Fish Communities of the Toronto and Region Waterfront: Summary and Assessment 1989-2016

Prepared by Environmental Monitoring and Data Management

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Abstract

Fish community data collected over the 1989-2016 period throughout the Toronto regional waterfront using standardized electrofishing methods were examined in the context of multiple indicators of fish community health. An increase in species richness and diversity scores in the open coast and a decrease in tolerant species abundance are indicators of improving fish community health. A decline in overall catch and biomass values was observed in the 1990's, however; this was followed by nearly two decades of stable catch and biomass values, indicating the decline is likely a lake-wide trend. Inconclusive observations concerning the trophic and thermal group dynamics need to be investigated further. Increase in invasive Round Goby, while a marker of declining fish community health, is a reflection of a lake-wide trend. Collectively, the results do not indicate an overall positive direction in terms of the fish community health. However, there were more positive or neutral trends than negative. It's also worth noting that a number of substantial changes detected took place in the late 1990's-early 2000's. These results contribute information towards the Toronto and Region Remedial Action Plan actions and the ongoing waterfront aquatic habitat management and monitoring activities carried out by the Toronto and Region Conservation Authority and our partners.

Contents

List of Figures

List of Tables

List of Appendices

1 Introduction

The Toronto and region fish communities residing within the regional watersheds and 72 kilometres of the Lake Ontario waterfront are recognized as societal resources that provide recreation, food and income for area residents. Since fish are sensitive to a wide array of environmental variables (Karr and Dudley, 1981; Minns *et al*., 1994; Randall and Minns, 2002), long-term assessment of fish communities provides valuable information on the status and health of the Toronto waterfront urban ecosystem.

In this report, we summarize and qualitatively evaluate the changes in the Toronto waterfront fish community from 1989 to 2016 in the context of fish community changes related to environmental degradation. We also assess changes in the fish community diversity. The report provides an update to *The Fish Communities of the Toronto Waterfront: Summary and Assessment 1989-2005* (Dietrich *et al*., 2008) and contributes information towards actions under the Toronto and Region Remedial Action Plan (RAP). In particular, the report contributes information towards reassessing the status of Beneficial Use Impairment # 3, Degradation of Fish and Wildlife Populations, which was recommended for more extensive remedial action in 2016 (Kidd, 2016). It also provides valuable information for the ongoing waterfront aquatic habitat management and monitoring activities carried out by the Toronto and Region Conservation Authority (TRCA) and our partners.

2 Background

2.1 Toronto Waterfront Fish Habitat

The waterfront is part of the Lake Ontario ecosystem which comprises the interacting physical, chemical and biological components. These interactions take place within and between the watershed and the nearshore and offshore lake zones. The nearshore zone includes the shallower exposed coastal zone and embayments, and the offshore zone is the main body of the Lake (Stewart *et al.,* 2013).

Toronto waterfront is located within the nearshore zone, which consists of three essential types of nearshore habitat: embayments, eastuaries and open coast. These habitat types are defined by physiographic structure, exposure to open lake and watershed conditions. These habitat types are all interconnected despite having unique characteristics. The degree of their interconnectedness varies across space and time, dependent on the coastal processes, watershed conditions, aquatic species mobility and movement patterns, and anthropogenic influences. Each type of habitat is described in the sections below.

2.1.1 Open Coast Habitats

Shorelines exposed to the open lake dominate the Toronto waterfront. These are coldwater habitats subjected to intense wave action, currents and water exchange, resulting in production of biota that are adapted to these conditions. Hypolimnetic upwellings of cold sub-surface waters from the offshore zone are common, leading to substantial temperature fluctuations.

In the past, open coast habitats were extensively utilized by spawning coldwater fishes such as Lake Trout and Lake Whitefish (Goodyear *et al.,* 1982 in Dietrich *et al*., 2008). As habitat quality declined over the last century and a half and native salmonid stocks were virtually eliminated, this is no longer the case. However, open coast shoreline still serves to connect other habitats along the waterfront and provides foraging habitat for a number of species (e.g., Smallmouth Bass) if the habitat quality is high enough to support forage fish. The longest stretches of open coast include the Scarborough waterfront and Port Union shoreline.

Open coast of Scarborough

2.1.2 Embayment Habitats

Embayment habitats are sheltered from the open lake, having been formed by coastal deposition processes enclosing bodies of water (see Dietrich *et al*., 2008 for details). In recent decades, manmade embayments such as waterfront parks and marinas have been created.

Embayments provide calm waters and thermal refuge to fish. Though variable in terms of size, depth and shape, they are characterized by the presence of soft sediments that typically support significant amounts of aquatic vegetation. Embayments provide habitat for all life stages of fish species, including spawning, nursery and foraging habitat. Species such as Pumpkinseed, Bluegill and Yellow Perch are commonly found in embayment habitats.

Local examples of this habitat include the embayments of Tommy Thompson Park, areas in the inner Toronto Islands, marinas, and Ashrbidge's Bay's Coastworth Cut.

EMBAYMENT HABITAT AT ASHBRIDGES BAY

2.1.3 Estuary Habitats

Estuaries are habitats associated with the lower reaches of streams and rivers entering Lake Ontario. In other words, they represent a physical connection between lotic and lentic ecosystems.

Estuary habitats are essential to the function of the entire waterfront. Healthy estuaries are very productive because they hold nutrients from the watersheds and provide stable thermal conditions. Backwater lagoons in estuaries are principal areas of production and provide a variety of habitats, including those used for spawning. Estuaries are critical for species that need both open waters and riverine habitats for their life cycle stages. Healthy, productive estuaries provide essential habitat to many species of fish, including basses and Northern Pike.

There are seven estuaries associated with the major streams and rivers along the Toronto waterfront: Etobicoke Creek, Mimico Creek, Humber River, Don River, Highland Creek, Rouge River and Petticoat Creek.

ROUGE RIVER ESTUARY

2.2 Habitat Alteration

Aquatic habitat along the Toronto waterfront has been subject to major alterations, particularly as a result of shoreline modifications, watershed urbanization and invasive species introduction. These processes are highlighted to provide context for the review of long-term fish community data presented in this report, as environmental degradation is often a direct result of habitat alteration.

Common historical shoreline modifications included dredging, lake filling and shoreline hardening. These actions disrupted natural coastal processes such as sediment transport, current patterns and water exchange. Watershed urbanization led to reduced water and sediment quality due to increased inputs of fine sediments, nutrients and chemical pollutants. Invasive aquatic species such as dreissenid mussels (zebra and quagga mussels), crustaceans (spiny water flea) and fish (Round Goby) affected the Lake Ontario food web, and, in some cases, water and habitat quality.

While some of the negative impacts caused by these alterations have been mitigated by specific resource management activities and rehabilitation efforts, significant impacts on the waterfront fish and fish habitat have been made, leading to long-lasting systemic changes.

3 Methods

3.1 Fish Community Sampling

Electrofishing surveys were conducted during the ice-free season from 1989 to 2016 at 31 different sites (stations) along the 72 kilometres of shoreline that falls within TRCA jurisdiction (Figure 1).

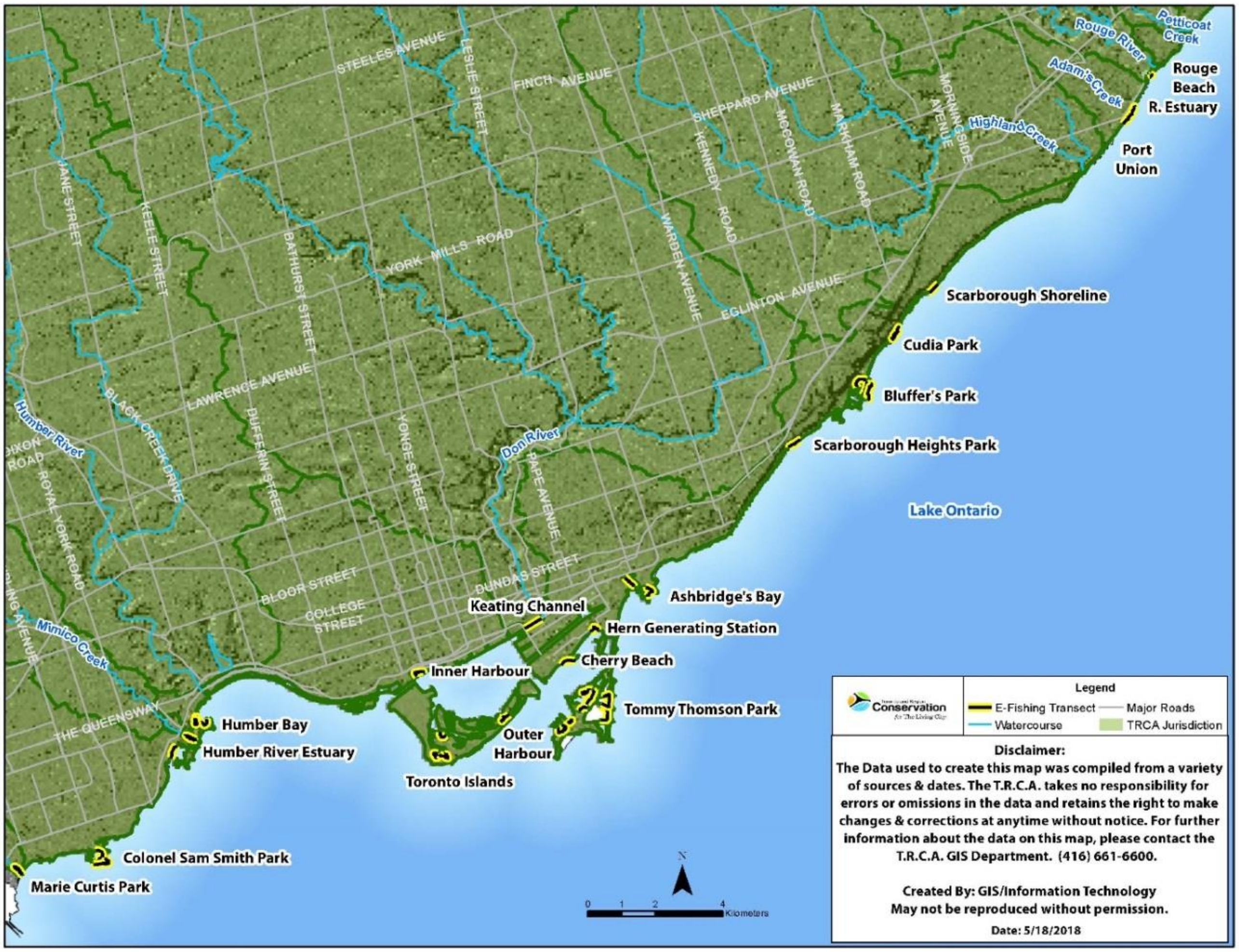

FIGURE 1. MAP OF THE TORONTO WATERFRONT ILLUSTRATING THE LOCATIONS OF THE ELECTROFISHING SITES SURVEYED BY THE TORONTO AND REGION CONSERVATION AUTHORITY FROM 1989 TO 2016.

