Autumn sampling for evidence of Northern Pike (Esox lucius) recruitment in Hamilton Harbour watersheds

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As top predators, Northern Pike (*Esox lucius*) provide important top-down control on littoral areas in freshwater systems. In the Hamilton Harbour Area of Concern, Northern Pike populations have declined well below historic (pre-20th century) levels and their recovery is deemed critical for more holistic recovery of fish populations in the harbour. In the autumn of 2020 and 2021, nearshore areas in Cootes Paradise, Grindstone Creek Marsh, Hamilton Harbour, Spencer Creek, and Red Hill Creek were sampled with the objective of looking for evidence of Northern Pike recruitment by identifying areas used by young-of-year (YOY) or juveniles. Fyke nets were used as the primary method of capture for both years, while light traps were also used in year one and seine nets in year two. Across all sites only one Northern Pike was captured in Van Wagner's Pond in Red Hill Creek. A variety of other fishes were captured and spatial differences in fish community assemblage are discussed. The lack of capture of YOY and limited capture of juvenile Northern Pike is a concern, and while other sampling programs have detected them recently they are typically observed in low densities. Paired with observed low capture rates of adult Northern Pike in electrofishing surveys in the main basin of Hamilton Harbour and recent declines in numbers arriving at the Cootes Paradise fishway, the near-term potential for natural recovery of Northern Pike populations seems limited.

RÉSUMÉ

Budgell E., Reddick D.T, Boston C.M., and Midwood J.D., 2024. Autumn sampling for evidence of Northern Pike (*Esox lucius*) recruitment in Hamilton Harbour watersheds. Can. Manuscr. Rep. Fish. Aquat. Sci. 3270: vii + 24 p.

En tant que prédateur de niveau trophique supérieur, le grand brochet (*Esox lucius*) exerce un fort contrôle descendant dans les zones côtières dans les systèmes d'eau douce. Dans le secteur préoccupant du port de Hamilton, les populations de grand brochet ont décliné bien en-dessous des niveaux historique (avant le 20^{e} siècle) et leur rétablissement est considéré comme essentiel pour un rétablissement plus holistique des populations de poissons dans le port. À l'automne 2020 et 2021, on a échantillonné les zones littorales du marais de Cootes Paradise, du marais de de la crique Grindstone, du port de Hamilton, du ruisseau Spencer et du ruisseau Red Hill dans le but de trouver des preuves du recrutement du grand brochet en identifiant les zones utilisées par les jeunes de l'année ou les juvéniles. On a utilisé des verveux comme principale méthode de capture; toutefois, on a également utilisé des pièges lumineux la première année et des sennes la deuxième année. Sur l'ensemble des sites, un seul grand broché a été capturé dans l'étang Van Wagner du ruisseau Red Hill; on a cependant capturé une variété d'autres poissons et les différences spatiales dans l'assemblage de la communauté de poissons sont abordées. L'absence de captures de jeunes de l'année et les captures limitées de grands brochets juvéniles sont préoccupantes, et bien que d'autres programmes d'échantillonnage aient permis de les détecter récemment, on les observe généralement en faibles densités. Combiné aux faibles taux de capture de grands brochets adultes observés dans les relevés par pêche à l'électricité dans le bassin principal du port de Hamilton et aux baisses récentes du nombre de poissons arrivant à la passe migratoire de Cootes Paradise, le potentiel à court terme de rétablissement naturel des populations de grand brochet semble limité.

INTRODUCTION

As top predators, Northern Pike (*Esox lucius*) are an important component of the Hamilton Harbour fish community. Due to historic habitat loss and degradation of remaining aquatic habitat, Northern Pike populations are well below historic levels in Hamilton Harbour (Whillans 1979) and other similar nearby habitats (Larocque et al. 2023). Piscivores in general are in low abundance in Hamilton Harbour, which was listed as an Area of Concern (AOC) by the International Joint Commission in 1985 (COA 1992). This low abundance of top predators contributes to ongoing impairment of the fish community in the system (Boston et al. 2016). The Hamilton Harbour Remedial Action Plan seeks to restore the fish community with a balanced trophic composition that includes top predators. A minimum value of 20% of total biomass comprised of top predator species has been suggested as a target for this criteria (Boston et al. 2016; Hoyle and Yuille 2016). In support of these efforts, Northern Pike spawning habitat has been the focus of habitat restoration efforts in coastal wetland areas of Hamilton Harbour, including the Cootes Paradise and Grindstone Creek marshes (Hamilton Harbour Remedial Action Plan 2012). Limited availability of spawning habitat has been frequently cited as a factor in declining Northern Pike populations in many lentic systems (Crane et al. 2015). However, in Hamilton Harbour, habitat suitability modelling has suggested fry and juvenile-adult habitat (i.e., nursey habitat) may be more limiting, despite being more abundant in total area than spawning habitat (Minns et al. 1996). Royal Botanical Gardens (RBG) has documented declining trends of adult Northern Pike passing through a manually operated fishway into Cootes Paradise Marsh and data from the Grindstone Creek marshes indicate a decrease in young of year (YOY) production since the 1990s (Theijsmeijer and Court 2021). The lack of larger individuals or later life stages may be due to these individuals requiring more relative area to fulfill their life history requirements (Minns et al. 1996). Presently in Hamilton Harbour, it is unclear whether low catch rates of Northern Pike are driven by recruitment failure (e.g., egg or fry mortality), a lack of accessibility to suitable habitat for different life stages, poor habitat condition, a lack of appropriate forage opportunities, or some combination of these factors.

The primary objective of this study was to sample wetlands and creeks throughout Hamilton Harbour in the autumn of 2020 and 2021 to look for evidence of Northern Pike recruitment (e.g., YOY or juveniles [<2 years old]; herein referred to collectively as juveniles). As an additional objective, we sought to tag any captured juvenile Northern Pike with acoustic transmitters to track their short-term movements (3-4 months) to better understand winter habitat use. Due to limited catch of Northern Pike, acoustic tagging of juveniles was not possible, however, a single individual estimated to be 2-3 years old was captured and tagged.

METHODS

STUDY AREA

The study area for this project included locations along the shoreline of Hamilton Harbour proximate to LaSalle Park in the north and Bayfront Park in the south-west (Figure 1). Red Hill Creek flows into the south-east corner of the harbour, and the creek itself was sampled as were Red Hill Marsh, Van Wagner's Marsh and Van Wagner's Pond. Grindstone Creek and marshes (Sunfish Pond and Osprey Marsh) situated in the north-west of the harbour and Cootes Paradise and Spencer Creek at the most western extent were also sampled (Figure 1).

Hamilton Harbour is a large (21.5 km^2), protected embayment at the western end of Lake Ontario. Despite its size, shallow, protected areas that would be suitable nursery habitat for Northern Pike are largely restricted to wetlands and the tributaries that flow into the main embayment. Red Hill Creek flows into a highly developed and industrialized portion of Hamilton Harbour's south shore. Across both years, sampling occurred in lower portions of Red Hill Creek as well as some of the marsh areas situated approximately two kilometers upstream from the outlet. The portion of the creek that is adjacent to Red Hill Marsh has been heavily altered by re-alignments and dredging activities related to the creation of the Red Hill Parkway and expansion of the QEW highway (C. Portt and Associates 2003). The marsh complex itself is mostly comprised of cattail stands and the level of connectivity between the various wetland units and the creek is dependent on water levels. Van Wagner's Pond and Van Wagner's Marsh, which are two large wetland units located between Red Hill Creek and Lake Ontario, were included in the Red Hill study area. Van Wagner's Marsh is connected to Red Hill Creek by culverts and channels while Van Wagner's Pond is isolated by an unused rail causeway (C. Portt and Associates 2003). The Woodward wastewater treatment plant servicing the City of Hamilton is discharged into Red Hill Creek below the areas sampled when the present study was conducted.

