlings were able to find sufficient forage)
	<i>Predator abundance</i>	Predation pressure influenced by other within-year factors (e.g., temperature)	Predation pressure influenced by other within-year factors (e.g., temperature)	Predation pressure influenced by other within-year factors (e.g., temperature)	Predators present Cannibalism may be a factor
	<i>Water clarity</i>	UV risk to eggs if water is too clear	Easier to find food in clear water Increased risk of predation in clear water	Easier to find food in clear water Increased risk of predation in clear water	Secchi within suitable ranges High variability based on discharge in some locations

Base	Factor	Situation In Systems with Naturally Recruiting Populations			Overall Situation In HH
		Eggs	Non-Swimming Fry	Swimming Fry	
	<i>Water quality</i>	Low oxygen Contaminants (influence growth, development, survival)	Low oxygen Contaminants (influence growth, development, survival)	Low oxygen Contaminants (influence growth, development, survival)	Summer hypolimnetic hypoxia and related upwellings major potential limiting factor Unknown influence of contaminants on early-life phases

Table 2: Summary of Walleye recruitment potential at six locations in the harbour (Figure 1; sites align with those presented in Croft-White et al. 2026). For each location and category, recruitment potential was assessed as: high (✓✓), moderate (✓), low (X), and unknown (?).

	West	North	Lasalle	Northeast	East	Southeast	South
<b>Positive</b>							Industrial Land use: Hardened shoreline
Adult Walleye Spawning	✓	✓	✓	✓	✓	✓✓	
Suitable Spawning habitat	✓	X	✓	X	X	✓	
High Density of Eggs	✓	✓	X	✓	✓	✓✓	
Nursery Habitat	✓	✓	✓	✓	X	✓	
YOY captured	?	?	?	?	?	✓*	
<b>Negative</b>							
Wave energy	X	✓	X	✓	✓	✓✓	
Silty deposition	✓✓	X	✓✓	✓	X	X	

\*Young-of-year have been detected at this location, but only during years when summer fingerlings were stocked into the system; importantly they were not stocked at this location.

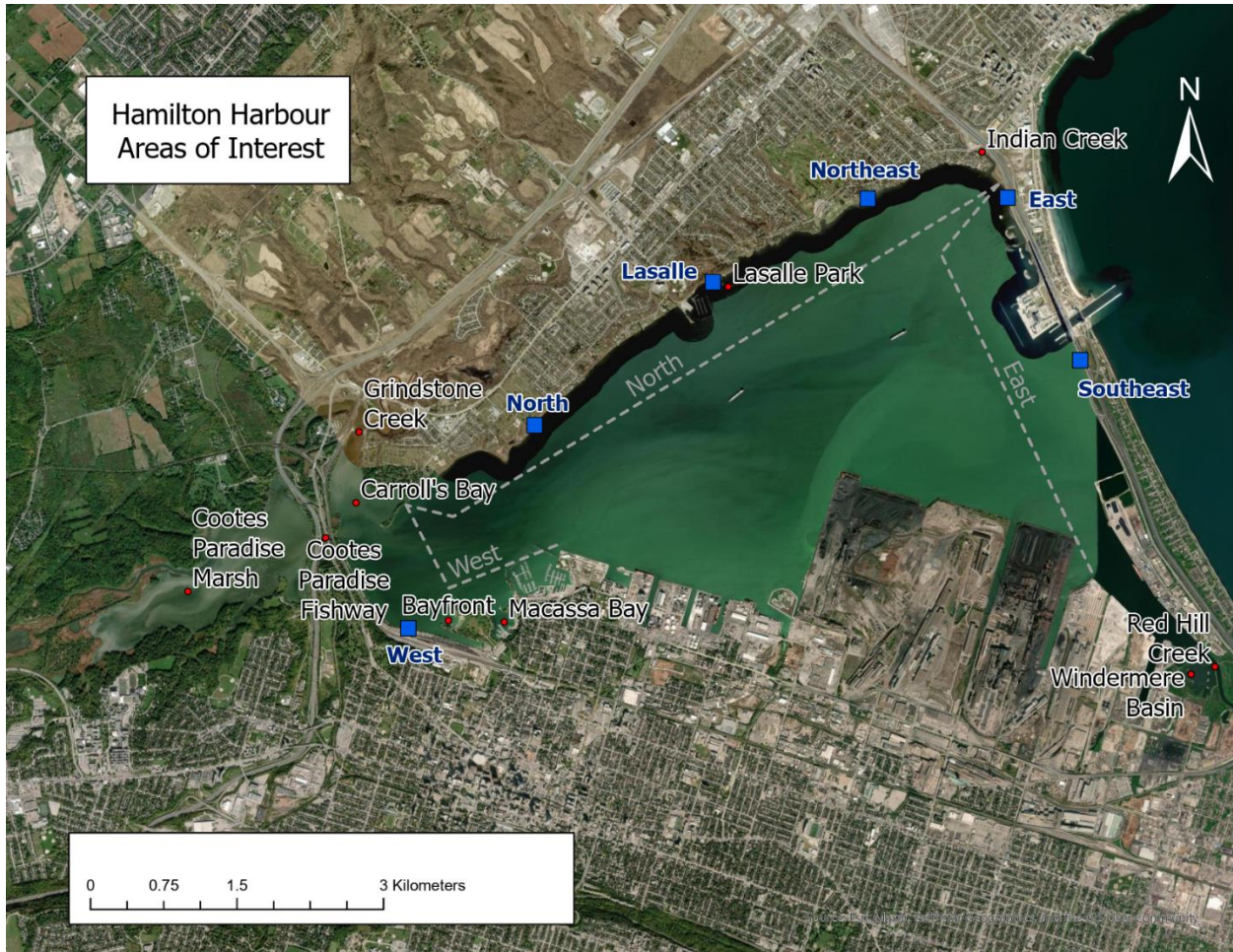


Figure 1: Locations of interest within the Hamilton Harbour Area of Concern. Specific areas mentioned in text that align with those presented in Croft-White et al. (2026) are noted by the blue squares.

## **APPENDIX A:** Assessment of early life phase catch from boat electrofishing and nursery habitat supply

### **Methods:**

Fisheries and Oceans Canada has sampled nearshore fish communities in Hamilton Harbour since 1988 using a standardized boat electrofishing protocol (Brousseau et al. 2005). This same protocol has also been applied in other areas of Lake Ontario, including the Bay of Quinte, where there is a well-established and productive Walleye population. Effort was summarized for the Hamilton Harbour and Bay of Quinte (including the Bay of Quinte proper, South Bay, and Weller's Bay) datasets, and all Walleye records were extracted. Since the Bay of Quinte has a comparatively stable Walleye population and serves as the source for stocked Walleye in Hamilton Harbour, we assumed that capture of adult, juvenile, or YOY Walleye in the Bay of Quinte was indicative that the boat electrofishing protocol has the ability to capture within year recruitment of Walleye and also be potentially informative with respect to the timing of this capture. Boat electrofishing surveys in Hamilton Harbour conducted at a similar time were presumed to be able to detect the presence of juvenile or YOY Walleye that were either stocked or recruited naturally.

We focused primarily on surveys that occurred between 2012 and 2023 (i.e., post-stocking in Hamilton Harbour) and plotted the observed monthly catch per unit effort (CPUE; #/transect) for both systems for: 1) all Walleye, 2) Walleye <215 mm in length (approximate Age-1 length for Bay of Quinte Walleye; Scott and Crossman 1998), and 3) Walleye <150 mm in length (an arbitrary smaller size group that were presumed to include solely YOY Walleye). The locations where Walleye <215 mm and <150 mm were captured in Hamilton Harbour were plotted to allow for comparisons where Walleye are stocked into the system. Finally, using the entire Walleye capture dataset (i.e., 1988-2023), the lengths of Walleye captured in Hamilton Harbour were plotted by year, alongside the timing of stocking events (see Table A1 for stocking details). Years when stocking occurred, and YOY Walleye were captured during boat electrofishing surveys, were interpreted as successful stocking events. In contrast, years with YOY Walleye capture that were out of sync with stocking were interpreted as natural recruitment.

