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Assessing occupancy of freshwater fishes in urban boat slips of Toronto Harbour

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*Hardening of natural shorelines in urban aquatic ecosystems can result in a loss of fish habitat and productivity. The north shore of Toronto Harbour (Lake Ontario) has been converted to hardened boat slips for commercial, industrial and recreational purposes, but its potential utility as fish habitat has not been evaluated. The objective of this study was to determine whether fish frequented and utilized four slips in the Inner Harbour of Toronto. Two western boat slips are adjacent to some natural features and have undergone some rehabilitation to increase the complexity of aquatic habitat (i.e. addition of large substrate, overhead cover, and in-water structure). In contrast, the two eastern slips are deeper and more influenced by the turbid Don River. We assessed the timing and duration of occupancy within all four slips for seven fish species using acoustic telemetry. In just under a year, tagged fishes spent a limited amount of time in any one slip. However, there was evidence for increased use at the two western slips by Northern Pike (*Esox lucius*) in spring, which is likely linked to the proximity of these slips to a known spawning area. Overall, there was no reliable evidence that the majority of the seven adult fish species evaluated frequented either the western or eastern slips. Despite efforts to track and tag a variety of species, insufficient detections prevented a detailed assessment of habitat selection for the majority of species of interest. A more detailed study of the spatial ecology of these fishes is therefore needed to understand the scale of their habitat use and inform the design of habitat rehabilitation projects for hardened shorelines.*

Keywords: acoustic telemetry, hardened shoreline, multi-species, spatial ecology

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Introduction

One third of the world's population lives within 100 km of a coastline (Gittman et al., 2015), resulting in continued pressure for development at the land-water interface. Within this zone, shoreline hardening (i.e. placement of bulkheads, riprap, breakwaters, etc.) is frequently used to protect developed areas from rising water levels and erosion (Gittman et al., 2015) or to create docks and quays for recreational, commercial, and industrial shipping. This type of development often replaces complex natural shorelines (e.g. wetlands, beaches) that support not only diverse assemblages of aquatic flora and fauna but are also key spawning and nursery habitats for many fishes (Dudgeon et al., 2006; Minns and Wichert, 2005; Sundblad and Bergstrom, 2014; Gittman et al., 2016). The resulting hardened shoreline typically has less heterogeneous substrate, aquatic vegetation, and bathymetry, which generally support fewer fishes and benthic fauna (Minns and Wichert, 2005; Seitz et al., 2006; Bilkovic and Roggero, 2008).

Despite expanding populations and demand for space, there are also increasing efforts to protect sensitive habitats (Hoekstra et al., 2005) and, when systems are degraded as when shorelines are hardened, various forms of ecological restoration (including enhancement, creation, rehabilitation, reclamation and true restoration; see Jackson et al., 1995; herein referred to collectively as "rehabilitation") can be undertaken to move the system back towards a more desired state (Hobbs and Harris, 2001; Benayas et al., 2009). Returning hardened shorelines back to their natural state (shoreline softening) can be challenging due to physical challenges (i.e. removal of the hardened material) as well as ongoing requirements to protect property and infrastructure (Gittman et al., 2016). As a result, in many urban environments hardened shorelines are likely to remain in some capacity such that an examination of their potential contribution and utility as aquatic habitat is warranted.

The Toronto and Region Area of Concern (AOC), which includes the coastal areas of Canada's largest city, remains one of the most degraded aquatic ecosystems in the Laurentian Great Lakes. The central portion of the city's waterfront is dominated by the port area, which is a remnant of the city's industrial and commercial era. This portion of the waterfront, referred to as the Inner Harbour, was the area most affected by historical commercialization (early to mid-1800s) and development through the infilling of wetlands and small streams, shoreline hardening, and channel reconfiguration (e.g. Don River). Throughout the Toronto and Region AOC, coastal habitat losses have been estimated at greater than 400 hectares of marsh habitat (Whillans, 1982). Based on a shoreline survey conducted in 2012, over one third of the remaining shoreline is comprised of hardened walls (Leisti et al., pers. comm., Fisheries and Oceans, Burlington, ON), with vertical concrete walls and sheet steel pilings having been installed in a number of slips along the northern and eastern waterfront for government, cargo, and passenger traffic. While use of these slips has shifted to recreational and commercial traffic, the slips continue to be an essential component of the port area.