Grindstone Creek is another tributary of Hamilton Harbour with natural lands and wetland features situated in its watershed below the Niagara escarpment, with more urbanization (e.g., Waterdown, a suburb of Hamilton) and agricultural development occurring in the upper reaches. The Waterdown wastewater treatment plant previously discharged into Grindstone Creek, but was taken offline in 2010 (Reddick and Theysmeyer 2012). The marshes sampled in the present study exist in a naturalized setting of protected areas owned by RBG. These marshes are protected behind berms with passive barriers for Common Carp (*Cyprinus carpio*) exclusion. The barriers are adjusted seasonally to prevent access by Common Carp (Bendo et al. 2021). Sites within the Grindstone Creek channel as well as Sunfish Pond, Blackbird Marsh, and Osprey Marsh were included in the study.

Cootes Paradise is a large wetland with many tributaries flowing into it, the most significant being Spencer Creek. The marsh drains through a man-made canal into the

west end of Hamilton Harbour where an actively managed fish barrier restricts access to Common Carp. Though the condition of the wetland has been improving, it still exists in a degraded state (Thomasen and Chow-Fraser 2012; Bendo et al. 2021). Sampling occurred within the wetland and in the Spencer Creek delta (Figure 1). Cootes Paradise was not resampled in 2021 due to low water conditions. Sites were instead chosen within Hamilton Harbour and specific sampling locations in the harbour were selected based on knowledge of habitat features and previous encounters with Northern Pike.

SITE CONDITIONS

In both years, water quality information was recorded adjacent to the frame of each fyke net using an EXO2 multi-parameter sonde (YSI, a Xylem brand, Yellow Springs, OH). Parameters recorded included: temperature, pH, dissolved oxygen (DO; mg/L), turbidity (TSS), and conductivity (µS/cm). Site depth (m) was also collected using a weighted measuring tape adjacent to the frame of each net, while percent vegetation cover and vegetation species present were recorded in a 1 m^2 area between the base of the net frame and the lead.

FISH SAMPLING

2020: Fyke nets and light traps

In 2020, the fish communities in Cootes Paradise, Red Hill Creek and Marsh, Van Wagner's Pond and Marsh, and Grindstone Creek were sampled from October 5th-7th. All wetlands were sampled with large fyke nets (frame dimension = 1.2 m x 0.9 m, hoop diameter = 0.8 m, throat diameter = 0.1 m, lead = 7.6 m x 0.9 m, wings = 3.6 m x 0.9 m, mesh size = 4.8 mm; Duluth Nets, Minnesota, USA) and at shallower sites with small fyke nets (frame dimension = 0.6 m x 1.2 m, hoop diameter = 0.6 m, throat diameter = 0.1 m, lead = 4.6 m x 0.6 m, wings = 3.9 m x 0.6 m, mesh size = 3.2 mm; Duluth Nets, Minnesota). All nets were set for approximately 24 hours with the net leads oriented to shore or dense emergent vegetation. Larval light traps (Quadrafoil traps, diameter = 30 cm, height = 25 cm, entry slits = 5 mm, Aquatic Research Instruments, Wellington Place, ID, USA) were paired with the fyke nets and were each illuminated with a single, green glow stick. Fyke nets were set in approximately 0.5 to 1.0 m of water, with the number of nets used at each site determined by net availability at the time of sampling and the size and depth of the system (see Table 1). All non-target fish species were identified, counted, and released. In some instances, juvenile Lepomis could not be identified to species due to their size and potential for hybridization among species; these individuals were grouped as *Lepomis* spp.

2021: Fyke Nets and Seining

Sampling was conducted again in the autumn of 2021 and Red Hill Creek (including Van Wagner's Marsh) and Grindstone Creek were re-sampled. Cootes Paradise could not be re-sampled because water levels were too low, so as an alternative, five

locations in Hamilton Harbour were sampled (Figure 1). Sites were first sampled the week of October 4th-8th using fyke and seine nets. The same fyke net sites were sampled again between October 28th and November 5th. Fyke nets were set in 0.4 to 1.0 m of water with the leads oriented to shore or emergent vegetation. A mix of large and small fyke nets of the same dimensions as in 2020 were used based on site depth. See Table 1 for details on the number of nets set in each location.

Seining was only conducted during the first sampling event of 2021 since the composition of captured fishes was comparable to fyke nets, but effort was considerably greater. The seine was a 15.2 m bag seine with 6.35 mm mesh, the bag was 1.2 m^3 and had a mesh of 3.18 mm. Each seine haul was approximately 20-30 m in length and was conducted parallel to shore near, or between, the fyke nets. Sampling effort across different sites varied. Three seine hauls were completed along the shoreline of Hamilton Harbour. Two seine hauls were completed in Grindstone Creek channel, one was completed in Sunfish Pond and one in Osprey Marsh. Three hauls were conducted in different locations within Red Hill Creek channel, one in Red Hill Marsh, and one in Van Wagner's Marsh (Table 2 and Figure 1). Habitat parameters were not collected while seining due to spatial proximity of the fyke net data.

Fish captured by both methods were identified, counted, and released. For both years, fish catch data from each location were summarized by species as catch per unit effort (CPUE) with effort measured in hours of net time for fyke nets and hauls for seining. *Lepomis* spp. was not included as a distinct species contributing to species richness summaries.

TAGGING AND RECEIVER DEPLOYMENT

While one of the main objectives was to acoustically tag captured juvenile Northern Pike, none were found. However, one Northern Pike was captured in Van Wagner's Marsh on October 6th, 2020 (423 mm fork length, 441 mm total length, wet mass 480 g). This individual was tagged with an acoustic transmitter that included a pressure sensor to monitor detection depths (V13P-1L; diameter = 13mm, dry mass = 11g, min delay = 130s, max delay = 270s est. battery life = 1244 days, Innovasea, Bedford, Nova Scotia) and a passive integrated transponder (PIT) tag was inserted into its dorsal musculature. The V13P-1L transmitter used for this study can be tracked on the existing Hamilton Harbour acoustic telemetry array (see Figure 1; Brooks et al. 2019).

The Northern Pike receiving an acoustic transmitter was immobilized during surgery and PIT tagging with electric fish handling gloves (Smith-Root electric fish handling gloves 32vmin -39v max, 4mA-25mA outputs, Washington, USA). A sub-cutaneous injection of 2% lidocaine (20 mg/ml, 6 mg/kg; Sneddon 2012) was made at the site of the surgical incision to provide a local anesthetic. A small incision (~2 cm) was made to insert the transmitter and the incision was closed with 2 sutures (3-0 polydioxanone-II violet monofilament, 24 mm; Ethicon, USA). Flowing water was pumped over the fish's gills for the duration of the surgery, which lasted less than three

minutes. Following surgery, the fish was placed in an aerated bin of fresh local water to recover before it was released at its site of capture. All tagging procedures followed the Great Lakes Laboratory for Fisheries and Aquatic Sciences Animal Use Permit #2079. No fish were tagged during 2021 sampling.

RESULTS

SITE CONDITIONS

Vegetation was absent or sparse at most sites in 2020, with white water lily (*Nymphaea odorata*) being the most common species (Table 1). In general, the Grindstone Creek sites were warmer (mean temperature = 17.1°C) than the Cootes Paradise sites (mean temperature = 12.5°C; Table 1). Conductivity was high across all sites with the highest values recorded in Van Wagner's Pond (>2000 µS/cm). Water depth was generally consistent across sites, which is largely a function of fishable depths for the fyke nets. Dissolved oxygen was consistent across all sites, with a minimum concentration of 6.8 mg/L observed at Grindstone Creek (Table 1).