To estimate nursery habitat supply in Hamilton Harbour, we used findings from (Pratt and Fox 2001) with free swimming age-0 Walleye first selecting areas with abundant submerged aquatic vegetation in a 2-5 m depth range before shifting to shallower areas with less cover (0-2 m). These parameters were applied spatially to the harbour using a digital elevation model (at 75.0 m elevation water depth) and submerged aquatic vegetation model (Gardner Costa et al. 2019). The resulting map highlighted where, in the harbour, potentially suitable habitat may occur. Other works have found age-0 free swimming Walleye to initially be more offshore oriented before moving to littoral areas (Engel et al. 2000) or to key in on prey items rather than a specific habitat (Leis and Fox 1996). For the present work, we relied on the more fixed habitat conditions detailed in (Pratt and Fox 2001) as they could be explicitly mapped within the system.

### **Results:**

#### *Bay of Quinte vs Hamilton Harbour Capture*

Effort was variable among years in Hamilton Harbour and the Bay of Quinte (Table A2), however, the boat electrofishing capture results make it clear that the protocol can effectively sample Walleye during May-October (Figure A1). Total catch and CPUE were markedly higher in the Bay of Quinte than in Hamilton Harbour in the period from 2012-2023. Peak catch of

Walleye (including adults) occurred in May in both systems, but Walleye were detected in every month sampled. Capture of the smallest size group of Walleye (<150 mm) peaked in the Bay of Quinte in September, and the three individuals of this size observed in Hamilton Harbour were also detected in September. For Age-1 Walleye (<250 mm), the Bay of Quinte peak occurred in May and June, but in Hamilton Harbour was not observed until September and October. CPUE was generally an order of magnitude lower in Hamilton Harbour than the Bay of Quinte for Age-1 or smaller Walleye (Table A3). Regardless of such differences, results from the Bay of Quinte indicate that the boat electrofishing surveys can provide insight on within-year recruitment of Walleye in Hamilton Harbour, particularly during the September and October survey window.

Within Hamilton Harbour, there were clear spatial patterns in the locations of capture of Walleye <215 mm, with one cluster proximate to the stocking site (Pier 4), another cluster on the shore immediately across the harbour from the stocking location, and a final one situated at the far eastern end of the harbour (Figure A2).

YOY Walleye were observed during boat electrofishing surveys in almost every year when summer fingerlings were stocked into the system (Table A1; Figure A3). The sole exception was in 2022; however, boat electrofishing that year was focused solely on the Piers 5-7 areas in Hamilton Harbour, a region where YOY Walleye have not been observed in other years, and so a spatial mismatch in sampling for 2022 is likely the driving factor. Catch of YOY Walleye was also low in 2016, with sampling effort again the likely reason for lower catch since no May or September surveys were completed in that year.

Plotting captured Walleye length by year also shows the different cohorts of Walleye within the population, with larger fish (215-315 mm) present in surveys the year after a stocking event (e.g., 2013, 2019, 2023).

The boat electrofishing dataset was not informative of the efficacy of stocking of swim-up fry compared to summer fingerlings, since typically both methods were used within the same year, and no electrofishing occurred in the only year when only swim-up fry were stocked (2014). Sampling in 2012 and 2020, when only summer fingerlings were stocked, found YOY Walleye, suggesting that it is an effective age to stock into the system.

Potential nursery habitat was available throughout the harbour, particularly along the north shore, where extensive beds of submerged aquatic vegetation are present at potentially suitable depths (Figure A2).

Table A1: Chronology of Walleye (Bay of Quinte strain, White Lake Fish Culture Station) stocked into the Hamilton Harbour Area of Concern 1993-2022. Adults in the 1990's were directly transplanted from the Bay of Quinte.

<b>Year</b>	<b>Month</b>	<b>Life-Stage</b>	<b>Number of Fish</b>	<b>Total Biomass (kg)</b>	<b>Efishing Obs?</b>
1993	Oct	Adult	185	111	No
1994	Oct	Adult	129	193.5	Not Sampled
1997	Oct	Adult	130	117	No
1998	Sept	Adult	120	163.7	Maybe?
1998	July	Summer Fingerling	5,000	2.5	No
1999	July	Summer Fingerling	6,000	3.2	Not Sampled
2012	July	Summer Fingerling	100,000	40.8	Yes
2012	Nov	Adult	74	77.7	Maybe?
2013	July	Summer Fingerling	10,000	5.1	Yes
2014	June	Swim-up Fry	950,000	-	Not Sampled
2015	May	Swim-up Fry	1,017,625	-	Not Sampled
2015	July	Summer Fingerling	52,963	15	Not Sampled
2016	May	Swim-up Fry	168,000	-	Yes
2016	June	Summer Fingerling	115,722	52.1	Yes
2018	May	Swim-up Fry	1,000,000	-	Yes
2018	July	Summer Fingerling	82,176	49.4	Yes
2020	July	Summer Fingerling	26,394	13.2	Yes
2022	May	Swim-up Fry	1,073,870	-	No
2022	July	Summer Fingerling	63,031	29	No

Table A2: Boat electrofishing effort (number of transects) by year for Hamilton Harbour and the Bay of Quinte (includes upper and lower Bay of Quinte, South Bay, and Weller's Bay [2023 only]). The dashed line indicates the year (2012) when summer fingerling Walleye were successfully stocked into Hamilton Harbour.

	Hamilton Harbour							Bay of Quinte						
	May	Jun.	Jul.	Aug.	Sep.	Oct.	Total	May	Jun.	Jul.	Aug.	Sep.	Oct.	Total
1988	6	106	118	68	0	0	298	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	34	0	0	34
1990	23	20	21	16	0	0	80	0	17	17	18	0	0	52
1992	43	0	30	7	0	0	80	0	0	23	20	0	0	43
1993	0	0	27	3	0	0	30	0	0	0	0	0	0	0
1995	8	21	12	16	23	0	80	0	0	0	0	0	0	0
1996	0	39	31	37	35	0	142	0	0	0	0	0	0	0
1997	21	0	33	39	40	1	134	0	0	0	0	0	0	0
1998	0	28	32	34	32	0	126	0	0	18	6	11	0	35
1999	0	0	0	0	0	0	0	0	42	42	42	22	13	161
2000	0	0	0	0	0	0	0	0	11	12	0	11	0	34
2001	0	13	1	23	0	21	58	0	20	17	14	7	20	78
2002	0	34	26	33	29	0	122	0	11	20	0	18	3	52
2003	0	0	0	0	0	0	0	0	39	2	0	26	0	67
2004	0	0	0	0	0	0	0	0	0	0	12	0	0	12
2006	0	31	31	0	31	0	93	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0	20	21	24	0	0	65
2008	0	30	37	30	31	0	128	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	24	22	18	0	0	64
2010	0	28	46	49	29	26	178	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	0	42	40	41	0	0	123
2012	0	43	30	72	32	0	177	0	0	0	0	0	0	0
2013	0	61	56	57	57	0	231	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	61	58	0	17	0	136
2016	0	50	64	30	0	27	171	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	34	51	0	0	85
2018	38	71	8	35	0	30	182	0	0	0	0	0	0	0
2019	40	68	67	63	0	40	278	0	0	0	0	0	0	0
2020	0	0	64	0	70	53	187	0	0	0	0	0	0	0
2021	0	0	38	38	0	39	115	0	0	0	0	0	0	0
2022	0	0	0	16	0	14	30	0	0	0	0	0	0	0
2023	28	0	34	0	29	11	102	32	0	64	17	0	77	190

Table A3: Summary of electrofishing effort (number of transects), catch, and catch per unit effort (CPUE) of Walleye in Hamilton Harbour (HH) and the Bay of Quinte (BoQ). Data reflect surveys completed between 2012-2023, see Table A2 for detailed yearly breakdown of effort and Figure A1 for length-based catch by year.