Given projected population growth in the Greater Toronto Area (42.9% by 2041; https://www.fin.gov.on.ca/en/economy/demographics/projections/), coastal development (i.e. hardening, infilling) will likely continue to be a major threat to the integrity of valuable and vulnerable coastal habitats within the AOC. As such, efforts have been made to partially rehabilitate two slips, Peter and Spadina, situated along the north-western portion of the Inner Harbour (Figure 1) by increasing in-water habitat heterogeneity (i.e. macrophytes, complex structures, woody debris, substrate diversity). The goal of these rehabilitation efforts was to improve habitat for native fishes including two recreationally important species, Largemouth Bass (*Micropterus salmoides*) and Northern Pike (*Esox lucius*). These species, and other cool- and warm-water freshwater fishes, depend on inshore/coastal habitats or associated tributaries for some part of their life cycle (Lane et al., 1996a,b,c; Minns and Wichert, 2005). Documenting the extent of their use of urban boat slips with various environmental conditions will help assess their importance in a regional context and also provide a baseline for future restoration efforts.

The objective of the present study was to assess the extent to which the slips along the waterfront of Toronto Harbour were frequented

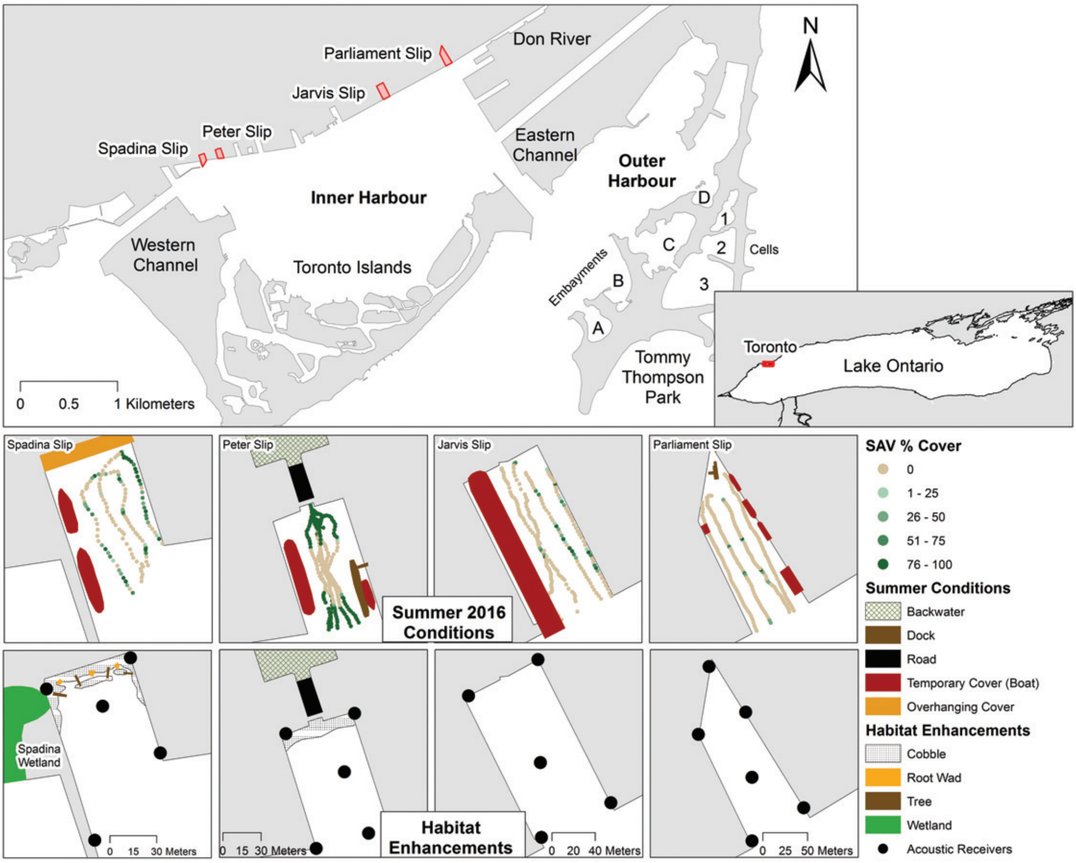

Figure 1. Location of the four slips and other key areas in Toronto Harbour and the positions of the acoustic telemetry receivers in each slip used to create a 2D positioning array. The environmental conditions in each slip (as assessed in summer 2016) are also presented with the location of both temporary and permanent cover as well as the distribution of submerged aquatic vegetation (SAV) in the slips. Finally, the locations of rehabilitation actions in Spadina and Peter slips are shown (N.B. the wetland west of Spadina Slip can be accessed by fish from the slip). The backwater area north of Peter Slip is shown and is connected under the road to the slip.

by Largemouth Bass and Northern Pike as well as other local fishes (i.e. Common Carp (*Cyprinus carpio*; a common non-native species), Walleye (*Sander vitreus*), Brown Bullhead (*Ameiurus nebulosus*), White Sucker (*Catostomus commersonii*) and Yellow Perch (*Perca flavescens*)) tagged with acoustic transmitters. To accomplish this, two-dimensional acoustic telemetry arrays were used to assess occupancy within the slips and determine the mean time per slip visit by each individual. Also, when possible, aggregated 95% percentage volume contours (PVC) were developed to determine where in each slip fish presence was clustered. Because the majority of our target species are typically associated with more structurally complex habitats (e.g. Largemouth Bass [Ahrenstorff et al., 2009] and Northern Pike [Cook and Bergersen, 1988]), we anticipated that more species and individuals would be detected in the western slips, which have received some level of rehabilitation, relative to the eastern slips.