Electrofishing sampling events were conducted primarily when weather conditions were favorable. Surveys were conducted using a 5.5-metre Smith-Root electrofishing boat and following a standardized electrofishing protocol established by the TRCA for the Toronto RAP and other monitoring purposes (Valere, 1996). Generally, stations were sampled for approximately 1,000 seconds. A five-person crew performed the sampling with one person driving the boat and operating the electrofisher, two people netting fish, and two people emptying the nets into the boat's live-well.

Captured fish were identified to species level and measured for total length and weight. Environmental conditions at the site and details about the electrofishing procedure used were recorded, including start time of sample, electrofishing duration, water temperature, air temperature, substrate (visual inspection to estimate percentage composition of sand, cobble, gravel, boulder), and water depth.

3.2 Sampling Site Selection

As mentioned above, 31 sites were included in the analysis. Sampling sites were selected based on the availability of long-term fish community data and represented the three aquatic habitat types found along the Toronto waterfront: embayment, estuary and open coast (see Section 2.1). A single sampling event was referred to as "transect". Only transects with electrofishing seconds greater than or equal to 400 and less than or equal to 1,200 were considered. The vast majority of transects were 1,000 seconds.

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Table 1 shows the number of stations visited each year and the number of transects conducted for each year and habitat type from 1989 to 2016. A total of 19 stations were included in the embayment habitat type analyses. Nine stations were included in the open coast habitat. Estuary habitat was the least sampled habitat type with only three stations, which is mainly due to the fact that there are few estuaries present along the Toronto waterfront. Overall, the number of sampling events for each habitat type was sufficient to characterize the fish communities by habitat type.

TABLE 1. TOTAL NUMBER OF STATIONS VISITED AND NUMBER OF TRANSECTS PERFORMED FOR EACH HABITAT TYPE ANNUALLY FROM 1989 TO 2016.

Year	Embayment		Estuary		Open Coast	
	Number of Stations	Number of Transects	Number of Stations	Number of Transects	Number of Stations	Number of Transects
1989	15	28	3	6	3	5
1990	14	27	3	6	4	6
1991	15	36	3	5	5	6
1992	15	32	3	5	4	4
1993	17	36	3	6	5	7
1994	14	24	1	1	4	4
1995	14	22	1	2	1	1
1996	8	10	0	0	1	1
1997	12	16	2	2	2	2
1998	17	31	3	4	5	7
1999	13	18	2	2	4	6
2000	18	53	3	4	2	2
2001	13	25	2	2	3	5
2002	18	30	3	5	4	5
2003	17	36	3	20	6	7
2004	18	42	3	15	6	14
2005	17	31	3	9	8	14
2006	18	43	3	14	9	20
2007	17	34	3	15	9	21
2008	18	32	3	15	8	16
2009	18	45	3	17	7	12
2010	16	37	3	12	9	17
2011	15	35	3	12	8	19
2012	13	30	3	12	9	19
2013	16	33	3	8	8	22
2014	15	30	2	7	8	27
2015	14	30	2	8	9	29
2016	14	34	2	7	9	31

3.3 Data Treatment

3.3.1 Assessment Framework

The following six assumptions regarding fish communities' change with environmental degradation based on Fausch *et al.* (1990) were investigated for the Toronto waterfront fish communities:

(1) The number of native species and of those in specific taxa or habitat guilds declines
This assumption was investigated via examining native species richness values over time.

(2) Fish abundance generally declines
Fish abundance dynamics were investigated via examining catch per unit effort (CPUE) and biomass per unit effort (BPUE) values over time (CPUE and BPUE calculation methods outlined below).

(3) The proportion of individuals that are members of tolerant species increases
This assumption was investigated via examining the proportion (see below for calculation method) of Common Carp and White Sucker, tolerant benthivores often dominating degraded environments (Karr and Dudley 1981, Miller *et al.,* 1988, Scott and Crossman 1973, Fausch *et al.,* 1990 in Dietrich *et al*., 2008)

(4) The proportion of trophic specialists such as insectivores and top carnivores declines,
(5) The proportion of trophic generalists, especially omnivores, increases
To investigate trophic group dynamics, CPUE of specialist, piscivore and generalist species were examined. Further, CPUE values of native top-order piscivores Northern Pike, Smallmouth Bass, Largemouth Bass and Walleye were assessed, as piscivore abundance is a key factor in maintaining a balanced fish community in eastern Lake Ontario (Hurley and Christie 1977 in Dietrich *et al.,* 2008).
and

(6) The proportion of individuals that are members of introduced species increases
To evaluate the change in native versus non-native species dynamics, native and non-native species CPUE values over time were examined. Further, abundance dynamics of two non-native species – Alewife and Round Goby – were examined via assessing their CPUE values over time.

In addition, potential changes in fish community structure with respect to temperature preference were investigated via examining average annual biomass for each thermal guild (cold-, cool- and warmwater).

Finally, fish community diversity was assessed using the reciprocal of the Simpson's diversity index (Simpson's $\frac{1}{D}$). Species diversity is linked to food web stability, ecosystem functioning and environmental quality in general.

As the Toronto waterfront is part of the Lake Ontario ecosystem, local fish community cannot be viewed in isolation. To provide context for the local fish community assessment, Index of Biotic Integrity (IBI) scores for other parts of the Lake – Hamilton Harbour and Bay of Quinte, in particular – were used.

Fish-based IBI developed by Minns *et al.* (1994) is a way of assessing ecosystem health in the littoral area of the Great Lakes. IBI uses fish assemblages to reflect the multiple factors (biotic and abiotic) affecting the fish and generally represents the biological integrity of an area (Minns *et al.*, 1994).

Biological integrity was defined by Karr and Dudley (1981) as the ability of an area to support a balanced community of organisms having a species composition and function comparable to that of the natural habitat of the region (Minns *et al.*, 1994). IBI scores for use in this report were provided by The Department of Fisheries and Oceans Canada (DFO). Data were provided to TRCA by the DFO for two sites: Hamilton Harbour (considered degraded) and Bay of Quinte (considered relatively unaffected). The Hamilton Harbour dataset included 15 years of data collected between 1988 and 2016, whereas Bay of Quinte dataset was limited to seven years of data collected between 1989 and 2016.

This report presents a qualitative examination of species richness values, CPUE, BPUE, diversity scores and IBI scores. There was variation in the number of transects sampled and the frequency of sampling within each year. In general, there were more transects sampled and sampling occurred more frequently between 2003 and 2016. These variations were not accounted for in the analysis and as such, temporal trends were interpreted qualitatively.

3.3.2 Data Grouping and Calculations

To facilitate the assessment of fish community trends and changes over the 1989-2016 period based on the framework described above, the following data groupings and calculations were performed:

Species-specific fish data were grouped based on whether the fish captured were native or non-native to Lake Ontario (Scott and Crossman, 1998), their thermal guild (cold, cool or warm) (Coker *et al*., 2001; Eakins, 2018) and their trophic (feeding) guild (Minns *et al.*, 1994). Trophic guilds of species not included in Minns *et al.* (1994) were determined based on the fish diet information provided in Coker *et al.*, 2001: a fish species with varied diet was considered a generalist, a species with fairly restricted diet was considered a specialist, and a species that had a high preference for fish as a food source was considered a piscivore.

Catch per unit effort (CPUE) was calculated for each transect. The number of fish per transect was divided by the transect length (in seconds) and then multiplied by 1,000 to calculate the number of fish captured per 1,000 electrofishing seconds. This allowed comparisons across all transects irrespective of sampling duration. Transects with no fish caught were also included in the analysis. CPUE was calculated per site by summing all the transects completed at a given site, in a given year, and dividing the total number of fish caught at the site by the total number of electrofishing seconds; this number was then averaged across all sites within each habitat type, for each year. Biomass data were calculated in the same manner, across stations, habitat type, and year. Biomass data were presented as the mean biomass (kg) per 1,000 electrofishing seconds (biomass per unit effort, or BPUE). For species- or guild-specific analysis only the catch data for the group of interest were used and means were calculated as above.

Degradation tolerant species proportion was calculated as follows:

> Degradation tolerant species proportion (%) for a given year = [(White Sucker catch + Common Carp catch) / Total catch] x 100

The reciprocal of the Simpson's diversity index (Simpson's $\frac{1}{D}$) for each site was calculated and averaged across the sites for each habitat type, each year. It incorporates species richness and evenness and describes the probability that a second individual chosen at random from a population will be the same as the first. Higher values indicated higher diversity.

$$p_i = \frac{n_i}{N_T}$$

$$D = \sum {p_i}^2$$

$$Reciprocal\ SDI = \frac{1}{D}$$

Where n_i is the number of individuals of the i^{th} species, N_T is the total number of individuals in the sample, and p_i is the proportion of individuals of one particular species found.

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4 Results

4.1 Species Richness and Fish Community Composition by Family

From 1989-2016 a total of 60 species were caught including 46 native species and 14 non-native species (Table 2). The majority of species (27) were classified as coolwater, 21 were considered warmwater and 12 were coldwater species. Specialist species were the most numerous (35 species), followed by piscivores (14 species) and generalists (11 species).

Table 2. Origin, common name, thermal guild, and trophic group for all species present in Toronto waterfront electrofishing database from 1989 to 2016.