During the 2021 sampling events, conductivity was highest in Red Hill Creek and in Grindstone Creek at Sunfish Pond, ranging from 1000-1640 µS/cm. Temperature ranged from 16.5 to 19.2°C across all sites during the first sampling event (October 4th – 8th) but dropped during the second sampling event (October 28th – November 5th) with a mean of 9.2°C (± 1.8 °C). The lowest observed dissolved oxygen concentration was in Van Wagner's Marsh at 4.2 mg/L during the first round of sampling and 7.4 mg/L in the second. During the second sampling event, Red Hill Creek had the lowest temperatures and Hamilton Harbour was generally the warmest. White water lily and cattails (*Typha* sp.) were most commonly observed when vegetation was present at sites, though vegetation was generally sparse (Table 1).

LIGHT TRAPS

No larval Northern Pike were captured in light traps, but a total of 10 *Lepomis* spp. were captured across all sites in 2020. Light traps were not used in the second year of sampling.

FYKE NETS

In 2020, the only Northern Pike captured was from a fyke net in Van Wagner's Marsh (age estimated as between 2-3 years from (Scott and Crossman 1998; Table 3)). Of the remaining catch, 27 fish species were encountered belonging to 12 families, with Grindstone Creek having the highest species richness (23 species; Table 3). CPUE varied across sites, with Red Hill sites having the highest CPUE (62.7 individuals/h) and Cootes Paradise the lowest (17.2 individuals/h). The six most common fish we encountered were Fathead Minnow (*Pimephales promelas)*, *Lepomis* spp.,

Pumpkinseed (*Lepomis gibbosus)*, Bluegill (*Lepomis macrochirus)*, Gizzard Shad *(Dorosoma cepedianum,)* and Rudd (*Scardinius erythrophthalmus*). Catches were not consistent across all sites; Fathead Minnow were only abundant in Van Wagner's Pond and Marsh (Table 3). Gizzard Shad, Brook Silverside (*Labidesthes sicculus*), and Rudd were the most abundant species in Cootes Paradise, while the catch in the Spencer Creek channel consisted mainly of Gizzard Shad, White Perch (*Morone americana*), and Rudd. Catch in Grindstone Creek Marshes was dominated by Bluegill and Pumpkinseed.

Northern Pike were not captured during 2021 sampling. Red Hill had the highest CPUE when using fyke nets during both the October and November 2021 sampling events (Table 4). CPUE in Red Hill was higher during the November sampling after water temperatures had dropped (16.5 individuals/h compared to 22.0 individuals/h). Hamilton Harbour sites had the second highest fyke net CPUE during the first sampling event (15.1 individuals/h) but the lowest CPUE during the second sampling event (2.1 individuals/h). CPUE in Grindstone Creek was similar during both sampling periods in 2021 (11.1 individuals/h and 11.8 individuals/h). Across all sites, 29 species and 11 families were encountered over the two weeks of sampling with fyke nets (excluding *Lepomis* spp.).

Species richness was similar across all sites during the first week, with Hamilton Harbour being the most diverse with 20 species. Grindstone Creek had the greatest species richness during the second sampling event with 25 species encountered compared to 17 species encountered at the other two sites (Table 4). Similar to 2020, Bluegill and Pumpkinseed were among the most common species in Grindstone Creek during fyke net surveys. Fathead Minnow was the most common species captured in fyke nets in Red Hill, while Bluegill was the most abundant species captured in Hamilton Harbour (Table 4).

SEINE NETS

During seine surveys, sites within Hamilton Harbour proper had the highest CPUE (645.6 individuals/haul), followed by Red Hill Creek (108.8 /haul). Grindstone Creek had the highest species richness but the lowest CPUE (17 species and 74 individuals/haul). A total of 21 species from 10 families were captured across all seine netting sites (excluding *Lepomis* spp.). The seine catch in Hamilton Harbour and Red Hill Creek was dominated by Round Goby (*Neogobius melanostomus*; 85% and 75% of the total catch, respectively; Table 5). The most commonly encountered species in Grindstone Creek were Fathead Minnow and Round Goby (Table 5).

TELEMETRY

The sole Northern Pike (Tag ID 12551; Serial # 1336205; PIT Tag # 160414) tagged during this study from Van Wagner's Marsh has not been detected on the Hamilton Harbour array as of October 2022.

DISCUSSION

The primary objective of this study was to capture juvenile Northern Pike in potentially suitable nursery habitats in Hamilton Harbour and connected waters. Only one Northern Pike was captured during the two years of sampling, and it was estimated to be 2-3 years old based on its length (Scott and Crossman 1998). While the present surveys failed to detect juvenile Northern Pike, they have been encountered recently in surveys conducted by other groups and some of these findings are documented herein. In addition, we also captured a variety of other fish species while sampling for juvenile Northern Pike and we discuss capture rates of some of these fishes in the context of previous sampling efforts in the harbour and its watersheds.

Northern Pike

RBG frequently samples marshes and other littoral areas at the west end of Hamilton Harbour. Prior to the construction of the Cootes Paradise Fishway, juvenile Northern Pike had an encounter rate of 0.04 individuals/transect (1994-1996 annual electrofishing surveys), which increased marginally after the Fishway was operational to 0.07 individuals/transect (1997 – 2020 annual electrofishing surveys). In Grindstone Creek surveys, encounter rates declined after 2001 from 0.15 individuals/transect to 0.06 individuals/transect. While this period (post-2001) aligns with the creation of pond berms and the installation of Common Carp exclusion structures in Grindstone Creek marshes, the structures were designed to allow passage of spawning fishes, and may not represent the cause of the decline in catch (Theijsmeijer and Court 2021).

In general, RBG caught more juvenile Northern Pike in the Grindstone Creek marshes than in Cootes Paradise during annual summer electrofishing surveys (1994-2020); however, they did not observe any individuals from 2017-2020 in Grindstone Creek, despite a slight increase in the catch in Cootes Paradise during the same time period. In late spring of 2018-2020, RBG captured a total of 34 YOY Northern Pike in Cootes Paradise and Grindstone Creek marshes. Autumn fyke netting by RBG in 2019 in the lower Spencer Creek and West Pond areas detected 16 YOY Northern Pike; this sampling was undertaken due to high water levels that prevented the use of the smaller traps typically employed by RBG (Theijsmeijer and Court 2021). RBG's sampling locations aligned with areas surveyed in this study (2020 – 2021) and some sampling gear (e.g., fyke nets) and timing were similar. The disparity between our dataset and the RBG dataset is noteworthy, but differences in effort (i.e., 16 spring trap locations, between 32-38 summer electrofishing transects per year, and three fyke nets for RBG), timing of sampling (e.g., spring trapping, summer electrofishing, and fall fyke netting by RBG), or interannual variation in recruitment rates may be partial explanations.

In support of potentially lower recruitment limiting capture success, capture rates of adult Northern Pike at the Cootes Paradise Fishway in 2020 were among the lowest on record (Theijsmeijer and Court 2021). Therefore, it is possible that our sampling effort aligned with a period of reduced spawning activity and ultimately lower recruitment for Northern Pike.