Materials and methods

Field site/receiver arrays

Differences among the four boat slips (Spadina, Peter, Jarvis and Parliament) selected for this study include size (surface area and depth), proximity to other aquatic features and aquatic habitat heterogeneity (Table 1; Figure 1).

Table 1. Physical characteristics of the four slips in Toronto Harbour. Depth (±standard deviation) and submerged aquatic vegetation (SAV) were assessed using hydroacoustics in August 2016. Temperature data were from Hobo temperature data loggers (Onset Computer Corporation, Bourner, MA).

	Slip			
Metric	Spadina	Peter	Jarvis	Parliament
Surface Area (ha)	5.8	7.9 (5.8)	12.0	10.9
Num. Survey Points	137	249	210	254
Mean Depth (m)	4.10 ± 0.38	7.46 ± 1.86	9.54 ± 0.54	7.70 ± 0.39
Depth Range (m)	3.31–4.79	2.12–9.09	8.51–10.69	6.72–8.45
Prop. Points with SAV	0.39	0.58	0.14	0.05
Temp. Range (°C)	0.8–24.1	0.2–22.0	0.3–21.3	0.6–22.5
Dominant Substrate	Silt	Silt	Silt	Silt
Rehabilitation	Rock, Roots Wads	Rock	–	–

In general though, these slips tend to be deeper and cooler than other parts of the harbour (i.e. Toronto Islands and Tommy Thompson Park; Figure 1; Hlevca et al., 2015). In 2008, habitat heterogeneity in Spadina was increased by supplementing 640 m^2 of substrate through the addition of logs, boulders, and granular substrate along the northern side of the slip. Similarly, in 2006, gravel, cobble, and boulders were added to the northern section of Peter (Figure 1). In addition to within-slip rehabilitation, Spadina is situated next to the Spadina Quay Wetlands (2,800 m^2), a wetland created in 1998 that is accessible to fish in high-water years (Figure 1). Similarly, Peter Slip is connected to a shallow back-basin that contains abundant submerged aquatic vegetation (SAV; Figure 1). The two remaining slips, Jarvis and Parliament, have no adjacent or connected habitat features, but are closer to the outflow of the Don River, which drains a large watershed (~360 km^2) and heavily influences water chemistry and clarity within the eastern portion of the central waterfront. Hydroacoustic surveys completed in the summer of 2016 documented greater overall cover of SAV in Peter and Spadina slips and generally shallower depths in Spadina and, to a lesser extent, Peter (S. Doka unpub. data; Table 1; Figure 1). Where present, the dominant SAV species' were *Elodea canadensis* and *Ceratophyllum demersum*. Finally, all four slips have some type of either permanent (e.g. wooden decks or docks) or intermittent (e.g. boats) surface cover that shades a portion of the slip. In general, habitat conditions in the two slips located in the western part of the Inner Harbour (Spadina and Peter) are similar to one another as are conditions in the two slips located more to the east (Jarvis and Parliament), which are more influenced by the Don River.