	<b>May</b>	<b>Jun.</b>	<b>Jul.</b>	<b>Aug.</b>	<b>Sep.</b>	<b>Oct.</b>	
<b>Effort</b>							<i>Total Effort</i>
HH	106	293	361	311	188	214	1473
BoQ	32	61	156	68	17	77	411
<b>Catch</b>							<i>Total Catch</i>
HH	26	18	26	42	30	41	183
BoQ	32	44	130	30	14	39	289
<b>CPUE</b>							<i>Overall CPUE</i>
HH	0.25	0.06	0.07	0.14	0.16	0.19	0.12
BoQ	1.00	0.72	0.83	0.44	0.82	0.51	0.70
<b>CPUE &lt;215 mm</b>							<i>Overall CPUE</i>
HH	0.01	0.02	0.00	0.00	0.06	0.06	0.02
BoQ	0.66	0.52	0.19	0.24	0.29	0.31	0.31
<b>CPUE &lt;150 mm</b>							<i>Overall CPUE</i>
HH	0.00	0.00	0.00	0.00	0.02	0.00	0.00
BoQ	0.09	0.08	0.04	0.04	0.18	0.10	0.07

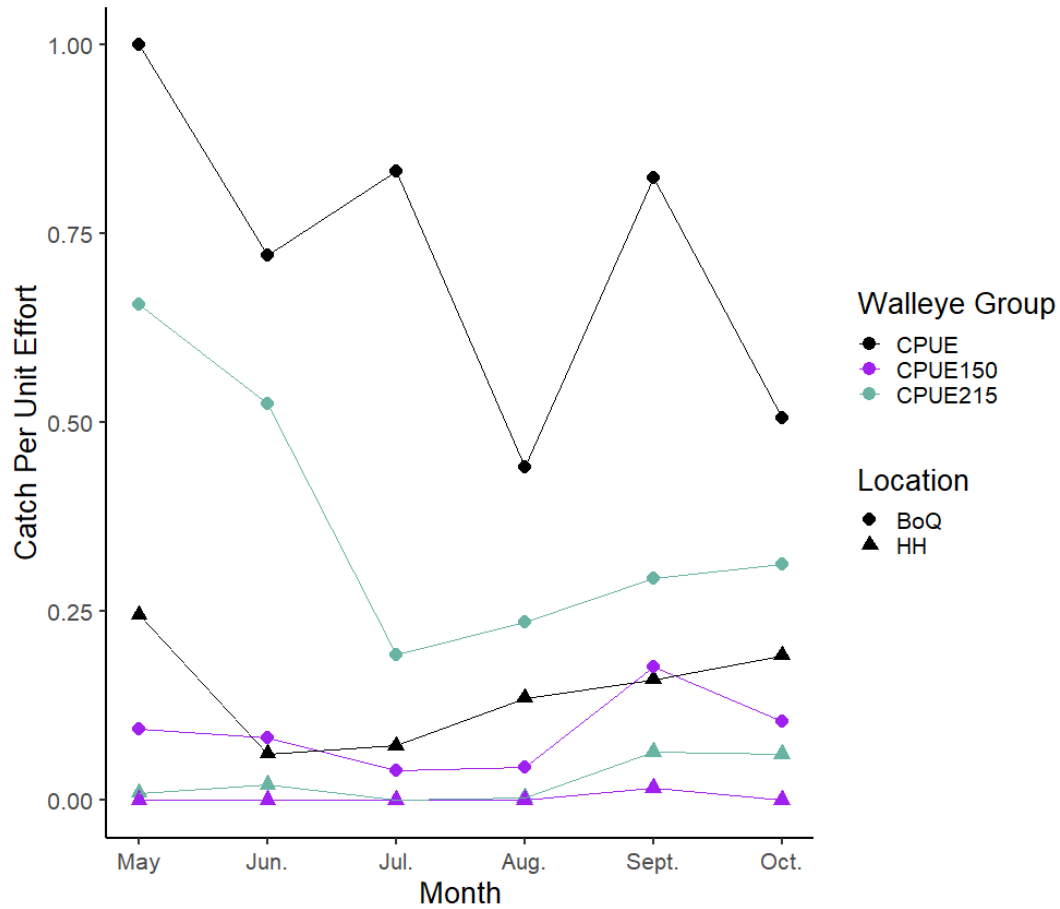


Figure A1: Catch per unit effort (CPUE; number of fish/ transect) by month for Walleye of different size groups including all (CPUE), individuals <150 (CPUE150), and individuals <215 mm (CPUE215). Data are split for capture in the Bay of Quinte (BoQ) and Hamilton Harbour (HH).

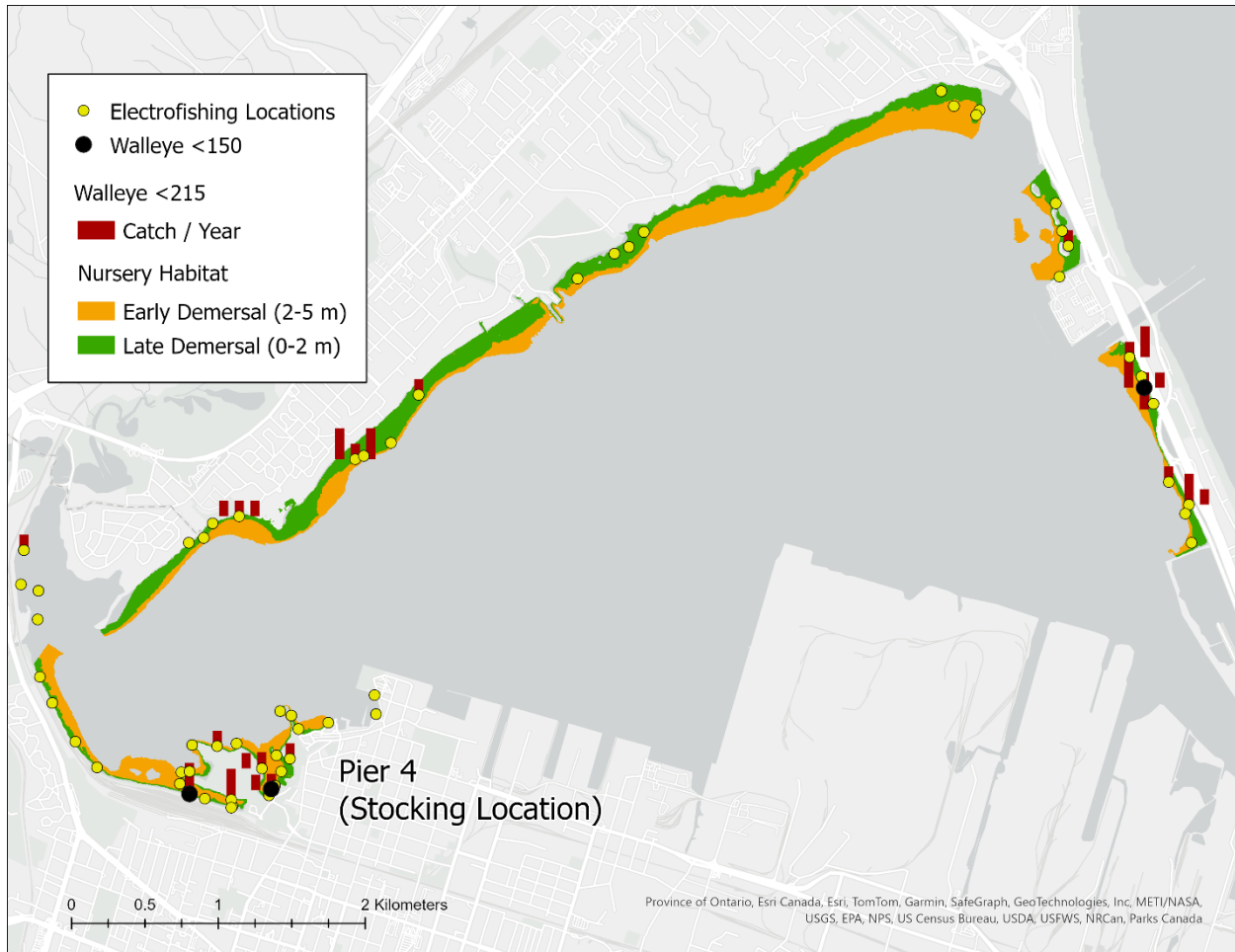


Figure A2: Mid-points for boat electrofishing transects in Hamilton Harbour (yellow circles) and catch of Walleye <215 mm in total length (#/year) at these transects. Only three Walleye <150 mm were captured and their locations are marked in black. Potential nursery habitat for early and late demersal Walleye are also plotted based on information from Pratt and Fox (2001).