The Aquatic Behavioural Ecology Lab at McMaster University has conducted fish community surveys in Hamilton Habour rivers and marshes as part of a larger project looking at the influence of wastewater treatment plant outfalls on fishes. As part of these works, McCallum et al. (2019) electrofished nine locations in Cootes Paradise and Red Hill Creek eight times between June and October between 2016 and 2018. In these surveys, they captured only two juvenile Northern Pike in Cootes Paradise, both near the Dundas wastewater treatment plant outfall (located ~1.5 km west of our NC-1 sampling site), and one in Red Hill Creek at an upstream location proximate to our autumn sampling sites (e.g., NR-4)(McCallum et al. 2019). Unpublished data associated with a similar fish community survey presented in Mehdi et al. (2021), detected 16 Northern Pike in Red Hill Creek between July and August in 2019. In this study, five Northern Pike were captured in portions of Red Hill Creek proximate to our sampling areas (e.g., NR-4), while the remainder (11 fish) were captured further downstream at or below the Woodward wastewater treatment plant outfall (~0.4 km below our NR-6 site). During winter sampling, Mehdi et al. (2021) only detected one Northern Pike, across all sites. Similar to the RBG dataset, we see sampling efforts prior to 2020 successfully capturing Northern Pike in areas that we did not observe them a year later. Differences in sampling gear (e.g., fyke vs. electrofishing), effort, and timing could all contribute to these differences. There is no Northern Pike information available for Red Hill Creek that is comparable to the Fishway dataset at Cootes Paradise in terms of sampling frequency. The potential role of interannual variation in adult runs, and thus recruitment, is unclear in Red Hill Creek. Northern Pike were documented in the lower stretches of Red Hill Creek prior to 1997, although successful recruitment in the system at that time was thought to be low and limited by the availability of nursery habitat (C. Portt and Associates 2003). Paired with the results from Mehdi et al. (2021), it is likely that Northern Pike can recruit as YOY within Red Hill Creek, but success is variable among years and annual water levels are a potential driver of this variability.

Collectively, our study along with those reported in the literature indicate that while juvenile Northern Pike are present in Hamilton Harbour, they occur in very low densities, in specific locations, and as such, sampling encounter rates are low. This type of spotty occurrence rate is consistent with larval fish trapping in 1985 and 1987 at some of the same locations sampled in this study. At that time, Northern Pike larvae were only detected in Grindstone Creek, and as such, encounters of Northern Pike were considered “uncommon” (Leslie and Timmins 1992). Such rarity both historically and currently highlights the significance of any juvenile Northern Pike occurrences. When paired with recent findings by RBG of declining trends in capture of spawning Northern

Pike at the Cootes Paradise Fishway (14 fish in 2020;Theijsmeijer and Court 2021), and low estimates of population sizes from recent mark-recapture work (event-based esimates of N=43 CI 19-103; Larocque et al. 2023), the general trajectory of Northern Pike populations in Hamilton Harbour is concerning.

While drivers of Northern Pike population trends are currently unknown, one potential factor is the influence of spring water levels on Northern Pike recruitment. The relationship between strong Northern Pike year classes and locally high spring water levels is well-established (Johnson 1957), and maintenance of sufficient depths throughout egg and fry development is also critical (Franklin and Smith 1963). In Hamilton Harbour, C. Portt and Associates (2003) identified potential connection issues with Red Hill Creek for the Van Wagner's Marsh/Pond complex when water levels dropped below 75.2 meters above sea level (m a.s.l.). Below this threshold, access by Northern Pike to the Red Hill Creek marshes would be limited and, in the late 1990s, water levels in excess of 75.2 (m a.s.l.) only occurred 20% of the time in a given year. Further, the timing of these water levels did not necessarily align with the timing of life history events such as spawning and recruitment. We noted similar issues during our autumn surveys at this site. An unobstructed channel of open water was not evident between the marsh and the creek at the water levels observed during the survey. However, it is plausible that fish were able to gain entry to the marshes during record high water levels that occurred in 2017 and 2019, which supported recruitment of the YOY Northern Pike captured by Mehdi et al. (2021). In contrast, comparatively lower water levels in the spring and summer of 2020 and 2021 may have limited access or reduced the suitability of available habitats. Since water level has the potential to not only increase or decrease the amount of available spawning habitat, but nursery habitat as well if the flooding of the emergent and meadow marsh areas is prolonged (Harvey 2009), further study of the role water levels play in Northern Pike recruitment is warranted.

Limited nursery habitat has been identified as a potential bottleneck to Northern Pike recruitment in Hamilton Harbour (Minns et al. 1996). Combined, periods of lower water levels may limit access to spawning habitat and potentially reduce the suitability of spawning and nursery habitat, leading to lower recruitment of Northern Pike in some parts of the harbour. Examination of the long-term RBG summer electrofishing dataset may prove fruitful to explore questions related to Northern Pike recruitment success based on water level changes. Modeling of submerged aquatic vegetation in that system predicts marked increases in submerged aquatic vegetation cover under high water scenarios (Tang et al. 2021), which could support greater Northern Pike spawning and recruitment. However, the greatest modelled increases rely on improvements in water clarity (i.e., Secchi depth) that have yet to be realized.

Should future surveys targeting Northern Pike recruitment be deemed necessary, shifting to summer electrofishing surveys may increase the likelihood of capture. If water temperature information is available, it can be used to guide sampling towards regions

with temperatures below 24°C, which aligns with the upper bounds of juvenile Northern Pike optimal growth and recruitment ranges (Casselman and Lewis 1996). Summer sampling aligns better with some of the aforementioned studies that have been more successful at capturing juvenile Northern Pike. Water temperatures likely constrain the distribution of Northern Pike during the summer (as observed by Mehdi et al. 2021), therefore, targeting areas with cooler water (< 24°C) could increase the likelihood of catching Northern Pike.

Fish Community

While the focus of these surveys was to identify areas that supported recruitment of Northern Pike, numerous other species were captured, with variable species assemblages among sampling locations. Such spatial variation in species assemblages within the harbour is well documented both historically (Leslie and Timmins 1992; Bowlby et al. 2009) and recently (Boston et al. 2016; Dugan et al. 2022). Layered on top of these spatial differences have been marked changes in the fish community assemblage throughout the harbour over the past 30 years, with both local (e.g., expanding urbanization, habitat creation and restoration, stocking of top predators) and more regional (Lake Ontario-wide, e.g., establishment of novel invasive species, shifts in primary production) factors identified as potential drivers (Dugan et al. 2022). Such systemic changes make temporal comparisons of fish communities challenging; even in the three weeks between or first and second sampling events in 2021 we observed marked changes in capture rates. Differences in survey designs and gear selectivity pose further challenges, however, here we provide a brief comparison of species assemblages during the present fyke net surveys with recent and some historic fish community surveys of these areas. A more in-depth discussion of results from seine netting was not undertaken due to more limited sampling effort, but in general catch using this gear tended to be dominated by more benthic species like Round Goby with variation in composition and abundance of other species among sampling locations.

Cootes Paradise

Long-term summer electrofishing surveys by RBG have identified 43 species that occur in the marsh (Theijsmeijer and Court 2021). In 2020, 18 species were captured with Bluegill and Pumpkinseed dominating those surveys followed by Brown Bullhead and Gizzard Shad. While the 2020 fyke net surveys did not encounter any species not found in the long-term RBG dataset, there were differences in relative abundance with Gizzard Shad dominating the fyke net catch followed by Rudd, Brook Silverside and *Lepomis* spp. Species composition was sampled using minnow traps and electrofishing from 2016 – 2018 and McCallum et al. (2019) found some areas to be more similar to the fyke net community composition of this study while others sites were more similar to the community assemblage RBG describes. RBG has noted significant year-to-year variation in YOY and adult community composition as being a normal scenario in Cootes Paradise (Bendo et al. 2021), but many of the species that are currently abundant were also abundant during larval surveys in the 1980s (e.g., Gizzard Shad, *Ictalurus* spp.; Leslie and Timmins 1992). The temporal differences in sampling pose

additional challenges since seasonal changes in species capture are well documented in Great Lakes wetlands (Diller et al. 2022). McCallum et al. (2019) demonstrated that the fish community composition varied spatially based on proximity to the wastewater outfall from the Dundas treatment plant (the area where fyke netting effort was focused in the present study). The noted differences in species composition and abundance among these various recent datasets are thus likely related to gear selectively, location of sampling, as well as the timing of sampling of a fish community where some species have a low frequency of occurrence.