In August 2012, Vemco (Vemco-Amirix Inc, Halifax, NS) Positioning System (VPS) arrays (Espinoza et al., 2011) were deployed in the four slips. Spadina, Peter and Jarvis were each equipped with five receivers while Parliament was equipped with six receivers due to its asymmetrical configuration (Figure 1). Based on results provided by Vemco, 90% of positions in each of Spadina, Peter, Jarvis and Parliament had an average horizontal position error (HPE) estimate of 2.2, 3.3, 7.0 and 3.0, respectively. This is a unit-less estimate of how sensitive a calculated position is to errors in its inputs (Smith, 2013) and would suggest that there is a lower degree of confidence in the positioning of fish on the Jarvis array compared to the other three. The VPS arrays were deployed from 20 August 2012 until 9 June 2013; however, two receivers remained in each slip until spring 2015 as part of a larger study of fish movements and habitat selection within the harbour.

Capture and tagging

Fish were collected using boat electrofishing (Smith-Root electrofishing boat model SR 18.EH; 250 V and 7 A for intervals of ~1,000 s) and were primarily captured in four areas: the Toronto Islands, Embayment C, Cell 2 and Cell 3 (Figure 1). Additionally, four of the tagged

Walleye originated from the Ontario Ministry of Natural Resources and Forestry White Lake Fish Culture Station (Sharbot Lake, ON). From September 2010 to July 2013, 229 fish were tagged with acoustic transmitters of varying sizes (Supplementary Table S1, available in the online supplementary information). Tagging efforts focused on Northern Pike (N = 71), Largemouth Bass (N = 66), and Common Carp (N = 47), but a smaller number of Brown Bullhead (N = 14), Walleye (N = 11), White Sucker (N = 10) and Yellow Perch (N = 10) were also tagged. Detailed methods for tagging are outlined in Peat et al. (2016) and Rous et al. (2016). Tagged fish were released at their location of capture.

Data preparation and statistical analysis

For each slip, the VPS provided detailed information on the 2-D position of detected fish. As a result, only those detections that fell within the boundaries of a slip were retained and those that fell outside (i.e. fish detected by the array that were actually in the Inner Harbour) were excluded. Consecutive detections were considered part of the same slip visit if they occurred within 30 min. This accounted for missed transmissions that can occur as a result of code collisions or other noise interference (Kessel et al., 2014). If there was a larger gap between detections, the residency counter was reset and the detections were treated as a new visit. Seasons were defined as follows; summer: 20 August 2012 to 20 September 2012, fall: 21 September 2012 to 20 December 2012, winter: 21 December 2012 to 20 March 2013, and spring: 21 March 2013 to 9 June 2013. All analyses were completed in R v 3.1.0 (R Development Core Team, 2013).

For each season and species, the number of tagged individuals detected within a slip was counted as was the total number of tagged individuals detected across all slips. For all individuals detected at any slip during each season, the total time in each slip (recorded as a zero for slips where not detected) and the mean time per visit were calculated. A statistical comparison of the duration of time spent within slips was only undertaken when there were greater than three individuals of a species detected in a single slip during a given season. Where possible, a Kruskal-Wallis test was used to compare the total time within each slip and the mean total time per visit among slips and a post-hoc Nemenyi test was used to identify differences between slips. The spatial distribution of fish within each slip and their association with enhancements or cover were assessed visually (Figure 1). For this, a kernel density estimate (KDE) for each individual in each slip for each season was calculated in ArcMap 10.2.1 (ESRI, Redlands, CA) with an output cell size set to 1 m^2 and a search radius of 10 m bounded by the extent of the slip. From these KDE, 95% PVCs were developed for each individual. Individual PVCs were then aggregated to identify areas that were frequented by a species during a given season within each slip. A comparison of PVC in the slips was only undertaken when at least three individuals were detected within at least two slips during a season.