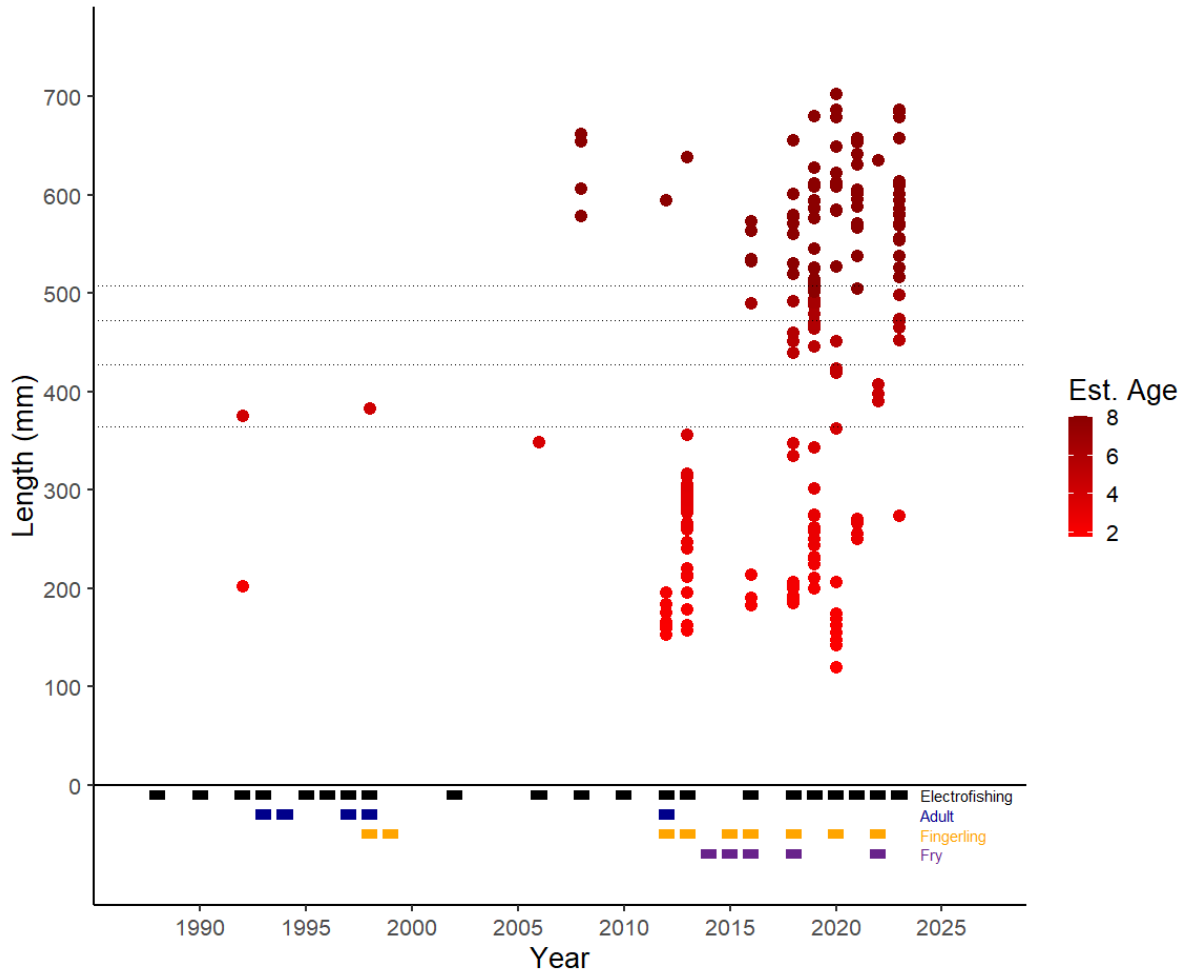


Figure A3: Lengths of Walleye captured in DFOs standardized fish community surveys of Hamilton Harbour, which typically occur between May and October. Red circles are captured Walleye with shading applied based on estimated age; horizontal dotted lines denoting mean lengths at age 2, 3, 4, and 5 for Walleye captured in Hamilton Harbour. Stocking events split by life stage at stocking are also shown at the bottom of the figure alongside when boat electrofishing surveys were completed. See Table A1 for specific numbers and biomass stocked during each event. N.B. sampling in 2022 was limited to just the Piers 5-7 region of the harbour with just 16 transect in August and 14 in October.

## **APPENDIX B: Water temperature during early life growth**

### **Methods:**

Modelled surface temperature data from station 1001 in Hamilton Harbour were available from 2013–2019 (R. Valipour, unpublished data). Hourly temperature values were plotted (Figure B1), and a mean daily temperature was derived to inform the calculation of the cumulative growing degree days (Base 0°C) for years when data were available for all 365 days (2014–2019). These values were compared to minimum growing degree day values deemed necessary for Walleye success in Minnesota Lakes (range 2422–3628, mean = 2993; Honsey et al. 2020).

In Lake Erie, the rate of warming between 01 April and 15 May (which typically covers the spawning and incubation period in this system) has been found to be a strong predictor of YOY abundance (Busch et al. 1975), with values of approximately 0.25 °C/day or higher optimal. This was further refined in (Roseman et al. 1996) to focus on the warming rate two weeks post peak egg deposition, with a “good” recruitment year warming at a rate of 0.22 °C/day and a “poor” recruitment year 0.16 °C/day. We derived mean annual warming rates for both of these periods. The peak egg deposition date for Hamilton Harbour was estimated to occur on 14 April (DOY 104), based on field surveys of egg deposition from 2019 (Midwood et al. 2026).

### **Results:**

Exceedances of the upper thermal maximum for Walleye [i.e., temperatures >27°C; (Raabe et al. 2020)] were rarely observed in surface waters, with one record from 18 July 2013 and intermittently between 11–20 August 2016 (26 hourly records in exceedance; Figure B1). Annual growing degree days for the harbour were well above minimum values deemed to be necessary in inland lakes (Table B1; Figure B2; Honsey et al. 2020).

Over the seven years where data were available, there were clear differences in both warming rates that were calculated (Table B2). There were two years where egg incubation rates were at or above those posited by (Roseman et al. 1996) to lead to “good” recruitment (2013 and 2017) and two years that were at or below potentially “poor” recruitment rates (2018 and 2019). Interestingly, the overall warming rates for the two “good” recruitment years were moderate and actually less than the lowest egg incubation warming year (2018). This suggests that egg incubation rate may be the preferred metric since it captures just the most critical growth period where Walleye eggs may be negatively affected by wind and wave action, sediment deposition, predation, and potentially low oxygen. Warming rates were rarely negative (noted exception of a period during 2016; Figure B3), which indicates warming tends to be continuous.

Table B1: Annual growing degree days (Base 0°C) for Hamilton Harbour. All values are well above the minimum requirement determined for Minnesota Lakes (Honsey et al. 2020).