Origin	Thermal Guild	Species Name	Common Name	Trophic Group
Native	Cold	*Salmo salar*	Atlantic Salmon	Piscivore
		Lota lota	Burbot	Piscivore
		Couesius plumbeus	Lake Chub	Specialist
		Salvelinus namaycush	Lake Trout	Piscivore
		Coregonus clupeaformis	Lake Whitefish	Specialist
		Percopisus omiscomaycus	Trout-perch	Specialist
	Cool	*Anguilla rostrata*	American Eel	Piscivore
		Fundulus diaphanus	Banded Killifish	Specialist
		Pomoxis nigromaculatus	Black Crappie	Specialist
		Culaea inconstans	Brook Stickleback	Specialist
		Luxilus cornutus	Common Shiner	Specialist
		Semotilus atromaculatus	Creek Chub	Specialist
		Notropis atherinoides	Emerald Shiner	Specialist
		Dorosoma cepedianum	Gizzard Shad	Specialist
		Notemigonus crysoleucas	Golden Shiner	Generalist
		Nocomis biguttatus	Hornyhead Chub	Generalist
		Etheostoma nigrum	Johnny Darter	Specialist
		Etheostoma nigrum x Etheostoma olmstedi	Johnny Darter x Tesselated Darter	Specialist
		Rhinichthys cataractae	Longnose Dace	Specialist
		Cottus bairdii	Mottled Sculpin	Specialist
		Margariscus margarita	Northern Pearl Dace	Generalist
		Esox lucius	Northern Pike	Piscivore
		Etheostoma caeruleum	Rainbow Darter	Specialist
		Ambloplites rupestris	Rock Bass	Specialist
		Micropterus dolomieu	Smallmouth Bass	Piscivore
		Notropis hudsonius	Spottail Shiner	Specialist
		Gasterosteus aculeatus	Threespine Stickleback	Specialist
		Sander vitreus	Walleye	Piscivore
		Catostomus commersoni	White Sucker	Specialist
		Perca flavescens	Yellow Perch	Specialist
	Warm	*Lepomis macrochirus*	Bluegill	Specialist
		Pimephales notatus	Bluntnose Minnow	Generalist
		Amia calva	Bowfin	Piscivore

Origin	Thermal Guild	Species Name	Common Name	Trophic Group
Native	Warm	*Labidesthes sicculus*	Brook Silverside	Specialist
		Ameiurus nebulosus	Brown Bullhead	Generalist
		Pimephales promelas	Fathead Minnow	Generalist
		Aplodinotus grunniens	Freshwater Drum	Specialist
		Lepomis cyanellus	Green Sunfish	Specialist
		Micropterus salmoides	Largemouth Bass	Piscivore
		Percina caprodes	Logperch	Specialist
		Lepisosteus osseus	Longnose Gar	Piscivore
		Lepomis gibossus	Pumpkinseed	Specialist
		Moxostoma macrolepidotum	Shorthead Redhorse	Specialist
		Cyprinella spiloptera	Spotfin Shiner	Specialist
		Morone chrysops	White Bass	Specialist
		Ameiurus natalis	Yellow Bullhead	Generalist
Non-Native	Cold	*Alosa pseudoharengus*	Alewife	Specialist
		Salmo trutta	Brown Trout	Piscivore
		Oncorhynchus tshawytscha	Chinook Salmon	Piscivore
		Oncorhynchus kisutch	Coho Salmon	Piscivore
		Osmerus mordax	Rainbow Smelt	Specialist
		Oncorhynchus mykiss	Rainbow Trout	Specialist
	Cool	*Neogobius melanostomus*	Round Goby	Specialist
		Scardinius erythrophthalmus	Rudd	Generalist
		Petromyzon marinus	Sea Lamprey	Specialist
	Warm	*Cyprinus carpio*	Common Carp	Generalist
		Carassius auratus	Goldfish	Generalist
		Cyprinus carpio x Carassius auratus	Goldfish x Common Carp	Generalist
		Morone americana	White Perch	Specialist
		Morone saxatilis x Morone chrysops	Wiper	Piscivore

Native fish species richness by habitat type and overall native species richness are shown in Figure 2. Species richness was highest in embayment habitats, followed by open coasts and estuaries. Embayment and estuary habitats had relatively stable species richness over time, whereas open coast habitat species richness was higher in 2000's and 2010's than in 1990's. Yearly species richness values are tabulated in Appendix 2.

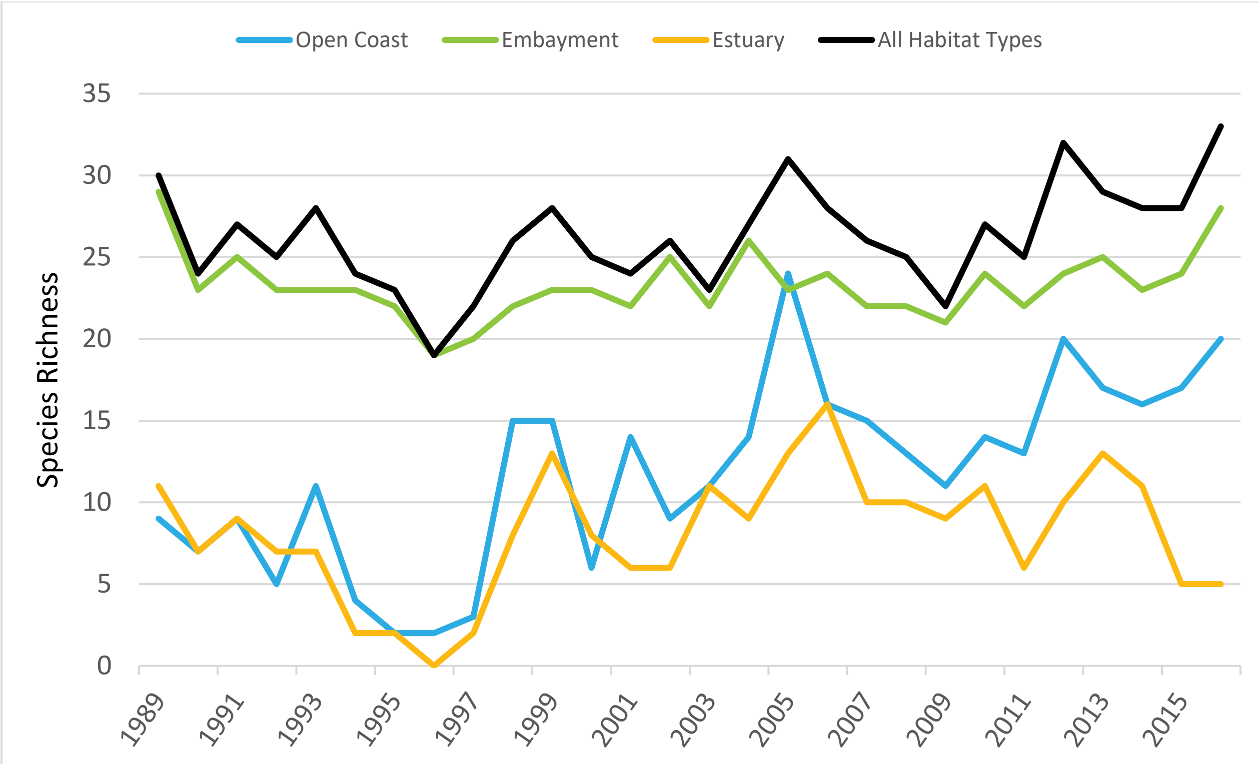

FIGURE 2: NATIVE FISH SPECIES RICHNESS BY HABITAT TYPE AND FOR ALL HABITAT TYPES COMBINED FOR THE TORONTO WATERFRONT, 1989 TO 2016.

SMALLMOUTH BASS

Catastomidae (suckers, primarily White Sucker) and Cyprinidae (minnows, primarily Common Carp) comprised most of the fish community by biomass in all habitat types (Figure 3). Salmonids and clupeids (Gizzard Shad) were prominent, too.

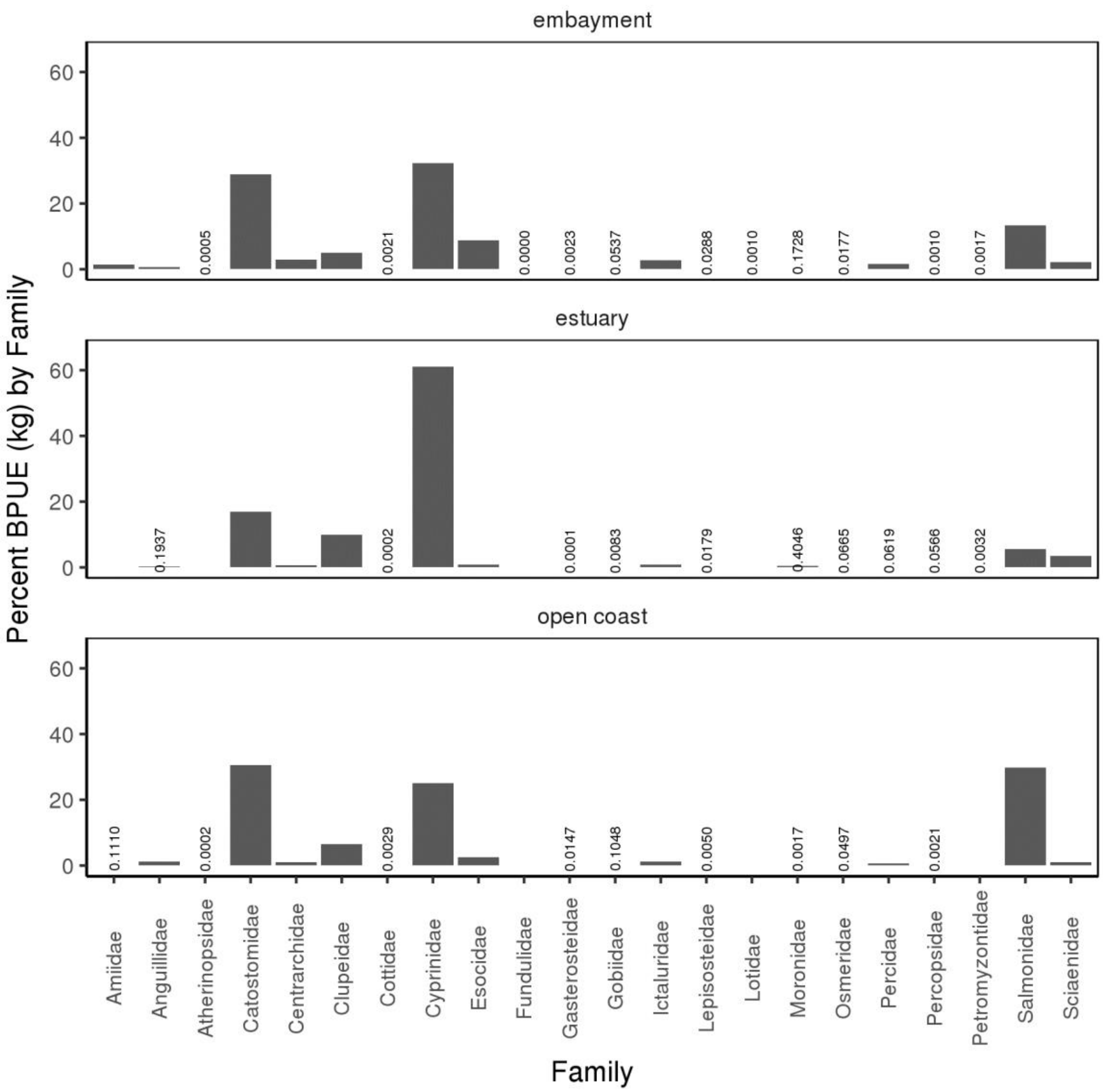

FIGURE 3. FAMILY-SPECIFIC PERCENT (%) COMPOSITION OF THE TORONTO WATERFRONT FISH COMMUNITY BASED ON BIOMASS IN KILOGRAMS FOR EACH HABITAT TYPE POOLED FROM 1989 TO 2016.