Results

Of the 229 fish that were tagged and active in the harbour during this study (Supplementary Table S1), 40 were detected inside one of the slips (Supplementary Table S2). These were primarily Northern Pike (N = 16) and Common Carp (N = 12); however, despite comparatively low initial tagging numbers, over half of the Walleye (N = 7) were detected in one of the slips. Only a few individuals from the remaining species (Largemouth Bass N = 2, White Sucker N = 2, and Yellow Perch N = 1) and no Brown Bullhead were detected. Given the paucity of detections for these four species, they were not evaluated further.

Northern Pike were detected in the western slips (Spadina and Peter) in all seasons, but were only present in the eastern slips (Jarvis and Parliament) in the winter (a single individual detected in Jarvis Slip) and spring (Supplementary Table S2; Figure 2). During the spring, there were more than twice as many individuals detected in the western than the eastern slips. All of the seasonal Kruskal-Wallis tests for Northern Pike were significant for both the total time and mean time spent in slips ($p < 0.001$). Based on a Nemenyi post-hoc analysis, Northern Pike spent significantly more time in total and during each visit in Spadina compared to both Jarvis ($p < 0.03$) and Parliament ($p < 0.03$) in the summer and fall. In the winter, these metrics were

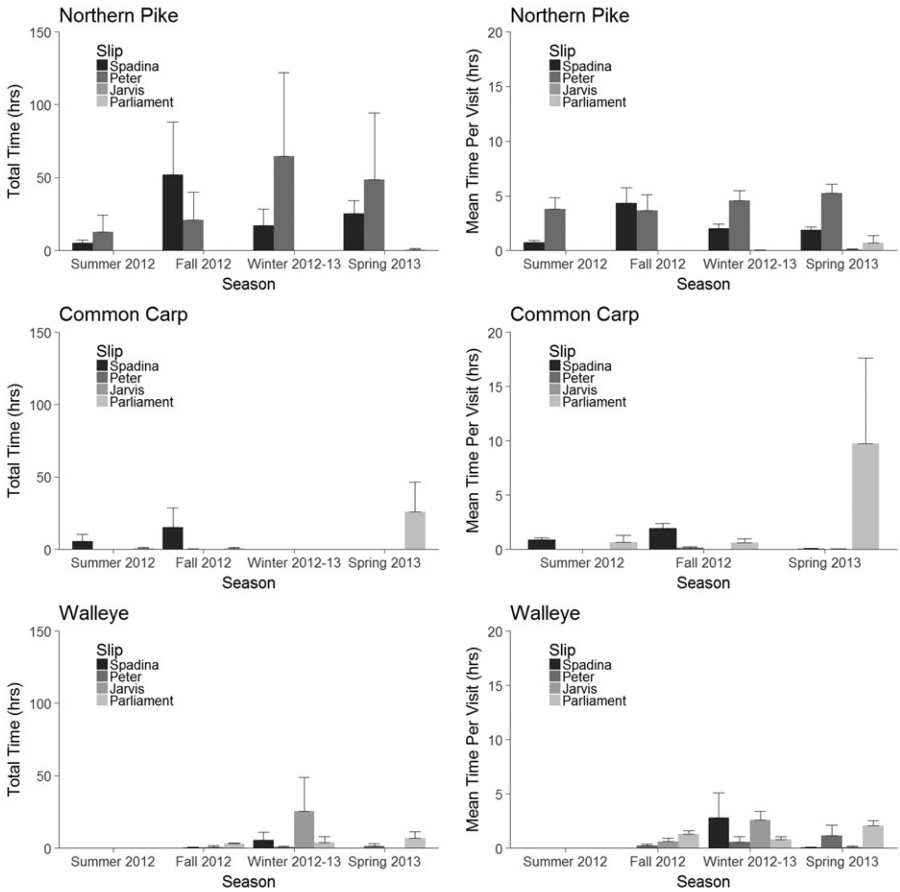

Figure 2. Total time spent in each slip and mean time per slip visit during each season by Northern Pike, Common Carp and Walleye. Error bars represent standard deviation. Sample sizes for each species by season are listed in Supplementary Table S1. Other species tracked in this study are not shown due to low sample sizes.