<b>Year</b>	<b>Cumulative Degree Days (Base 0°C)</b>
2014	4329
2015	4645
2016	4879
<b>2017</b>	<b>4610</b>
2018	4523
2019	4085

Table B2: Annual warming rate (°C/day) in Hamilton Harbour measured for the whole spawning period (01 April – 15 May) and just the estimated egg incubation period (14 April – 28 April).

<b>Year</b>	<b>Spawning Period (01 Apr – 15 May)</b>	<b>Egg Incubation (14 Apr – 28 Apr)</b>
<b>2013</b>	<b>0.225</b>	<b>0.226</b>
2014	0.226	0.183
2015	0.240	0.192
2016	0.230	0.199
<b>2017</b>	<b>0.215</b>	<b>0.245</b>
2018	0.233	0.124
2019	0.199	0.167

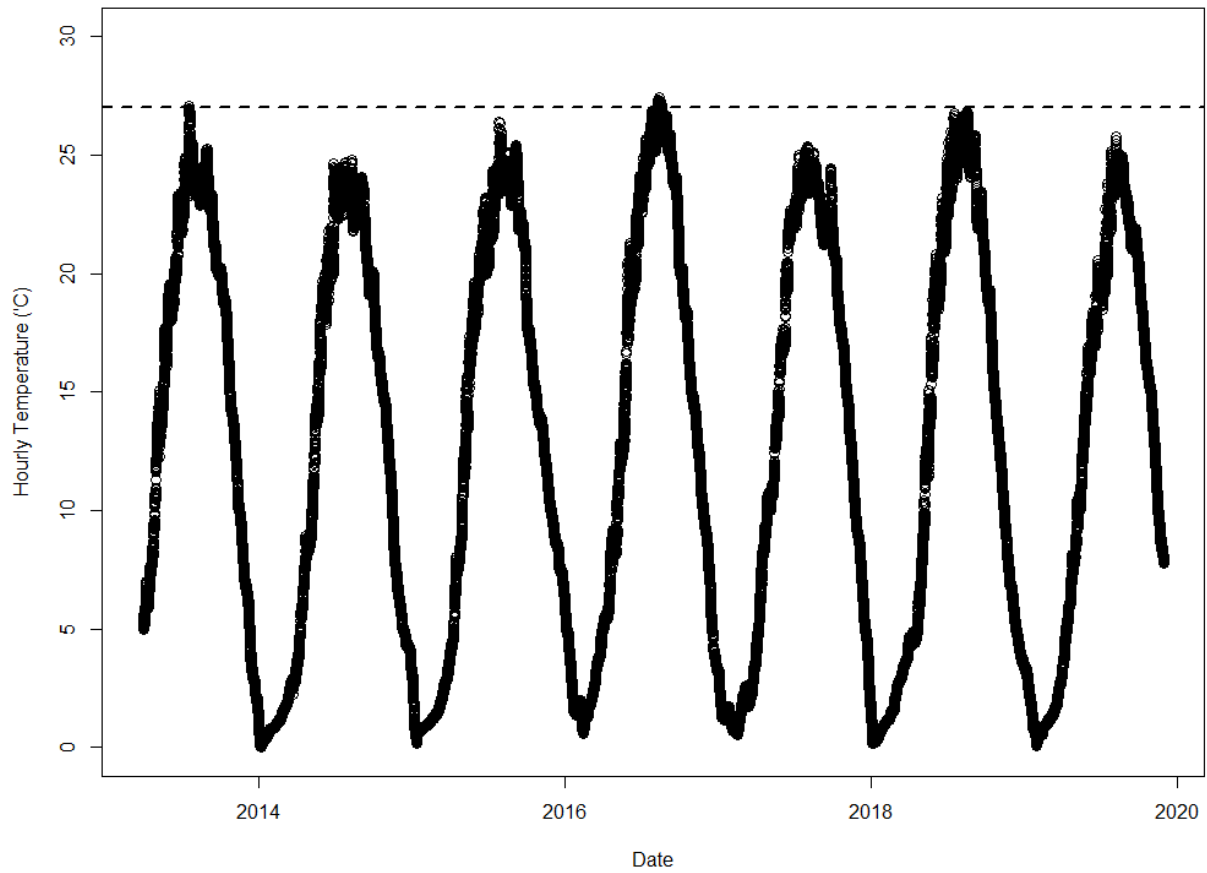


Figure B1: Hourly temperature for station 1001 (combination of observed and modelled temperatures; R. Valipour, unpublished data). The dashed line indicates the lower thermal maxima for Walleye of 27°C (Raabe et al. 2020).

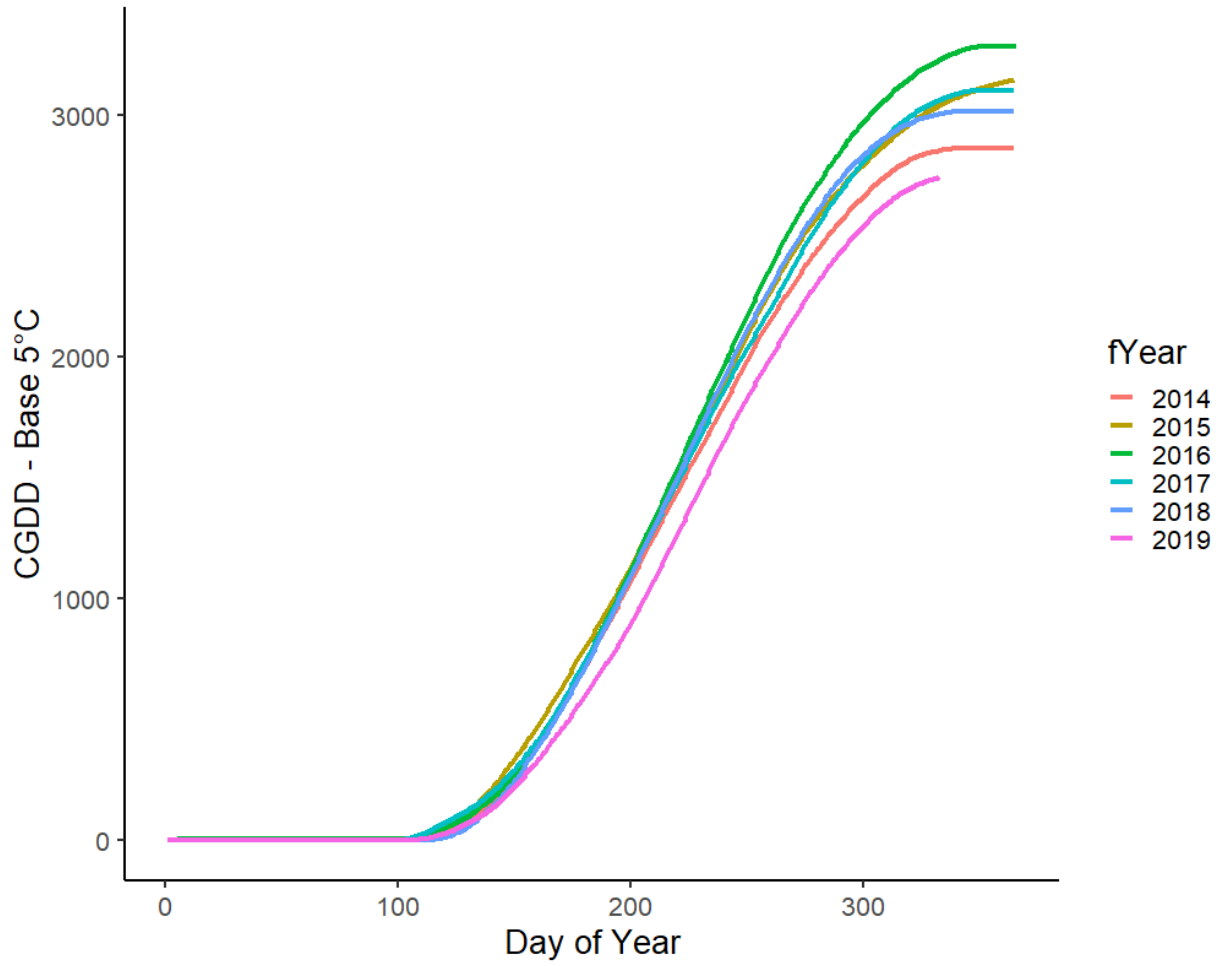


Figure B2: Daily cumulative growing degree days (Base 0°C) by year from Station 1001 in Hamilton Harbour.