Grindstone Creek

Results from our 2020 and 2021 fyke netting correspond well with the reported fish community assemblages from summer electrofishing sampling reported by RBG in the Grindstone Creek area. The most common species captured was Bluegill followed by Pumpkinseed and Bluntnose Minnow for both survey methods across the same years. On a site-by-site basis, fyke netting captured more diversity and higher total numbers of fish than RBG electrofishing, but *Lepomis* spp. dominance in the catch was consistent regardless of differences in abundance (Bendo et al. 2021; Norris et al. 2021). Despite similarities in species composition, three species not currently in the long-term electrofishing dataset for the Grindstone Creek Marshes were captured during fyke or seine netting: Alewife (*Alosa pseudoharengus*), Brook Stickleback (*Culaea inconstans)*, and Tubenose Goby (*Proterorhinus semilunaris*).The first two species were generally uncommon across all sampling locations since they rarely occur in wetlands as Alewife are more often associated with pelagic habitat and Brook Stickleback lentic systems (although they have been detected in ponds further upstream in Grindstone Creek using other sampling methods; A. Court, personal communication). Tubenose Goby, however, have not been observed in western Lake Ontario and the single individual in our dataset was not retained as a voucher. As such, we cannot independently confirm the identification of this individual and suggest that additional sampling in Grindstone Creek be undertaken with suitable vouchering to confirm presence of this species.

Spring larval fish surveys from the 1980s noted low capture rates of larval fishes with Central Mudminnow (*Umbra limi*), White Sucker, and Pumpkinseed comparatively common (albeit in low numbers; Leslie and Timmins 1992). Our more recent surveys noted only two Central Mudminnow and White Sucker were similarly in lower abundance than many other species. It should be noted, however, that our autumn sampling effort in Grindstone Creek was more focused on the marshes than the main channel, which may partially explain these discrepancies beyond the seasonality difference. Central Mudminnow have also been detected by RBG staff in upper Grindstone Creek ponds during other sampling initiatives (A. Court, personal communication).

Red Hill Creek

To our knowledge there are no long-term sampling datasets available for Red Hill Creek, and changes that have been made to aquatic habitat in Red Hill Creek (e.g.,

channel realignment, marsh creation) present challenges in finding data sources that cover the sampling area in their current habitat state. A benchmark synthesis of the fish community for Red Hill Creek (Staton 1996) and a follow up survey of most of the watershed, with considerable effort near our fyke sampling sites (C. Portt and Associates 2003), pre-date the Red Hill Valley Parkway and the subsequent stream realignment that occurred in association with the project. Habitat connectivity for portions of the Red Hill Creek marshes was improved during the expansion of the QEW highway (work which was associated with the Parkway project). Despite marked changes in habitat conditions, fish community assemblages in these historic surveys, as well as the current study and other similar recent works (e.g., McCallum et al. 2019; Mehdi et al. 2021), showed commonalities with Fathead Minnow dominating catches followed, albeit at much lower numbers, by a variety of *Lepomis* species (Pumpkinseed in particular). Notably absent from our current survey were Blacknose Dace (*Rhinichthys atratulus*), Longnose Dace (*Rhinichthys cataractae*), and Creek Chub (*Semotilus atromaculatus*), despite being present in low abundances and restricted to further upstream riffle-pool areas during historic sampling (C. Portt and Associates 2003). We also did not capture Goldfish (*Carassius auratus*) during either of the 2021 survey events, despite some limited capture in 2020 and their noted presence in both 1996 and again in the mid-2010s. Location of sampling (as well as gear, and timing) likely drive some of the noted differences since areas both above and below our sampling area were covered by C. Portt and Associates (2003). Also, three of the four sampling locations in McCallum et al. (2019) were below our study area, with only their reference site being in the same reach. Comparisons and trends discussed with regards to Red Hill Creek fish community should be done while keeping in mind the aforementioned context of habitat differences and the impact of the wastewater treatment plant outfall.

Hamilton Harbour

Since fyke netting was not possible in Cootes Paradise in 2021 due to low water levels, we opportunistically sampled additional areas within Hamilton Harbour and targeted areas proximate to submerged aquatic vegetation and where Northern Pike had been captured previously. Bluegill was the most abundant species captured in both sampling events, but Round Goby and Brook Silverside were also commonly captured. Bluntnose Minnows (*Pimephales notatus*) were abundant during the first event, but Spottail Shiners (*Notropis hudsonius*) were more abundant in the second. Fisheries and Oceans Canada (DFO) has long-term electrofishing sites in the same general area as where nets were set and results from those surveys show little change in the community structure from 2020 to 2021 (C. Boston, unpub. data). In terms of species catch, there were some differences between electrofishing and netting, with Gizzard Shad, and to a lesser degree, Brook Silverside, White Perch, and Logperch (*Percina caprodes*) being common in electrofishing surveys. Differences in species assemblage between electrofishing and netting are well documented (Cvetkovic et al. 2012), so such discrepancies are to be expected. These types of gear are generally thought of as complementary (Beck and Hatch 2009) and indeed the marked differences in capture of

Pumpkinseed between the two gear types highlight this further (e.g., Pumpkinseed were the fifth most common species in fyke nets but show considerable declines in electrofishing surveys since 2002 (C. Boston, unpub. data)).

Rudd

Rudd, a relatively recent invasive species to the Great Lakes (Crossman et al. 1992) was found at all surveys sites in Hamilton Harbour. It was first detected in 2006 at the Cootes Paradise Fishway by RBG and has been detected at the fishway every year since 2008 (Norris et al. 2021). Adult Rudd were also captured in Hamilton Harbour (Macassa Bay) during a hoop netting survey by Fisheries and Oceans Canada that same summer (C. Boston, personal communication) and recruitment was first confirmed in 2012 proximate to the Dundas wastewater treatment plant outfall above West Pond by RBG staff (D. Reddick, personal communication). During this study, Rudd were captured across Hamilton Harbour and its watersheds in both years with fyke nets catching most individuals. During the 2020 surveys, 819 Rudd were captured across all sites: Cootes Paradise Marsh (160), Spencer Creek (570), Grindstone Creek (89), and Red Hill Creek (570). In 2021, fewer Rudd were captured: Hamilton Harbour (9), Grindstone Creek (29), and Red Hill Creek (34). Understanding the spatial distribution of Rudd and other aquatic invasive species is essential for developing management or control strategies (Britton et al. 2011).

CONCLUSION

While far from exhaustive, the noted similarities and differences among fish species assemblages in the present study compared to a handful of past and current works highlight some of the spatial and temporal differences present in the Hamilton Harbour AOC. Differences in sampling protocol makes direct comparisons challenging, however, recent works focused purely on species presence (e.g., DiBattista et al. 2022) hold promise as an approach for integrating the numerous data sources that have been compiled within the system. Such an integration would support the assessment of fish populations within the Hamilton Harbour AOC by identifying areas within the harbour and its watersheds where species, currently in low abundance, may still be present or, as in the case of Northern Pike, areas where potential recruitment may still be possible.