higher in Peter compared to Jarvis ($p < 0.02$) and Parliament ($p < 0.006$). Differences in total time and mean time per visit were particularly evident in the spring with Northern Pike spending significantly more time in the western relative to the eastern slips (Kruskal-Wallis $p < 0.0001$; Nemenyi post-hoc pairwise, Peter-Jarvis [$p < 0.024$], Peter-Parliament [$p < 0.006$], Spadina-Jarvis [$p < 0.002$], and Spadina-Parliament [$p < 0.0003$]; Figure 2). Despite these between-slip differences, the mean total time in any one slip was generally quite low (<65 h) and the longest single visit to a slip was just under 11 h (Figure 2).

Common Carp were detected in the slips during all seasons except for winter (Supplementary Table S2; Figure 2). For the remaining seasons, a Kruskal-Wallis test suggested there may be differences in the total time and mean time per visit in the slips in the summer ($p < 0.018$), but the post-hoc Nemenyi test did not identify any pairwise differences (all $p > 0.16$). Generally, low numbers of Walleye precluded detailed statistical comparisons, but the majority of the individuals were detected in the spring ($N = 6$; Supplementary Table S2) and these were primarily found in Parliament where on average they spent less than 7 h in total (Figure 2).

The PVC allowed for a visual assessment of habitat use within each slip; however, due to low samples sizes, this type of assessment was only completed for Northern Pike and Common Carp. Northern Pike were more frequently detected in the central basin of Spadina during the spring and adjacent to but not directly over some of the rehabilitated habitat features located at the back

Figure 3. Aggregated 95% percent volume contours for Northern Pike in each slip by season. Darker areas represent areas frequented by numerous individuals during a season.

of this slip (Figure 3). In the other seasons, Northern Pike were primarily detected at the mouth of the slip in close proximity to the Inner Harbour (Figure 3). For Peter Slip during the spring, Northern Pike detections were concentrated adjacent to some of the rehabilitated habitat features along the northern wall of the slip. In the fall and winter, detections were more concentrated in the middle of the slip, but in proximity to rehabilitated habitat features (Figure 3). Finally, similar to Spadina, summer detections were concentrated at the mouth of the slip (Figure 3). Limited detections in Jarvis and Parliament prevented an evaluation of space-use by Northern Pike in these slips. Common Carp were not detected in the slips in the winter and, despite detections of multiple individuals in the other seasons, there were no clear areas of aggregation in any slip for this species (Supplementary Figure S1). The generally short duration of each visit to the slips by Common Carp likely precluded the identification of clear aggregation areas in the slips.

Discussion

The main objective of this study was to compare the frequency and duration of detections of tagged fishes among four urban boat slips. Results suggest that the majority of tracked species do not frequent any of the slips. Northern Pike were the sole exception, spending significantly more time in the western slips, particularly during the spring. Common Carp were also detected in the slips; however, they generally spent only a short time in any one slip. With the exception of Northern Pike, the present study did not find that adults of the species tagged frequented any of the urban boat slips.

Northern Pike were present in the western slips across all seasons, with clear selection for these slips during the spring. This timeframe coincides with the spawning window for Northern Pike, although habitat conditions within any of the slips do not reflect typical spawning habitats for Northern Pike (i.e. flooded emergent vegetation; Casselman and Lewis, 1996). Northern Pike may use deeper sub-optimal habitat when their preferred habitat is unavailable, which can result in an ecological sink (Farrell et al., 2006). However, Northern Pike have access to suitable spawning habitat in other parts of Toronto Harbour (e.g. Toronto Islands), so a more likely explanation is that Northern Pike detected in the western slips during the spring were staging in preparation for spawning in the Spadina Quay Wetland, which is directly adjacent to Spadina Slip (Figure 1). Northern Pike have been observed spawning in this created habitat (L. Matos, pers. comm.); however, to our knowledge no evaluation of recruitment from this system has been undertaken. Furthermore, this area does not provide appropriate habitat for YOY Northern Pike, so an assessment of the use of Spadina Slip and Spadina Quay Wetland by YOY Northern Pike is likely warranted.