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4.2 Fish Abundance Dynamics

Based on the CPUE values observed throughout the 1989-2016 period, fish were more abundant in estuaries and embayments than in the open coast habitat (Figure 4). Estuaries had the highest CPUE values observed with the highest values occurring in the 1990's.

All CPUEs by habitat type observed in the 2000's were lower than the values observed in the 1990's. With a few exceptions, CPUE in estuary habitat in the 1989-2000 period was between 100 and 250, and between 50 and 150 in open coast habitat for the same years. From 2001 onward the average CPUE was between 0 and 200 in estuary and between 0 and 120 in open coast. Embayment CPUE remained most stable throughout the monitoring period, though most yearly values exceeded 100 in the 1990's and were below 100 in the 2000's.

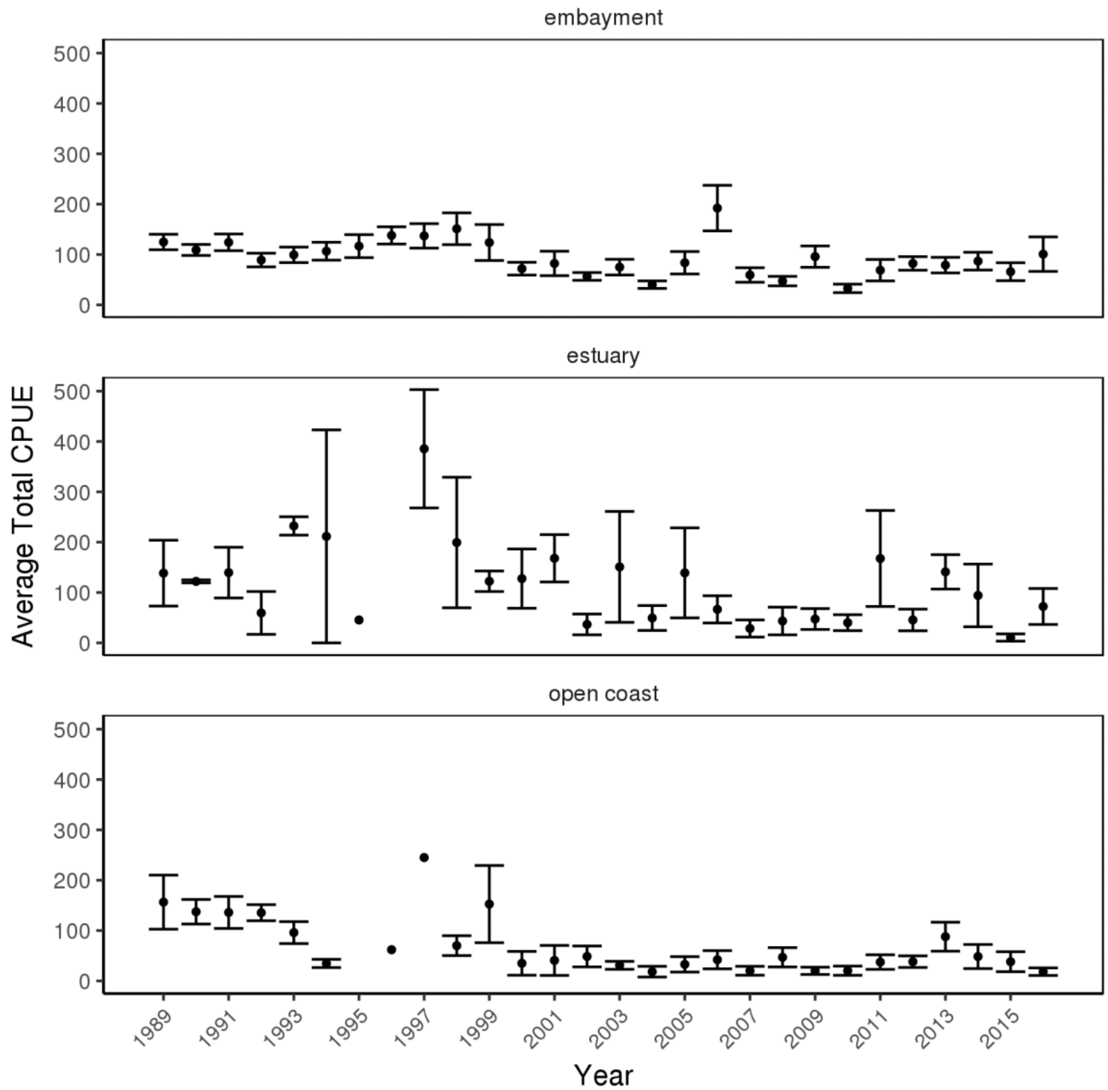

FIGURE 4: AVERAGE ANNUAL CATCH OF ALL SPECIES PER 1,000 SECONDS OF ELECTROFISHING (± STANDARD ERROR) FOR EACH HABITAT TYPE IN THE TORONTO WATERFRONT FROM 1989 TO 2016.

Similar to CPUE, 2000's BPUE in each habitat type was generally lower than 1990's BPUE (Figure 5). BPUE in embayments and estuaries was generally higher than in the open coast. Most estuary BPUE values observed in the 1990's were between 24 and 43 kg and decreased to 4 to 22 kg from 2002 onward. Embayment BPUE ranged between 24 and 50 kg in the 1990's and decreased to 9 to 22 kg from 2000 onward. As with the other two habitat types, open coast has remained relatively consistent in average BPUE since 2002, with values ranging between 4 and 14. This was very different from the first six years of monitoring when open coast BPUE varied between 18 and 71 kg.

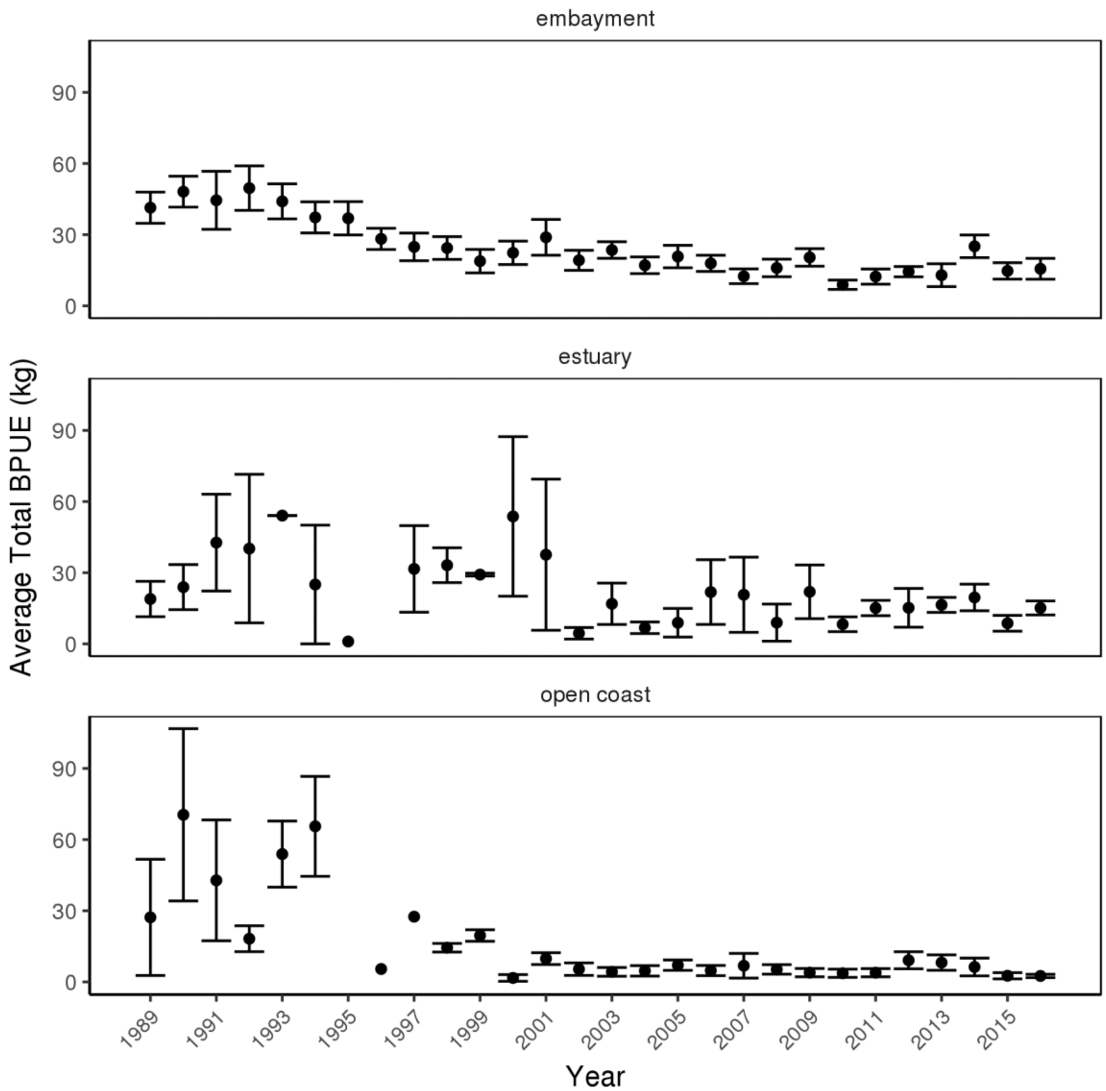

FIGURE 5. AVERAGE ANNUAL BIOMASS IN KILOGRAMS FOR ALL SPECIES PER 1,000 SECONDS OF ELECTROFISHING (± STANDARD ERROR) FOR EACH HABITAT TYPE IN THE TORONTO WATERFRONT FROM 1989 TO 2016.

4.3 Tolerant Species

Similar to abundance dynamics of all species combined, degradation tolerant Common Carp and White Sucker CPUE values observed in the 2000's were lower than those observed in the 1990's in all habitat types (Figure 6). Embayment habitat CPUE was between 20 and 40 from 1989-1995, dropping to below 20 thereafter. There was an increase in CPUE variability in estuaries between 1993 and 1999, with a minimum CPUE of 0 in 1995 and a maximum of 144 in 1997. These highly variable values were likely due to the small number of transects completed in those years. Post-1999 estuary CPUE values did not exceed 30. Open coast habitat CPUE varied between 15 and 50 from 1989-1994, and stabilized to between 0 to 15 after 1995.