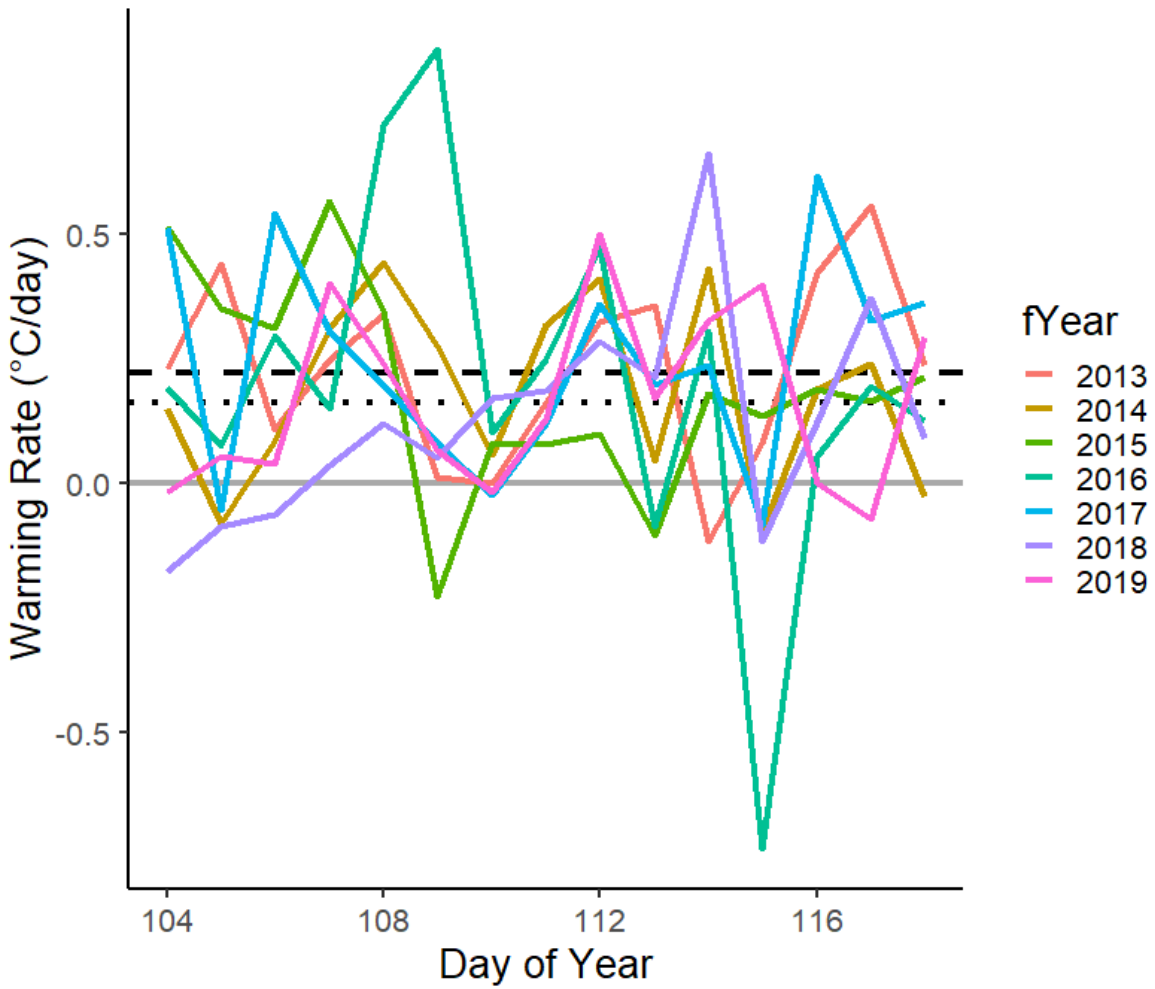


Figure B3: Daily warming rates in Hamilton Harbour for the estimated egg incubation period (14 April [Day of Year 104] to 28 April [Day of Year 118]). For context, warming rates identified as indicative of a “good” recruitment year warming (0.22 °C/day, dashed line) and a “poor” recruitment year (0.16 °C/day, dotted line; Roseman et al. 1996) are shown.

### APPENDIX C: Secchi depth information

Secchi depth information were collected by Environment and Climate Change Canada at multiple stations in Hamilton Harbour (D. Depew, unpublished data). Mean annual Secchi depth across stations was calculated and ranged from a low 2.1 m in 2017 to a high of 3.1 m in 2016.

Table C1: Mean, standard deviation, and quantiles for Secchi depth data collected at multiple locations in Hamilton Harbour.

<b>Year</b>	<b>Mean</b>	<b>Standard Deviation</b>	<b>Quantile 1 (5%)</b>	<b>Quantile 2 (25%)</b>	<b>Quantile 3 (75%)</b>	<b>Quantile 4 (95%)</b>
2013	2.3	0.6	1.5	2.0	2.5	3.5
2014	2.1	0.9	1.0	1.7	2.5	3.6
2015	2.7	1.1	1.5	2.0	3.2	4.2
2016	3.1	1.0	1.7	2.5	3.5	5.0
2017	2.1	0.6	1.3	1.7	2.5	3.1
2018	2.1	0.8	1.0	1.5	2.5	3.5

## **APPENDIX D: Boat electrofishing catch of potential predators and planktivores**

Details on sampling methods and protocols can be found in Brousseau et al. (2005) and most recently these data have been used to inform an assessment of the status of fish populations in the Hamilton Harbour Area of Concern (Midwood et al. 2024) and evaluate trends in fish species and community metrics in the Hamilton Harbour and Bay of Quinte Areas of Concern (Turner et al. 2025). Briefly, fish community surveys follow fixed 100-m transects parallel to shore in Hamilton Harbour at an approximately 1.5 m contour. All fish possible are netted within the transect, identified to species, and their length and wet mass are measured. To evaluate conditions when stocked Walleye were in the system, only data collected between 2013 and 2023 were included. The dataset was further refined to focus solely on catch during night surveys. Transects were grouped based on their proximity to the six sampling areas outlined in Croft-White et al. (2026), which resulted in two transects for the Southeast, West, North, and Northeast locations, three for Lasalle, and four for the East. To adjust for differences in effort, catch per unit effort (CPUE; # individuals / # transects) was calculated for each species for each combination of year, season (spring [May and June], summer [July and August], and fall [September and October]), and location. Mean annual CPUE was plotted based on data from all sampling years (2013, 2016, 2018, 2019, 2020, 2021, 2023).

Species were selected based on whether they are known predators of Walleye during their early life phases [White Perch, Logperch, Yellow Perch, and Round Goby; (Roseman et al. 2006)], predators for early life phases and juveniles [Largemouth Bass; (Davis and Isermann 2024)], or potential early life phase competitors for plankton resources (Alewife, Emerald Shiner, Brook Silverside, and Spottail Shiner). Early life phase predators CPUE was plotted for spring, Largemouth Bass CPUE for all three seasons, and plankton competitors for spring and summer.