Outside of the spring, Northern Pike spent significantly more time in Spadina (summer and fall) and Peter (winter) than in either of the eastern slips. An important caveat to this finding is that the PVCs for Northern Pike in Spadina indicated that, outside of spring, their spatial distribution was focused around the mouth of the slip, suggesting more peripheral use of the slip. In contrast, Northern Pike were found in the deeper central waters of Peter Slip in the fall, winter and spring, but were again concentrated at the mouth of the slip in the summer. This summer shift to the more open waters of the harbour was likely driven by increasing water temperatures in the slips (Supplementary Figure S2). Indeed, a focused study of Northern Pike in Toronto Harbour documented active selection of cooler waters (20 °C or less) during the summer (Peat et al., 2016).

In general, the hardened shore of the Toronto waterfront does not conform to what is typically thought of as Northern Pike habitat (i.e. vegetated littoral areas; Cook and Bergersen, 1988); however, many of the Northern Pike tagged for this study were captured in this region. Northern Pike are ambush predators, but more detailed studies of Northern Pike behaviour have identified several behavioural types (i.e. using a restricted area, moving among a group of favourite areas, using large areas with frequent shifts in habitat; Jepsen et al., 2001). Northern Pike captured along this hardened shoreline may therefore fall within this last category, suggesting that they have adapted to the new urban habitat conditions. Expanded tracking of Northern Pike within Toronto Harbour will help to assess the frequency of use of the hardened waterfront relative to more traditional Northern Pike habitats that are also present in the harbour (i.e. shallow vegetated areas in the Toronto Islands and eastern Outer Harbour).

Common Carp were present in the slips during all seasons except for winter, which is consistent with previous studies that found Common Carp tend to overwinter in deeper offshore areas (Penne and Pierce, 2008; Bajer and Sorensen, 2009). Similarly, their limited use of the slips in the other seasons is also not surprising given their preference for warm, shallow, vegetated areas, particularly for spawning in the early summer (Penne and Pierce, 2008). While portions of the Peter and Spadina slips meet some of these habitat requirements (i.e. presence of aquatic vegetation), they are still deeper than where Common Carp are typically found in the spring, summer, and fall (<2.5 m, Penne and Pierce, 2008).

In contrast to Common Carp, Walleye were primarily detected in the slips during winter and spring, although these detections were of short durations. While these detections occurred close to Walleye spawning season, it is unlikely that they were spawning in the slips given their preference for tributaries or offshore reefs (Olson and Scidmore, 1962; Strange and Stepien, 2007). In addition, Walleye seek spawning habitats with flowing water and silt-free substrates to ensure that their eggs will receive sufficient oxygen (Corbett and Powles, 1986); habitats unlikely to be found in slips. Detected Walleye were therefore likely moving past the slips into the Don River to attempt to spawn (confirmed by detections in a receiver deployed in the Don River; data not shown). Given current conditions in the Don River (i.e. high turbidity) further study is required to determine the success of Walleye spawning efforts in this system.

Tagged Largemouth Bass in Toronto Harbour were infrequently detected in the slips, despite being one of the target species of the rehabilitation works. Sub-optimal water temperatures in the slip likely partly explain the absence of Largemouth Bass since rarely were temperatures observed in their optimal range for growth (24–30 °C; Stuber et al., 1982; Supplementary Figure S2). Additionally, it is important to note that the majority of Largemouth Bass tagged for this study were captured in the Toronto Islands and Tommy Thompson Park (eastern Outer Harbour). This, paired with their generally small and restricted home ranges (<1.4 ha; Winter, 1977) suggests that home ranges of tagged Largemouth Bass in the present study may simply not encapsulate the slips. Indeed, electrofishing efforts over the past 10 years by the Toronto Region Conservation Authority have documented a small number of Largemouth Bass in both Peter (N = 12) and Spadina (N = 2) slips (R. Portiss, unpub. data). Collectively this suggests a low level of use of the slips, and preference for the warmer, shallower, and vegetated habitats available elsewhere in the harbour.