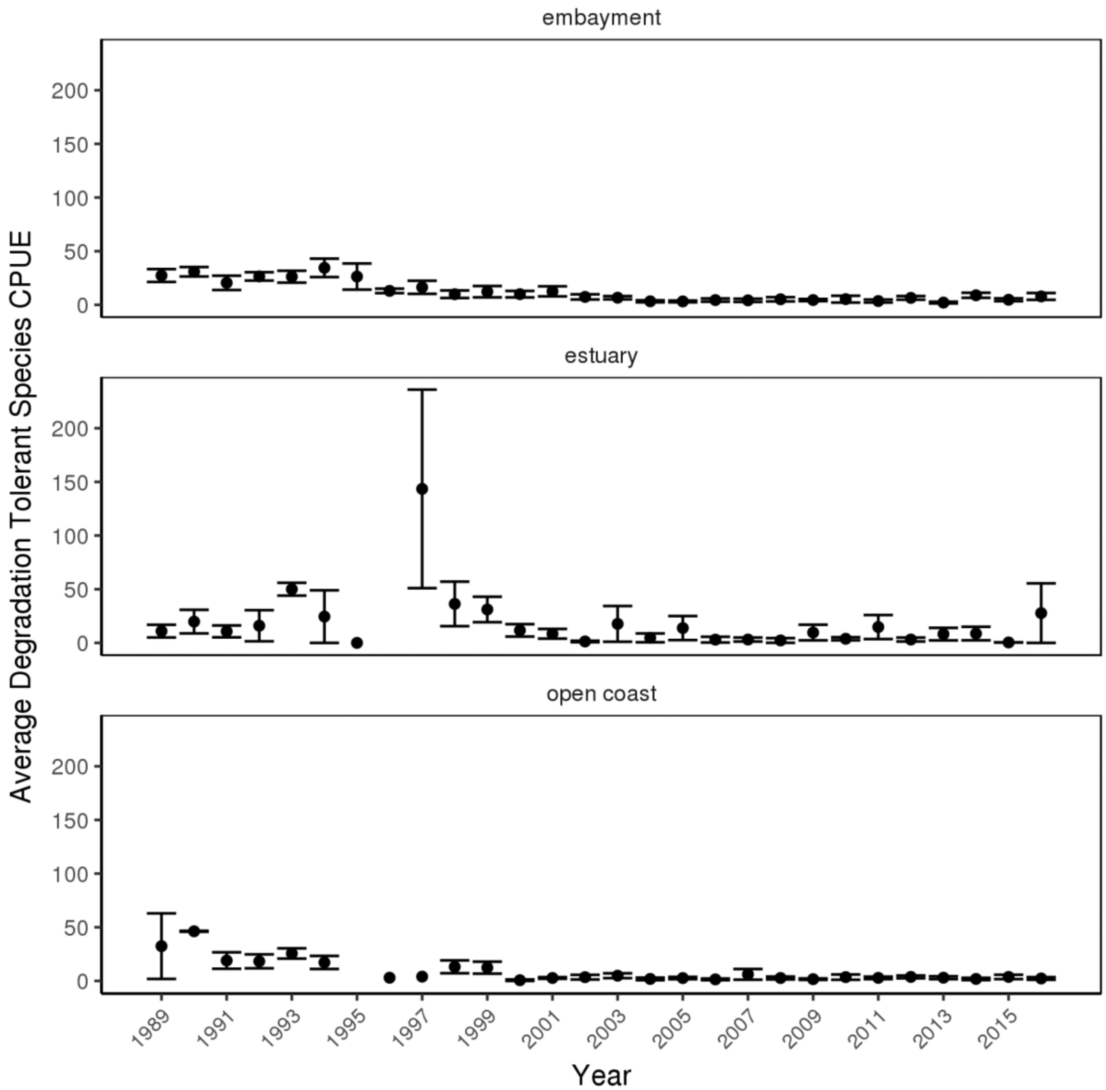

FIGURE 6. AVERAGE ANNUAL CATCH OF DEGRADATION TOLERANT SPECIES (WHITE SUCKER AND COMMON CARP) PER 1,000 SECONDS OF ELECTROFISHING (± STANDARD ERROR) FOR EACH HABITAT TYPE IN THE TORONTO WATERFRONT FROM 1989 TO 2016.

COMMON CARP

The proportion of degradation tolerant species decreased in each habitat type since 1990's (Figure 7). This was most evident in embayments where composition of degradation tolerant species was between 15 and 30 percent of the total catch from 1989-1995. Since 1995 the composition remained fairly consistent, never surpassing 15 percent. Estuaries had more variable percent composition across the entire 1989-2016 time period. Annual proportions in estuaries appeared to be consistently low between 2000 and 2015, rarely exceeding 10 percent; however, the 2016 proportion reached 28 percent, the second highest composition recorded for that habitat. Proportion of degradation tolerant species in the open coast habitat was variable despite the fairly consistent CPUE from 1996 onward.

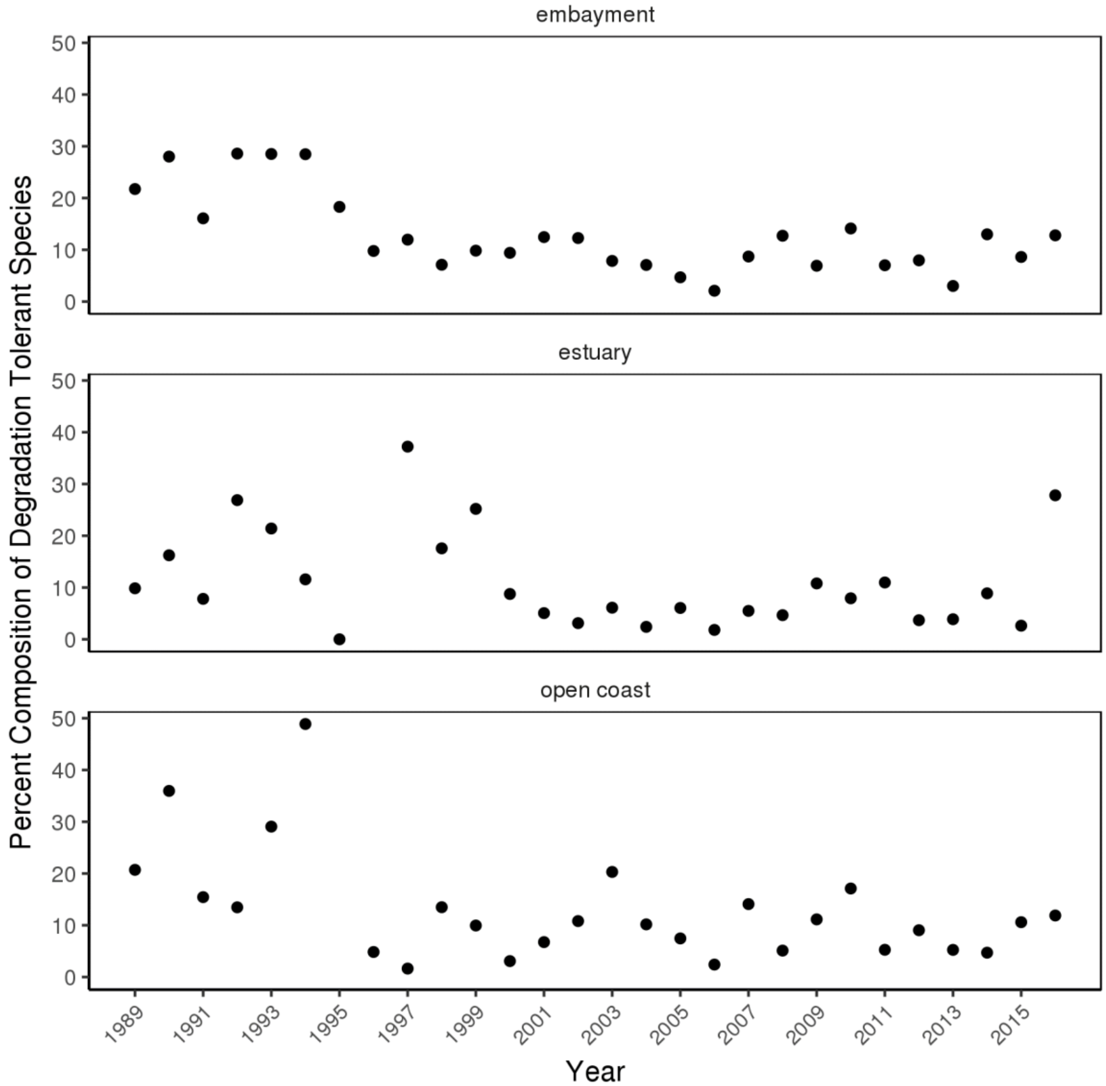

FIGURE 7. DEGRADATION TOLERANT SPECIES (WHITE SUCKER AND COMMON CARP) ANNUAL PERCENT COMPOSITION OF TOTAL CATCH FOR EACH HABITAT TYPE IN THE TORONTO WATERFRONT FROM 1989 TO 2016.

4.4 Native versus Non-native Species Abundance Dynamics

Native species CPUE was generally highest in embayments, followed by estuaries and open coast (Figure 8). Though yearly CPUE values varied in all habitat types (particularly estuary habitats), native species catch remained fairly stable over the years. CPUEs in all habitats were generally below 100. Most of embayment CPUEs were between 20 and 68, estuary CPUEs between 7 and 95, and open coast CPUEs between 4 and 48.