The initial objective of the work documented in this report was to sample wetlands and creeks connected to Hamilton Harbour for evidence of Northern Pike recruitment. We captured one Northern Pike during this study in Red Hill Creek, but otherwise found no evidence of recruitment in the areas surveyed in 2020 or 2021. As documented herein, others survey have recently captured juvenile Northern Pike, which suggests recruitment is possible in the system, albeit highly variable. Future work should attempt to determine the environmental factors that influence interannual variability in recruitment, with water levels a promising initial area of exploration. Additionally, capture of juvenile Northern Pike, even when present, is clearly challenging, so a review of the methods used in more successful sampling programs

(i.e., timing, sampling location, gear, and local habitat features) would help in the design and refinement of future sampling programs that should be applied consistently across the system.

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Table 1. Site conditions and water quality data for each fyke net in 2020 and 2021. Vegetation species present include: cattail (CT; *Typha* spp.), lesser duckweed (LDW; *Lemna minor*), water celery (VAL; *Vallisneria americana*), and white water lily (WWL; *Nymphaea odorata*). See Figure 1 for net locations.

Net ID	Sampling Date	Location	Water depth (m)	Cover (%/m^2)	Vegetation species	Temperature (ºC)	Dissolved Oxygen (mg/L)	Turbidity (NTU)	pH	Conductivity (µS/cm)
NC-1	7/10/2020	Cootes	0.6	0	None	12.87	11.7	8.3	8.44	918
NC-2	7/10/2020	Cootes	0.4	0	None	11.97	6.9	26.7	7.97	1076
NC-3	7/10/2020	Cootes	0.5	0	None	12.4	10.7	18.7	8.39	880
NS-1	8/10/2020	Spencer	0.5	0	None	12.41	12.4	7.2	8.63	1384
NG-2	6/10/2020	Grindstone	0.5	5	WWL	19.39	14.3	22.3	8.91	885
NG-3	6/10/2020	Grindstone	0.6	0	None	15.21	13	18.7	8.4	1009
NG-4	6/10/2020	Grindstone	0.4	60	WWL	18.02	16.2	24.2	8.89	952
NR-1	5/10/2020	Red Hill	0.5	0	None	15.6	24.6	20.5	9.92	799
NR-2	5/10/2020	Red Hill	0.4	0	None	14.08	13.5	9.4	8.58	595
NR-3	5/10/2020	Red Hill	0.7	10	LDW, WWL	14.63	8.8	23.4	7.83	1623
NR-4	5/10/2020	Red Hill	0.4	60	WWL	12.8	11.5	54.3	8.33	1854
NR-5	6/10/2020	Red Hill	0.5	0	None	14.35	12	13	8.35	618
NR-6	6/10/2020	Red Hill	0.8	5	CT	12.69	10.1	56.4	8.14	2102
NG1-1	7/10/2021	Grindstone	0.7	10	CT	16.52	9.6	16.5	8.42	822
NG1-2	7/10/2021	Grindstone	0.6	5	WWL	19.23	6.8	28.8	7.85	761
NG1-3	7/10/2021	Grindstone	0.7	0	None	17.44	9.4	24.1	8.33	856
NG1-4	7/10/2021	Grindstone	0.4	0	None	18.22	8.7	41	8.07	1098
NH1-1	4/10/2021	Hamilton	0.8	0	None	18.42	10.2	8.1	8.71	568
NH1-2	4/10/2021	Hamilton	0.7	30	VAL	17.92	7.8	2.4	8.18	576
NH1-3	4/10/2021	Hamilton	0.8	40	VAL	18.03	5.5	1.3	7.84	578
NH1-4	4/10/2021	Hamilton	0.5	15	CT, WWL	17.32	8.8	40.3	8.29	614
NH1-5	4/10/2021	Hamilton	0.4	0	WWL, CT	17.46	9.2	50.9	7.87	622
NR1-1	5/10/2021	Red Hill	0.5	10	WWL	18.42	4.2	4.5	7.69	1044
NR1-2	5/10/2021	Red Hill	0.6	0	None	18.59	4.3	21.8	7.67	1044
NR1-3	6/10/2021	Red Hill	0.5	5	CT	17.31	10.5	5.1	8.34	1385
NR1-4	6/10/2021	Red Hill	0.8	5	CT	17.29	10.5	5.1	8.31	1374
NR1-5	6/10/2021	Red Hill	0.7	10	WWL, CT	18.35	6.9	17.2	7.79	1254
NR1-6	6/10/2021	Red Hill	0.5	0	None	19.96	15.6	20.3	8.74	854
NR1-7	5/10/2021	Red Hill	0.7	0	None	17.3	10.6	6	8.41	1379
NG2-1	28/10/2021	Grindstone	0.7	10	CT	9.49	10.9	9.3	8.46	776

NG2-2	2810/2021	Grindstone	0.6	5	WWL	9.63	9.9	17.1	8.27	799
NG2-3	28/10/2021	Grindstone	0.8	0	None	9.61	11	13.5	8.45	803
NG2-4	28/10/2021	Grindstone	0.4	0	None	11.14	11.2	21.3	8.53	1163
NH2-1	4/11/2021	Hamilton	0.8	0	None	12.18	9.4	4.9	8.07	568
NH2-2	4/11/2021	Hamilton	0.7	20	VAL	11.98	9.4	2.6	8.12	600
NH2-3	4/11/2021	Hamilton	0.9	20	VAL	12.08	8.8	8.4	8.04	601
NH2-4	4/11/2021	Hamilton	0.5	10	WWL	10.22	10	21.3	8.16	615
NH2-5	4/11/2021	Hamilton	0.4	0	WWL, CT	9.14	10.4	10.4	8.3	620
NR2-1	2/11/2021	Red Hill	0.5	5	WWL	7.42	7.4	31.1	7.7	1233
NR2-2	2/11/2021	Red Hill	0.6	0	None	7.83	7.9	23.4	7.37	1240
NR2-3	3/11/2021	Red Hill	0.5	5	CT	7.68	11.9	4.5	8.35	1427
NR2-4	3/11/2021	Red Hill	0.8	5	CT	7.7	11.9	5.1	8.33	1418
NR2-5	3/11/2021	Red Hill	0.7	10	WWL,CT	7.21	10.9	9	7.98	1640
NR2-6	3/11/2021	Red Hill	0.6	0	None	6.41	12	20.3	8.47	1293
NR2-7	3/11/2021	Red Hill	0.8	0	None	8.02	12.1	3.8	8.35	1431

Table 2. Coordinates, general location, and name of the sampling site for surveys in 2020 and 2021 with method of capture (e.g., fyke net vs seining). The sample column indicates the sampling year and whether a site was sampled twice in 2021 (S1 for the first round and S2 for the second round). Locations are plotted in Figure 1.