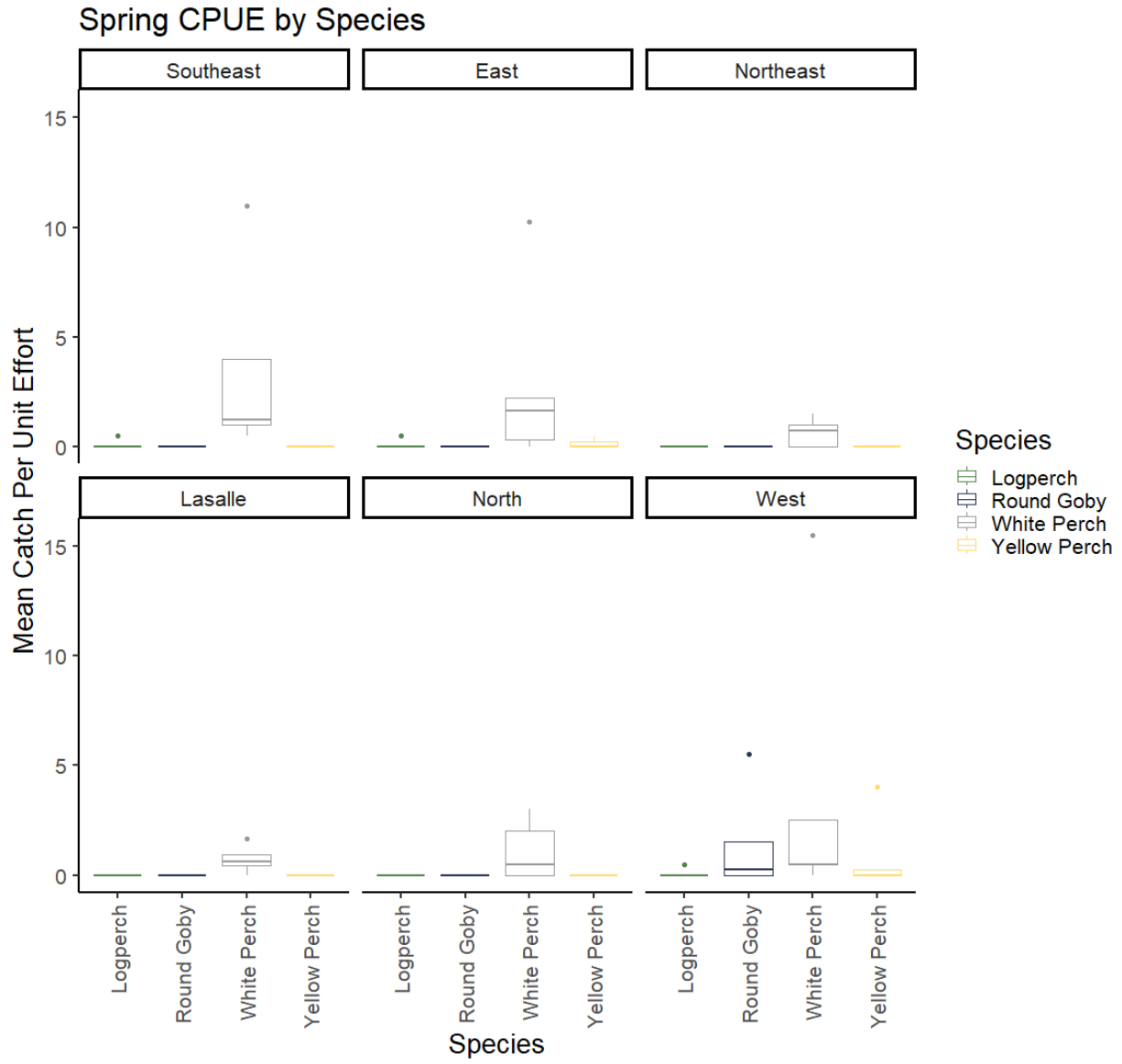


Figure D1: Mean spring catch per unit effort for potential early life phase (eggs and larvae) predators of Walleye by location in Hamilton Harbour (data summarized for samples between 2013 and 2023).

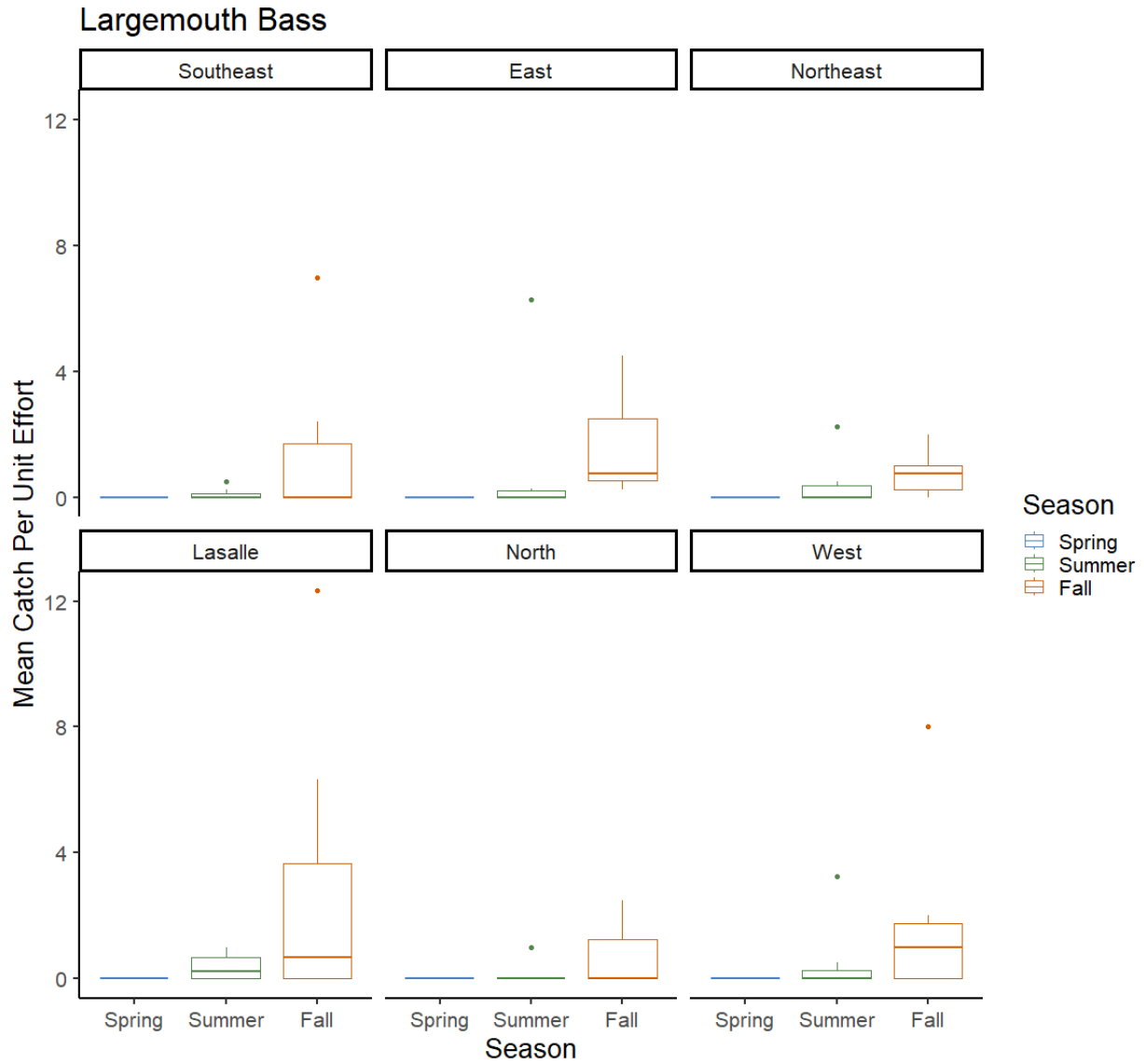


Figure D2: Mean seasonal catch per unit effort by location in Hamilton Harbour for Largemouth Bass, a common predator of early life phase and juvenile Walleye (data summarized for samples between 2013 and 2023).