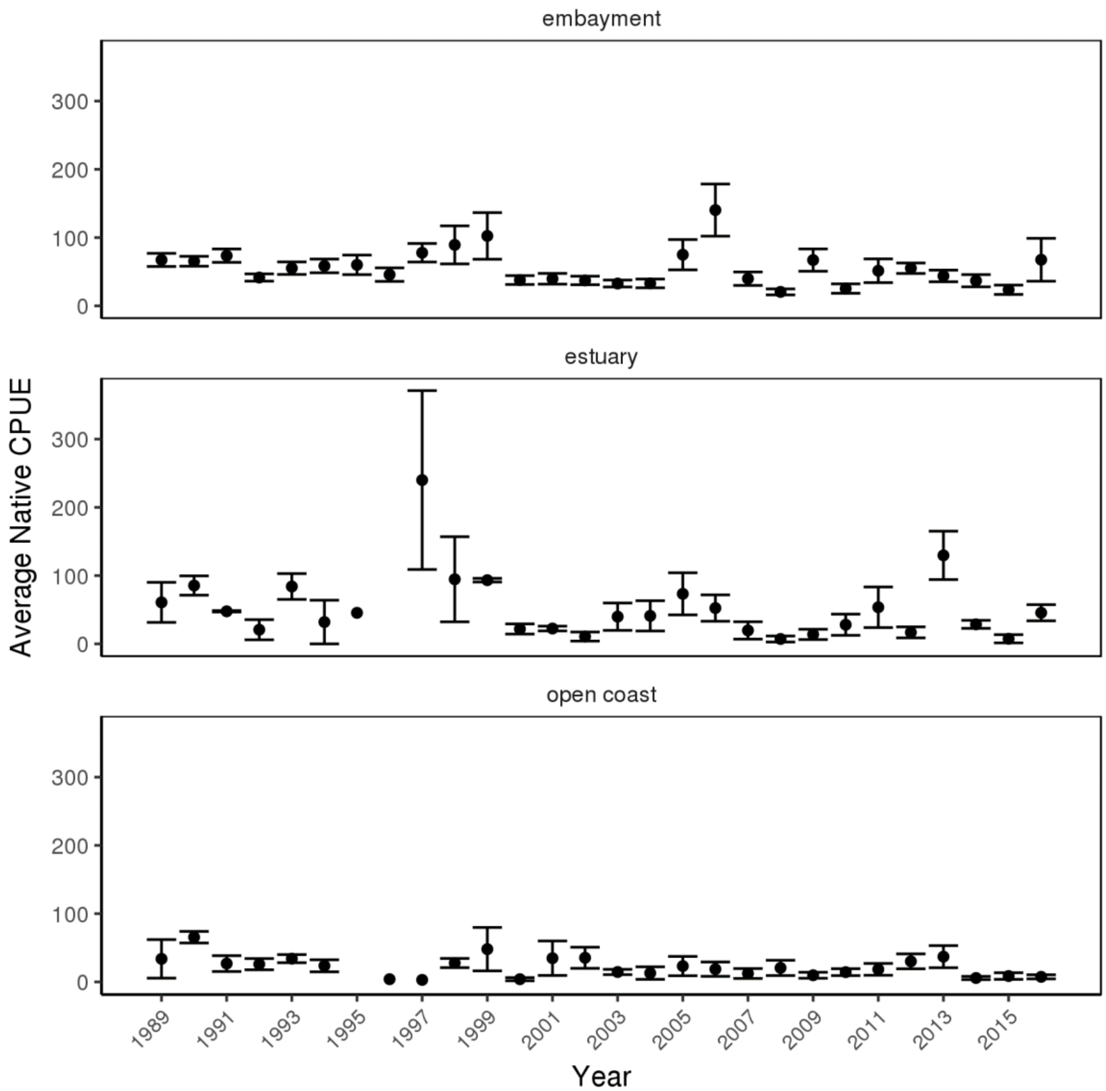

FIGURE 8. AVERAGE ANNUAL CATCH OF NATIVE SPECIES PER 1,000 SECONDS OF ELECTROFISHING (± STANDARD ERROR) FOR EACH HABITAT TYPE IN THE TORONTO WATERFRONT FROM 1989 TO 2016.

The non-native species CPUE did not follow the same pattern over time. There was a lot more variability in the average annual CPUE values observed, particularly in estuaries and open coast habitats (Figure 9). Embayment CPUEs varied least: all CPUE values were between 7 and 57. Estuary CPUEs varied most, with high (as high as 180 in 1994) and low (as low as 0 in 1995) values observed in alternating years, especially during 1990's and early 2000's, followed by lower CPUEs (generally below 65) occurring more frequently from approximately 2002 onward. Open coast CPUEs varied most within the first 11 years of sampling (as low as 7 in 1994 to as high as 242 in 1997), with the magnitude of variation decreasing from 2000 onward where all values were between 5 and 51. Both estuary and open coast non-native species CPUEs were generally higher in 1990's. Non-native species CPUE pattern over time is similar to that of Alewife, a non-native fish whose temporal abundance trends are shown in Figure 10.

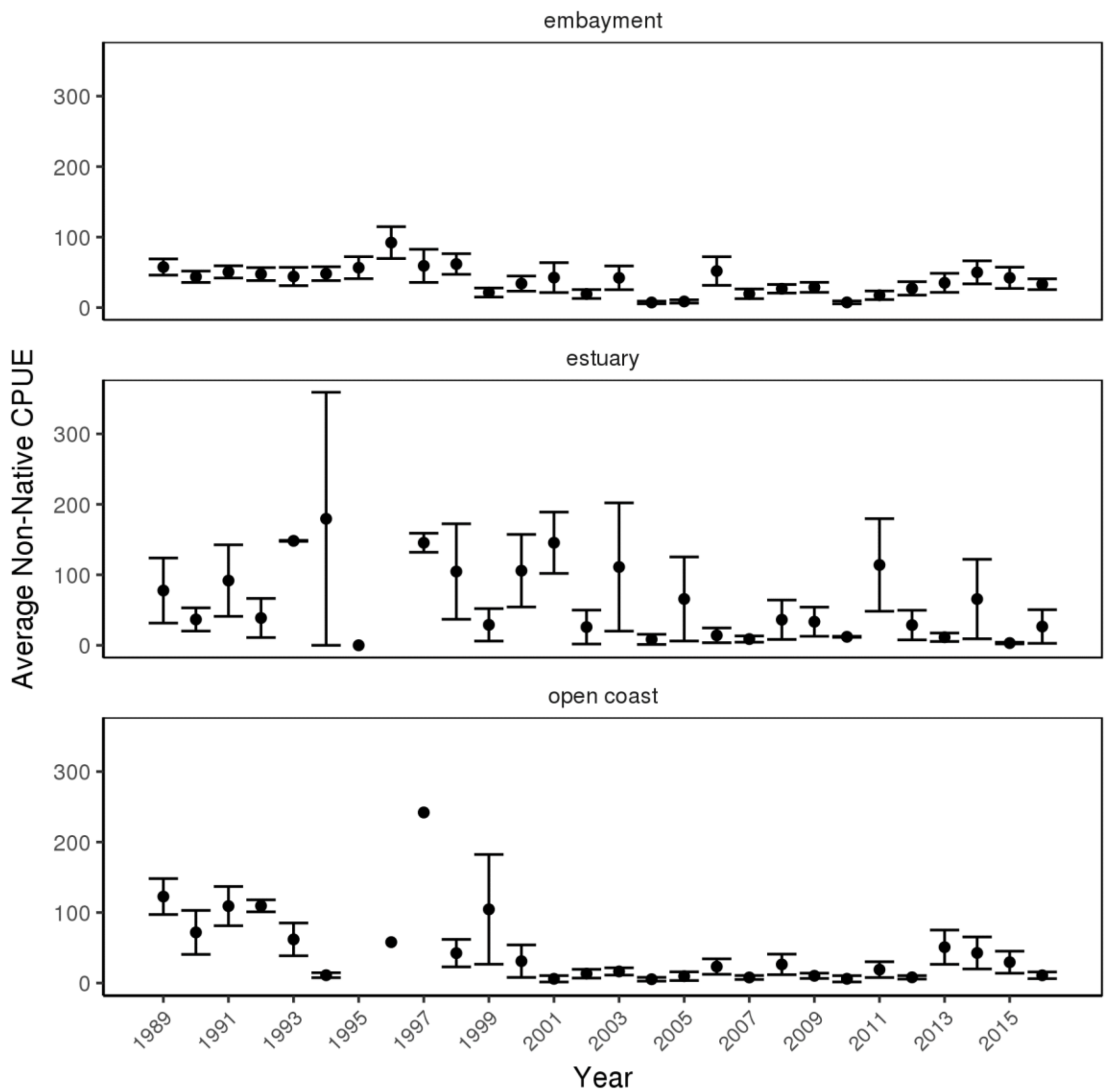

FIGURE 9. AVERAGE ANNUAL CATCH OF NON-NATIVE SPECIES PER 1,000 SECONDS OF ELECTROFISHING (± STANDARD ERROR) FOR EACH HABITAT TYPE IN THE TORONTO WATERFRONT FROM 1989 TO 2016.

Alewife catch was fairly stable in the embayments, and displayed substantial yearly variation in estuaries and open coast (Figure 10). Most embayment CPUEs ranged between 17 and 46. Estuary CPUEs were as low as 0 and as high as 167, with the majority of high values occurring in the 1990's and early 2000's. Open coast CPUEs were also highest in the 1990's, frequently exceeding 50, whereas post-2001 CPUEs were mostly below 50.

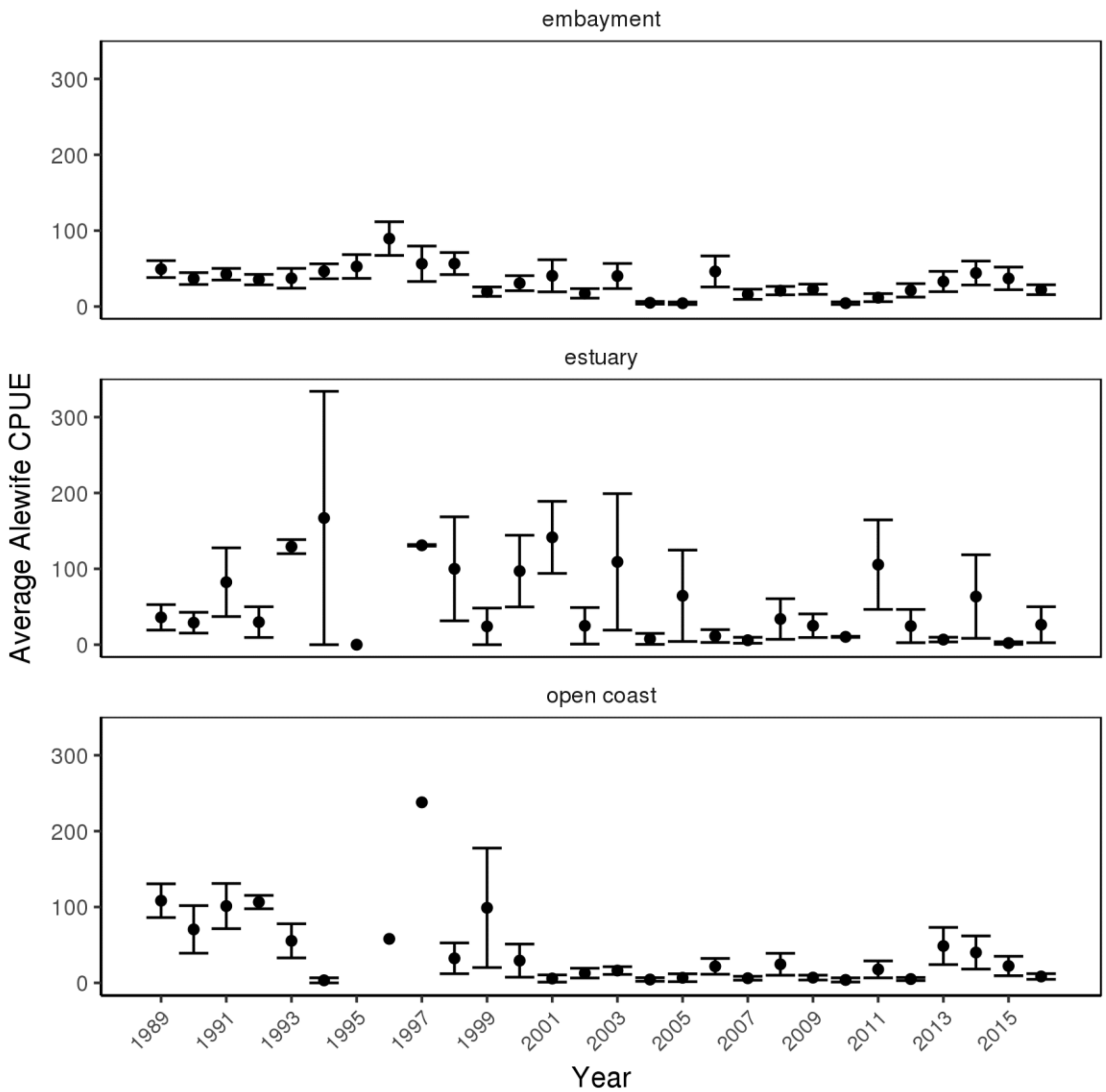

FIGURE 10. AVERAGE ANNUAL CATCH OF ALEWIFE PER 1,000 SECONDS OF ELECTROFISHING (± STANDARD ERROR) FOR EACH HABITAT TYPE IN THE TORONTO WATERFRONT FROM 1989 TO 2016.