Net ID	Method	Sample	Location	Latitude	Longitude	General Description
NC-1	Fyke	S2020	Cootes	43.27271	-79.924919	Spencer Creek
NC-2	Fyke	S2020	Cootes	43.273516	-79.919288	Desjardins Canal
NC-3	Fyke	S2020	Cootes	43.277369	-79.911524	Spencer Creek delta
NS-1	Fyke	S2020	Cootes	43.267857	-79.927883	Spencer Creek, Cootes Dr.
NG-1	Fyke	S2020	Grindstone	43.290608	-79.885735	Sunfish pond
NG-2	Fyke	S2020	Grindstone	43.291304	-79.883695	Channel
NG-3	Fyke	S2020	Grindstone	43.290258	-79.882402	Osprey March
NR-1	Fyke	S2020	Red Hill	43.249950	-79.764780	Parkway pond
NR-2	Fyke	S2020	Red Hill	43.248550	-79.767400	Channel
NR-3	Fyke	S2020	Red Hill	43.252050	-79.764450	Pond QEW
NR-6	Fyke	S2020	Red Hill	43.254029	-79.763098	Van Wagner's pond
NR- 4	Fyke	S2020	Red Hill	43.253513	-79.762273	Van Wagner's marsh
NR-5	Fyke	S2020	Red Hill	43.253180	-79.766290	Channel
NG1-1	Fyke	S1-2021	Grindstone	43.29316	-79.88377	Channel
NG1-2	Fyke	S1-2021	Grindstone	43.29015	-79.88272	Osprey Marsh
NG1-3	Fyke	S1&2-2021	Grindstone	43.28921	-79.88355	Channel
NG1-4	Fyke	S1&2-2021	Grindstone	43.29013	-79.88587	Sunfish pond
NG2-1	Fyke	S2-2021	Grindstone	43.293086	-79.883747	Channel
NG2-2	Fyke	S2-2021	Grindstone	43.290226	-79.88275	Osprey Marsh
NGS-1	Seine	S2021	Grindstone	43.29351	-79.8837	Channel
NGS-2	Seine	S2021	Grindstone	43.28916	-79.88268	Osprey Marsh
NGS-3	Seine	S2021	Grindstone	43.289417	-79.884187	Channel
NGS-4	Seine	S2021	Grindstone	43.290475	-79.885895	Sunfish pond
NH1-1	Fyke	S1&2-2021	Hamilton	43.271619	-79.874694	Bayfront beach
NH1-2	Fyke	S1&2-2021	Hamilton	43.303163	-79.84069	LaSalle
NH1-3	Fyke	S1&2-2021	Hamilton	43.30243	-79.84298	LaSalle
NH1-4	Fyke	S1-2021	Hamilton	43.28166	-79.89012	Carrols bay
NH1-5	Fyke	S1-2021	Hamilton	43.28175	-79.88967	Carrols bay
NH2-4	Fyke	S2-2021	Hamilton	43.281994	-79.890266	Carrols bay
NHS-1	Seine	S2021	Hamilton	43.272043	-79.87455	Bayfront beach
NHS-2	Seine	S2021	Hamilton	43.30223	-79.84395	LaSalle
NHS-3	Seine	S2021	Hamilton	43.28082	-79.88393	Carrols bay
NR1-1	Fyke	S1-2021	Red Hill	43.25376	-79.76257	Van Wagner's marsh
NR1-2	Fyke	S1-2021	Red Hill	43.253426	-79.762212	Van Wagner's marsh
NR1-3	Fyke	S1&2-2021	Red Hill	43.253528	-79.766509	Channel
NR1-4	Fyke	S1&2-2021	Red Hill	43.25303	-79.76608	Channel
NR1-5	Fyke	S1-2021	Red Hill	43.25224	-79.76445	Pond QEW
NR1-6	Fyke	S1&2-2021	Red Hill	43.250018	-79.764645	Pond
NR1-7	Fyke	S1&2-2021	Red Hill	43.248857	-79.7674	Channel
NR2-1	Fyke	S2-2021	Red Hill	43.253426	-79.762212	Van Wagner's marsh
NR2-2	Fyke	S2-2021	Red Hill	43.25376	-79.76257	Van Wagner's marsh
NR2-5	Fyke	S2-2021	Red Hill	43.251944	-79.76416	Pond QEW under bridge
NRS-1	Seine	S2021	Red Hill	43.25358	-79.76218	Van Wagner's marsh
NRS-2	Seine	S2021	Red Hill	43.25501	-79.767	Channel
NRS-3	Seine	S2021	Red Hill	43.25354	-79.7665	Channel
NRS-4	Seine	S2021	Red Hill	43.249639	-79.764968	Pond
NRS-5	Seine	S2021	Red Hill	43.249125	-79.767173	Channel

Table 3. Summary of fish captured using fyke nets in 2020 in Cootes Paradise, Grindstone Creek, Red Hill Creek, and Spencer Creeks (N= total sampling events).

Family	Scientific Name	Common Name	Cootes Paradise (N=3)	Grindstone Creek (N=3)	Red Hill Creek (N=6)	Spencer Creek (N=1)
Amiidae	*Amia calva*	Bowfin	1			
Clupeidae	*Dorosoma cepedianum*	Gizzard Shad	606	18	349	
Esocidae	*Esox lucius*	Northern Pike			1	
Umbridae	*Umbra limi*	Central Mudminnow		2		
Cyprinidae	*Carassius auratus*	Goldfish		9	8	1
	Cyprinus carpio	Common Carp	1	1	1	
	Luxilus cornutus	Common Shiner			49	
	Notemigonus crysoleucas	Golden Shiner		2	24	
	Notropis atherinoides	Emerald Shiner		1		
	Notropis hudsonius	Spottail Shiner			944	
	Pimephales notatus	Bluntnose Minnow	3	80		
	Pimephales promelas	Fathead Minnow	2	2	2,792	
	Scardinius erythrophthalmus	Rudd	160	89	342	570
Catostomidae	*Catostomus commersonii*	White Sucker		3	7	2
Ictaluridae	*Ameiurus nebulosus*	Brown Bullhead	17	32	8	1
	Noturus gyrinus	Tadpole Madtom		4		
Percichthyidae	*Morone americana*	White Perch	23	15	4	186
Centrarchidae	*Ambloplites rupestris*	Rock Bass		5		
	Lepomis cyanellus	Green Sunfish		20	260	
	Lepomis gibbosus	Pumpkinseed	30	703	946	26
	Lepomis macrochirus	Bluegill	7	1,015	311	
	Lepomis spp.	Lepomis spp.	151	3	2,228	
	Micropterus salmoides	Largemouth Bass		42	3	
	Pomoxis nigromaculatus	Black Crappie		18		2
Percidae	*Perca flavescens*	Yellow Perch	5	14	19	57
	Percina caprodes	Logperch	2	3	17	3
Atherinidae	*Labidesthes sicculus*	Brook Silverside	155	1	104	
Gobiidae	*Neogobius melanostomus*	Round Goby	14	35	210	25
Total catch:			1,177	2,117	8,627	1,158
Total species richness:			14	23	20	11
Total effort (hr):			68.3	68.1	157.5	22.6
CPUE (individuals/hr):			17.2	31.1	62.7	51.2

Table 4. Summary of fish captured using fyke nets in 2021 in Grindstone Creek, Hamilton Harbour, and Red Hill Creek during two separate sampling events. The first sampling event occurred on October 4th – 8th (S1) and October 28th – November 5th (S2). N= total sampling events.