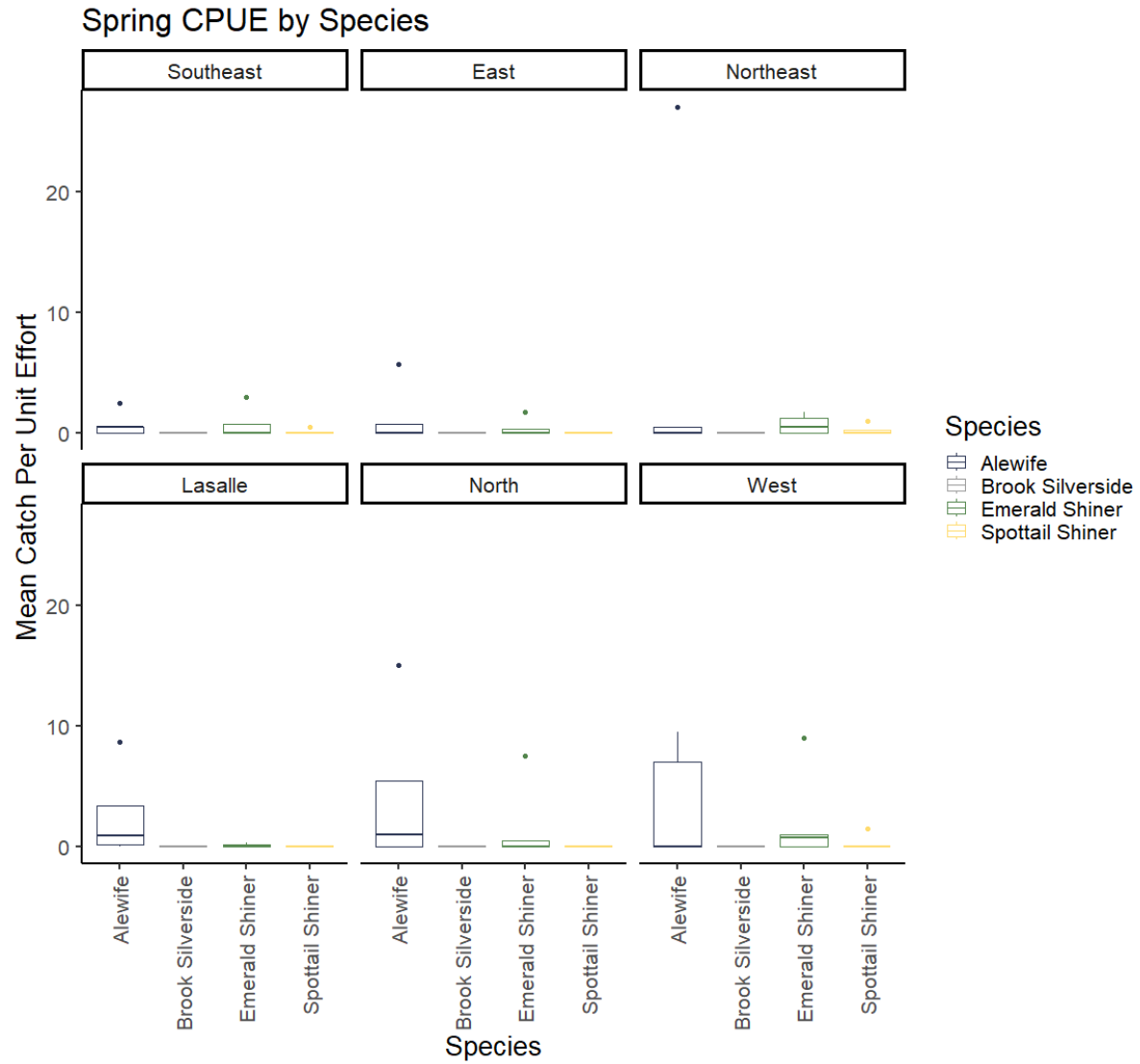


Figure D3: Mean spring catch per unit effort for potential plankton competitors by location in Hamilton Harbour (data summarized for samples between 2013 and 2023).

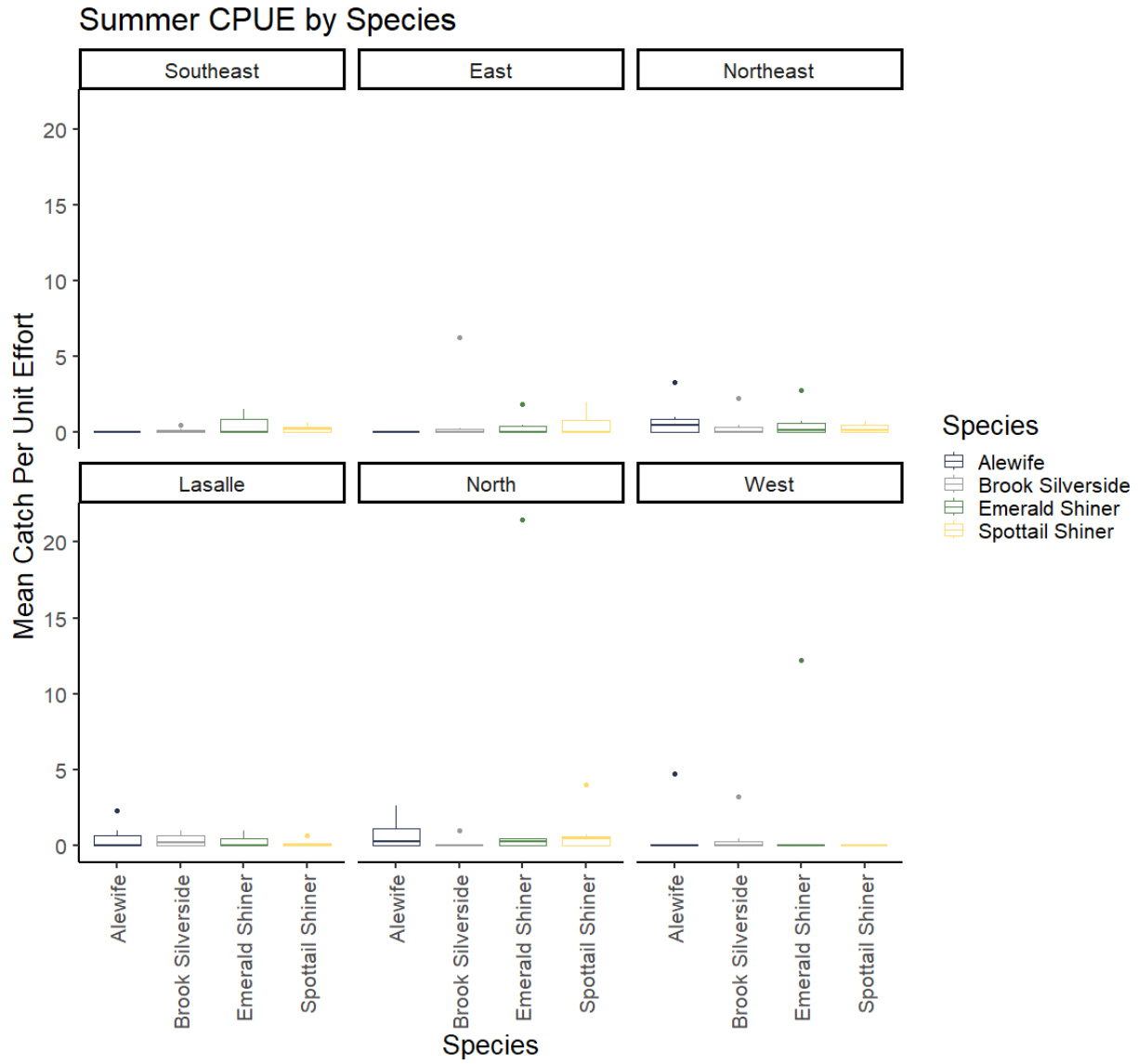


Figure D4: Mean summer catch per unit effort for potential plankton competitors by location in Hamilton Harbour (data summarized for samples between 2013 and 2023).