Round Goby was not detected in the electrofishing surveys of the waterfront habitats until early 2000's (Figure 11). Since then, Round Goby CUPEs were highest in the embayments (0.4 - 7), followed by open coast (0.1 - 6) and estuaries (0.1 – 2.3).

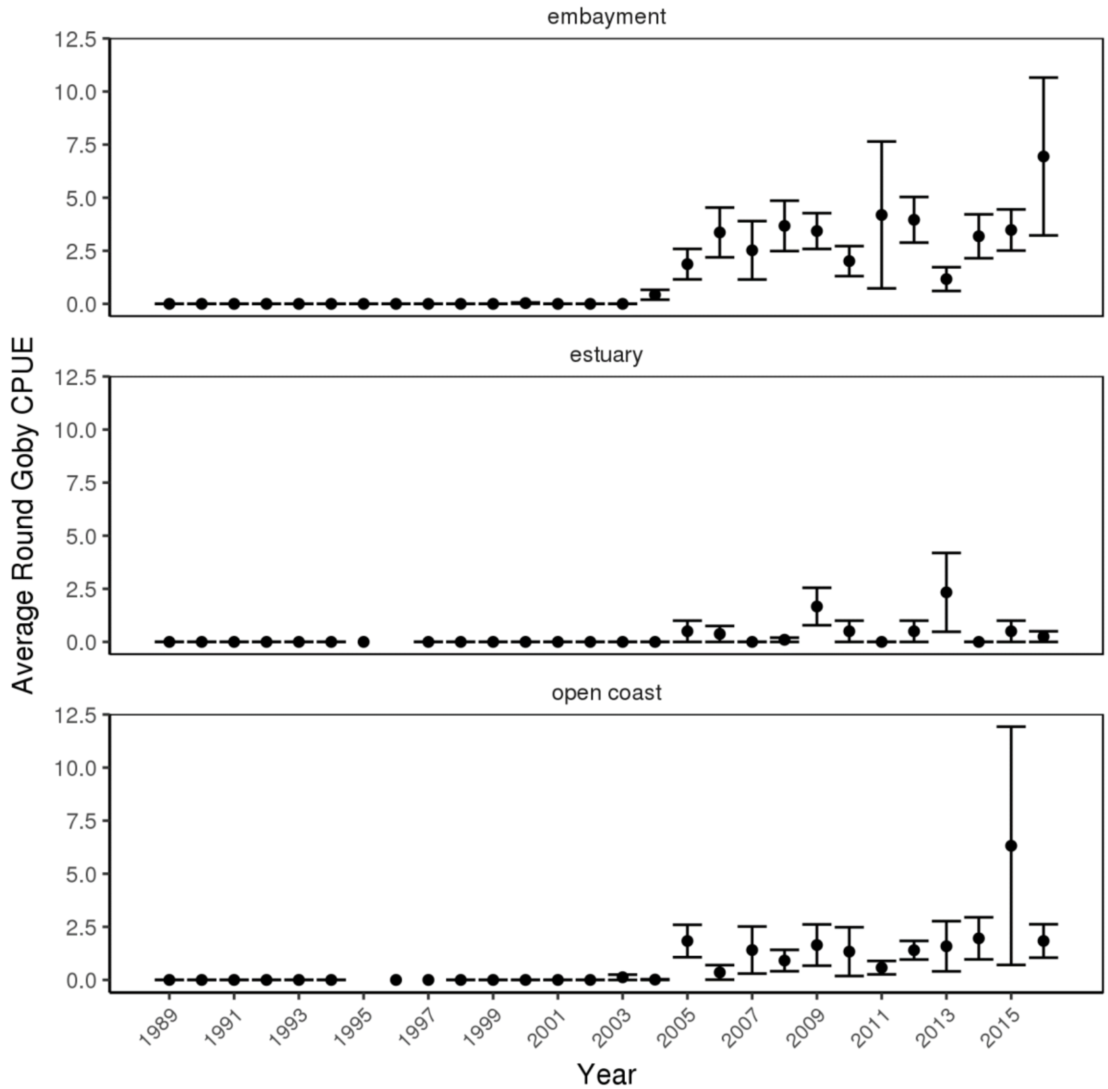

FIGURE 11. AVERAGE ANNUAL CATCH OF ROUND GOBY PER 1,000 SECONDS OF ELECTROFISHING (± STANDARD ERROR) IN EACH HABITAT TYPE IN THE TORONTO WATERFRONT FROM 1989 TO 2016.

LARGEMOUTH BASS

4.5 Trophic Group Dynamics

Specialist species comprised the largest proportion of catch (56% or more) in all habitat types over time (Figure 12). By percent composition in individual habitat types, specialist fish were most numerous in estuaries, followed by open coast and embayments. Generalists and piscivores were most abundant (again, by percent composition) in embayments.

In embayments, the proportion values of piscivores observed in 2000's were generally higher than those observed in the 1990's, with the highest proportion in that habitat type (22%) occurring in 2002. The proportion values of generalists observed in the late 1990's and 2000's were higher than the values from the early 1990's.

Estuaries had the highest proportion of specialists (over 80% in most years) and the lowest proportion of piscivores (under 5% in most years). With the exception of 1992 and 1994 values, proportion of generalists did not exceed 6%.

In the open coast habitat, highest values of piscivores' proportion by catch occurred in the early 1990's (as high as 34% in 1994), and didn't exceed 10% since. Conversely, proportion values of specialists were generally lowest in the early 1990's (as low as approximately 66% in 1994) and highest thereafter (most exceeded 85%). Catch proportion of generalists generally remained the lowest throughout the 1989-2016 time period in this habitat type.

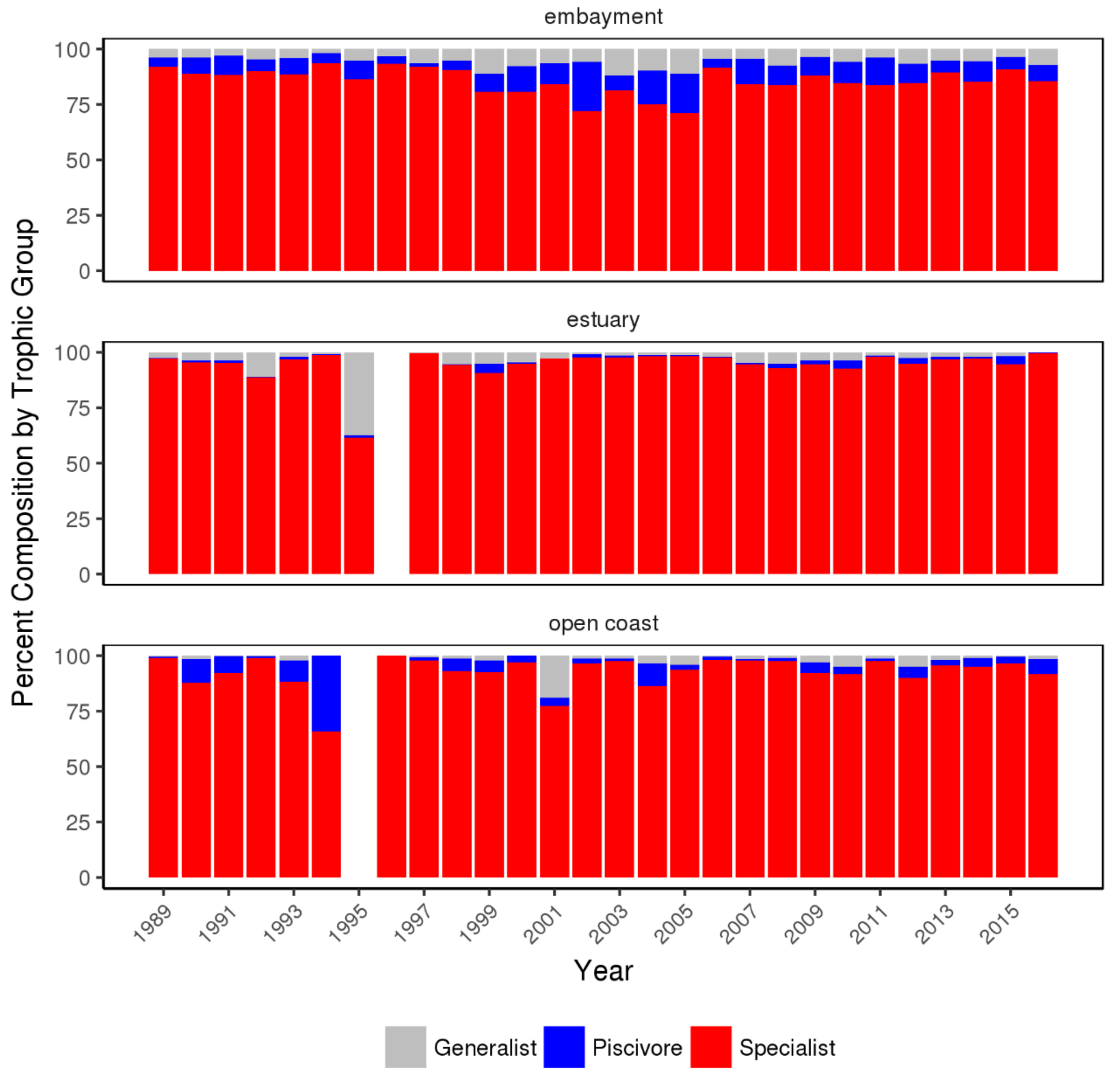

FIGURE 12. TROPHIC GROUP PERCENT (%) COMPOSITION OF TOTAL CATCH IN THE TORONTO WATERFRONT FOR EACH HABITAT TYPE FROM 1989 TO 2016.