Family	Scientific Name	Common Name	Grindstone Creek (N=4)		Hamilton Harbour (N=5)		Red Hill Creek (N=7)	
			S1	S2	S1	S2	S1	S2
Amiidae	*Amia calva*	Bowfin			1			
Clupeidae	*Alosa pseudoharengus*	Alewife	2					
	Dorosoma cepedianum	Gizzard Shad	12	7	56	8	21	103
Cyprinidae	*Carassius auratus*	Goldfish		14	6	11		
	Cyprinella spiloptera	Spotfin Shiner			6			
	Cyprinus carpio	Common Carp	20	7	13	2	31	5
	Luxilus cornutus	Common Shiner		2			2	8
	Notemigonus crysoleucas	Golden Shiner		2			2	1
	Notropis hudsonius	Spottail Shiner		5	1	14	1	
	Notropis volucellus	Mimic Shiner	1	1				1
	Pimephales notatus	Bluntnose Minnow	7	133	345	9		
	Pimephales promelas	Fathead Minnow	2	5	1		1,869	2,766
	Scardinius erythrophthalmus	Rudd	6	23	9		11	22
Catostomidae	*Catostomus commersonii*	White Sucker		28			1	15
Ictaluridae	*Ameiurus nebulosus*	Brown Bullhead	32	43	10	3	9	4
	Noturus gyrinus	Tadpole Madtom		1				
Gasterosteidae	*Culaea inconstans*	Brook Stickleback				1		
Percichthyidae	*Morone americana*	White Perch	2	1	11	3	3	79
Centrarchidae	*Ambloplites rupestris*	Rock Bass		1	14	4		
	Lepomis cyanellus	Green Sunfish	6	10	34		86	54
	Lepomis gibbosus	Pumpkinseed	180	248	101	5	75	59
	Lepomis macrochirus	Bluegill	557	386	654	93	37	39
	Lepomis spp.	*Lepomis* spp.	68				5	
	Micropterus salmoides	Largemouth Bass	6	29	17	4	2	1
	Pomoxis nigromaculatus	Black Crappie	12	4		1	2	
Percidae	*Perca flavescens*	Yellow Perch	1	8	3	6		3
	Percina caprodes	Logperch	1	11	2	2	2	
Atherinidae	*Labidesthes sicculus*	Brook Silverside	39	2	157	31		13
Gobiidae	*Neogobius melanostomus*	Round Goby	7	28	249	40	338	213
	Proterorhinus semilunaris	Tubenose Goby		1				
Total catch:			961	1,000	1,690	237	2,497	3,386
Total species richness:			18	25	20	17	17	17
Total effort (hrs):			86.5	84.8	112.1	111.9	151.6	154
CPUE (#/hr):			11.1	11.8	15.1	2.1	16.5	22

Table 5. Summary of fish captured using seine nets in 2021 in Grindstone Creek, Hamilton Harbour, and Red Hill Creek during the first sampling event (October 4th – 8th). N= total sampling events.

Family	Scientific Name	Common Name	Grindstone Creek (N=4)	Hamilton Harbour (N=3)	Red Hill Creek (N=5)
Clupeidae	*Dorosoma cepedianum*	Gizzard Shad	5		47
Cyprinidae	*Carassius auratus*	Goldfish	2		1
	Cyprinus carpio	Common Carp	3		1
	Notropis atherinoides	Emerald Shiner	2	7	
	Notropis hudsonius	Spottail Shiner	17	16	
	Pimephales notatus	Bluntnose Minnow	3	47	3
	Pimephales promelas	Fathead Minnow	94	1	69
	Scardinius erythrophthalmus	Rudd			1
Catostomidae	*Catostomus commersonii*	White Sucker	9		
Gasterosteidae	*Culaea inconstans*	Brook Stickleback	5		
Ictaluridae	*Ameiurus nebulosus*	Brown Bullhead			1
Percichthyidae	*Morone americana*	White Perch		5	
Centrarchidae	*Ambloplites rupestris*	Rock Bass		1	
	Lepomis cyanellus	Green Sunfish	5	2	
	Lepomis gibbosus	Pumpkinseed	32	7	1
	Lepomis macrochirus	Bluegill	28	31	1
	Lepomis spp.	Lepomis spp.		40	
	Micropterus salmoides	Largemouth Bass	5	25	
Percidae	*Perca flavescens*	Yellow Perch	2	3	
	Percina caprodes	Logperch	4	75	1
Atherinidae	*Labidesthes sicculus*	Brook Silverside	31	39	13
Gobiidae	*Neogobius melanostomus*	Round Goby	50	1,638	405
Total catch:			297	1,937	544
Total species richness:			17	14	12
CPUE (#/haul):			74	645.6	108.8

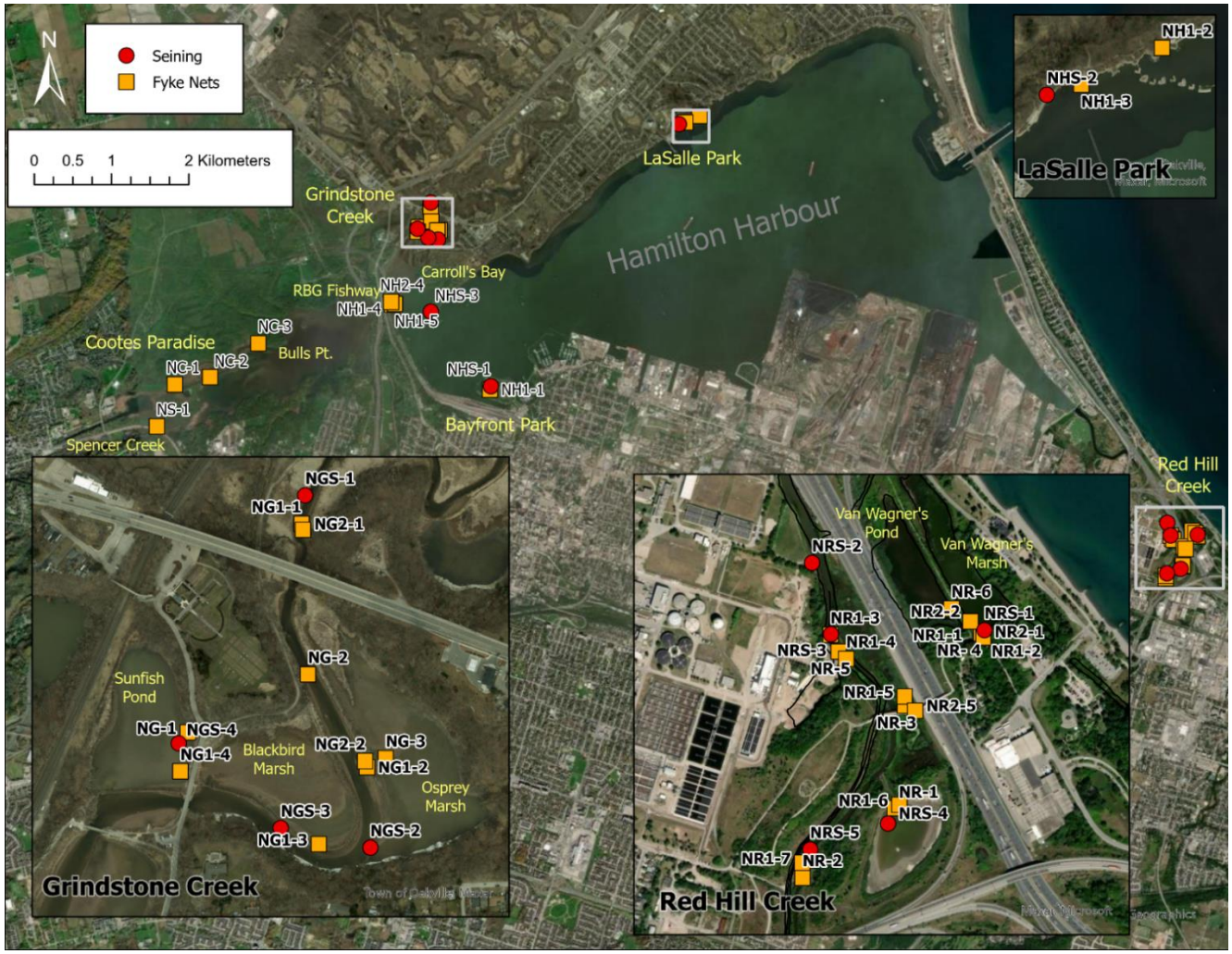

Figure 1. Sampling locations of fyke nets in 2020 and 2021 (orange squares) and seine nets (red circles) in 2021. See Table 2 for details related to site name and coordinates for each sampling location.