None of the other tagged species were frequently detected in the slips. White Sucker were sporadically detected in Parliament Slip during the spring, which likely coincided with their spawning migration into the nearby Don River where they were detected on an additional acoustic receiver (data not shown). None of the 14 tagged Brown Bullhead or 10 tagged Yellow Perch were detected in the slips. These species have been found to have limited home ranges (4.5–19.7 ha; Sakaris et al., 2005 and 0.5–2.2 ha; Fish and Savitz, 1983, respectively) and, given their initial tagging locations (Brown Bullhead in the Toronto Islands and Yellow Perch in Embayment C), their absence in the slips is not surprising.

Caveats

An initial goal for this study was to attempt to evaluate whether the rehabilitation works in the western slips had resulted in increased use by fishes. However, due to the lack of pre-rehabilitation positioning data, we were unable to determine whether the habitat rehabilitation works in Spadina and Peter slips resulted in increased use. A better study design would have incorporated a before-after control-impact (BACI) design (Conquest, 2000) but unfortunately this was not possible. In addition to the lack of a BACI design, in it is important to emphasize some fundamental differences in habitat between the western and eastern slips (as mentioned previously). First, water clarity in both Jarvis and Parliament slips is heavily influenced by high amounts of suspended sediments and nutrients flowing from the Don River relative to the other two slips, which are more influenced by Lake Ontario water that flows through the western gap (Hlevca et al., 2018). While reduced water clarity undoubtedly contributes to the observed differences among slips in the proportional coverage of SAV, its direct influence on Northern Pike is less clear. In a comparative study of Northern Pike in a clear water lake and turbid reservoir, Jepsen et al. (2001) found Northern Pike used non-vegetated areas more frequently and were in better condition in the turbid reservoir. This suggests that they can adapt and thrive in turbid conditions; however, given the option to use turbid un-vegetated habitat (eastern slips) or clear vegetated areas (western slips) in the present study, local Northern Pike spent more time in the latter.

It is unknown whether the habitat quality of Spadina and Peter slips were always superior (from a fish perspective) to Jarvis and Parliament prior to their rehabilitation or whether all four slips were equally degraded, with habitat rehabilitation causing increased fish usage. More replicate sites as well as longer study duration could help draw more robust conclusions, but these types of comparisons are by their very nature opportunistic and driven by the timeline for implementation of expensive rehabilitation projects. Given that a small proportion (0.18) of the total number of tagged fish visited the slips voluntarily and these spent only a short amount of time in any one slip, an expanded examination of habitat selection by these species across the entire harbour would help determine the regional importance of the slips. Additionally, the current study focused solely on a small subset of fishes common to the Toronto region, which may not best reflect those likely to occur in the slips. Indeed, some of the species most often encountered during electrofishing in these slips (i.e. Alewife [*Alosa pseudoharengus*], and Emerald Shiner [*Notropis atherinoides*]; R. Portiss, unpub. data.) could not be tagged due to tag size limitations. These types of species provide an important forage base within the harbour and the potential benefits to their populations of slip rehabilitation efforts should be evaluated. Similarly, an expanded evaluation of the use of these habitats by different life stages of our target species, particularly larval or juvenile stages, would contribute to an evaluation of the potential efficacy of in-slip rehabilitation efforts.

Conclusions

Our results support the notion that hardened shorelines provide only limited habitat for many freshwater fishes. Combining telemetry monitoring with other techniques such as community-level and population-level surveys (electrofishing, seine or fyke net, etc.) across life stages would likely provide a more complete assessment of the different fish species and life histories that use hardened shorelines. These features are abundant in both marine and freshwater ecosystems so placing their importance as habitat in a regional context will be essential for determining if and where habitat rehabilitation actions aimed at softening shorelines should be implemented.

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Supplemental material

Supplemental data for this article can be accessed on the publisher's website.

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