CPUE values of native piscivore species Largemouth Bass, Northern Pike, Smallmouth Bass, and Walleye were variable in each habitat type (Figure 13). These species were most numerous in embayments. Largemouth Bass showed a highly variable but overall upward trend since 1989. Northern Pike had an average CPUE of 1 - 3 in most years. The average CPUEs of Smallmouth Bass and Walleye were lower - between 0 and 0.5.

Catches of these piscivores in estuaries remained less than one since 2000, except for Smallmouth Bass in 2010, when this species' CPUE was 1.5. Smallmouth Bass had its highest CPUE of 3.4 in 1999 after years of predominately no catch, but thereafter CPUE values remained low (with the exception of 2010, as stated above).

Open coast had very low piscivore catch overall, especially prior to 1998. Catches of all four piscivore types were consistently below one individual per transect, with the exception of Largemouth Bass in 1997-1999. However; after 1997, Largemouth Bass, Northern Pike, and Smallmouth Bass were captured more consistently. Walleye were not caught in any years in open coast habitat except 2005, which had an average CPUE of 0.125 (in other words, only a handful of fish were caught that year in all of open coast sites).

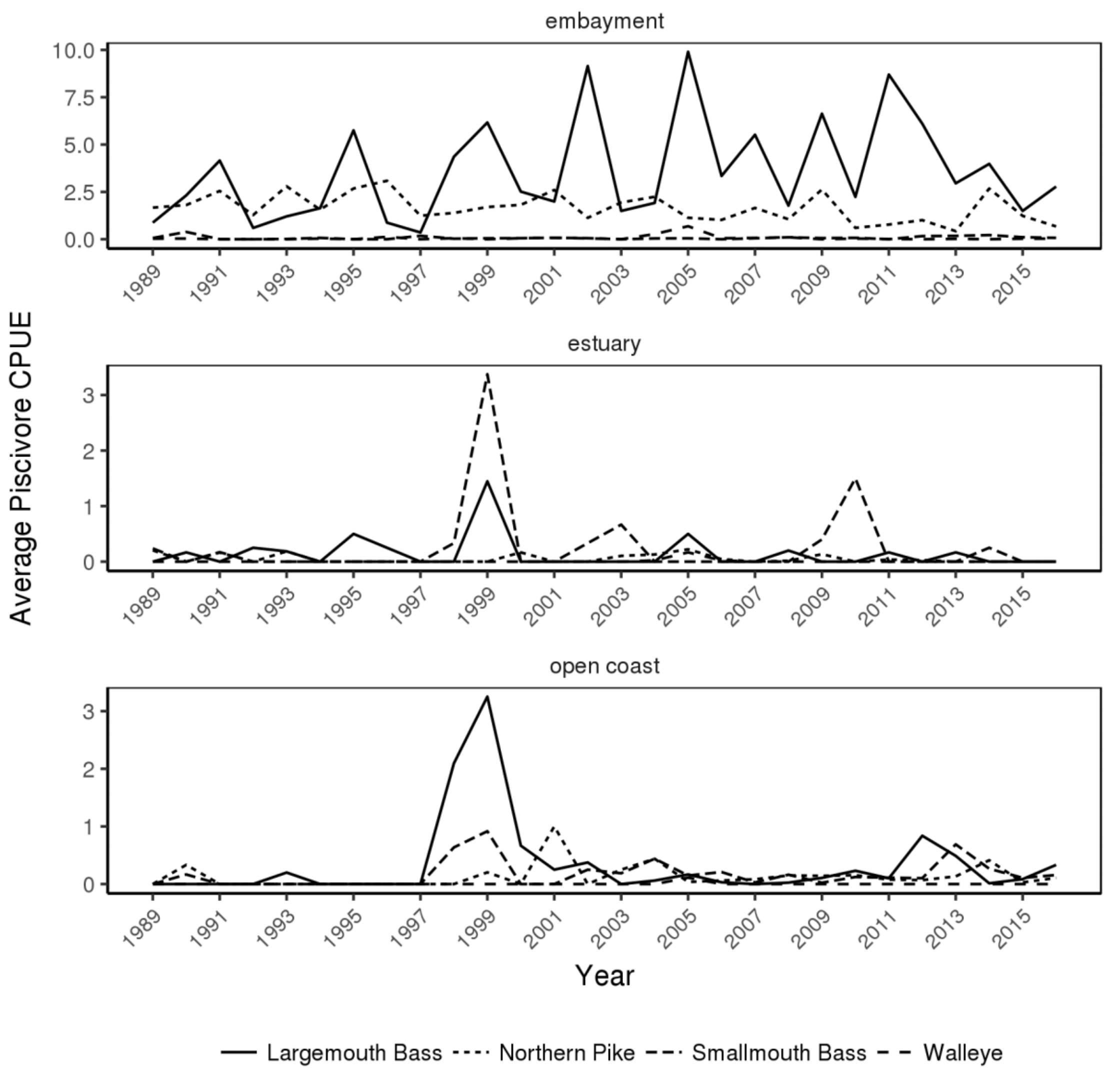

FIGURE 13. AVERAGE ANNUAL CATCH OF RESIDENT PISCIVORE SPECIES (LARGEMOUTH BASS, NORTHERN PIKE, SMALLMOUTH BASS, WALLEYE) PER 1,000 SECONDS OF ELECTROFISHING FOR EACH HABITAT TYPE IN THE TORONTO WATERFRONT FROM 1989 TO 2016.

4.6 Thermal Guild Dynamics

In embayments, BPUE of both cold and coolwater fish species declined since late 1990's, while warmwater species BPUE did not show substantial increases or decreases (Figure 14). In estuaries, warmwater species BPUE showed a fairly substantial decrease from early 2000's onward. In the open coast, both cool- and coldwater species BPUE showed a substantial decrease since the late 1990's. The drop in coldwater species BPUE was particularly prominent. This could potentially be linked to a decline in catch of large-bodied salmonids in this habitat type where these species constituted a large proportion of biomass.

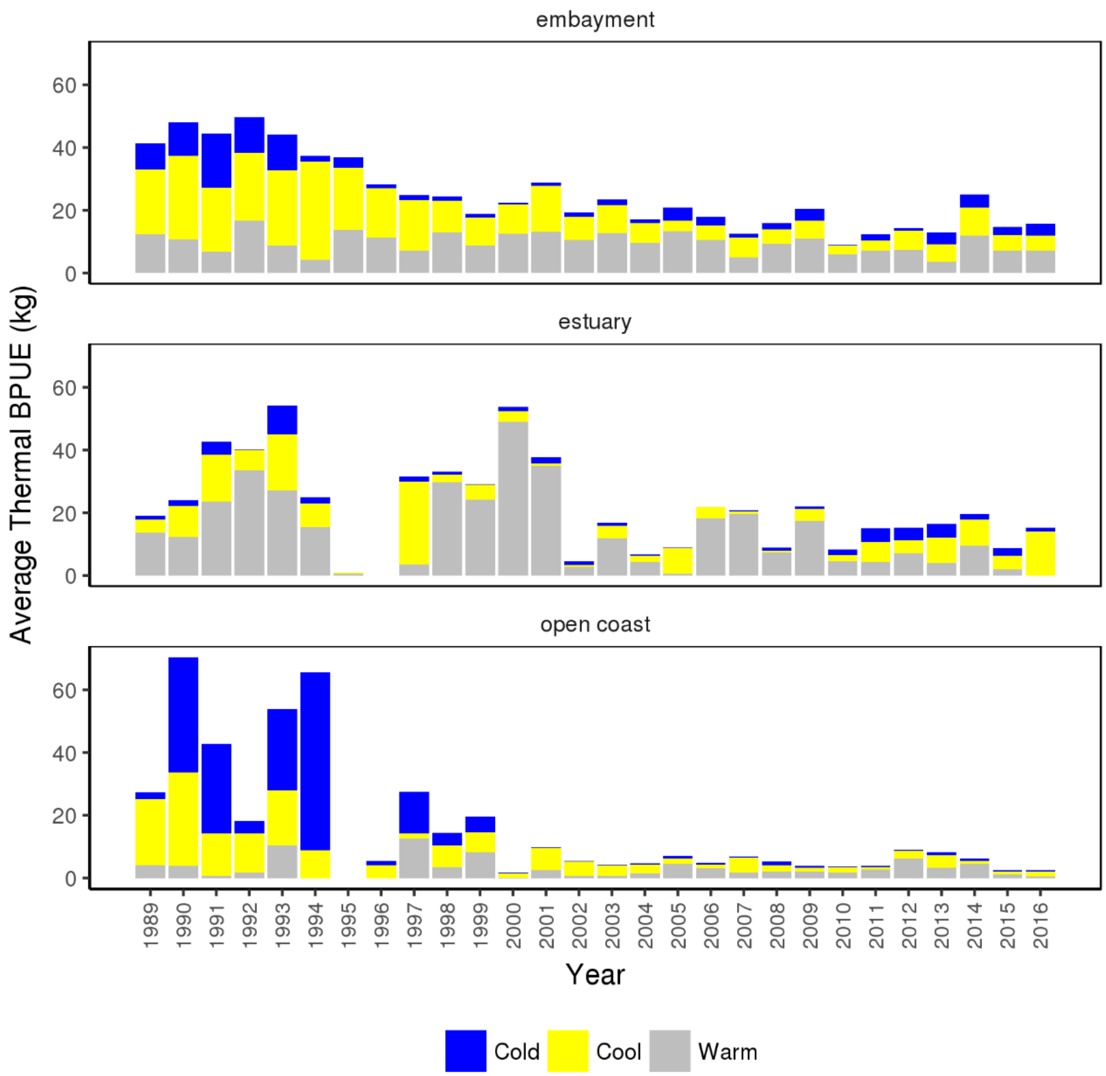

FIGURE 14. AVERAGE ANNUAL BIOMASS PER 1,000 SECONDS OF ELECTROFISHING FOR COLD, COOL, AND WARM THERMAL GUILDS FOR EACH HABITAT TYPE IN THE TORONTO WATERFRONT FROM 1989 TO 2016.

Salmonid species average CPUE values were highest between 1989 and 1994, dropping to nearly 0 in the 2000’s and showing a slight increase in the late 2000’s and 2010’s (Figure 15). Among the different habitat types, open coast had the largest average salmonid catch (up to 11.6), followed by embayments (up to 4) and estuaries (up to 2.7). Lake Trout and Lake Whitefish, present in the 1990’s, were not caught in subsequent years, whereas the opposite was true for Atlantic Salmon: seven Atlantic Salmon were caught between 2006 and 2016, but had not been caught previously.

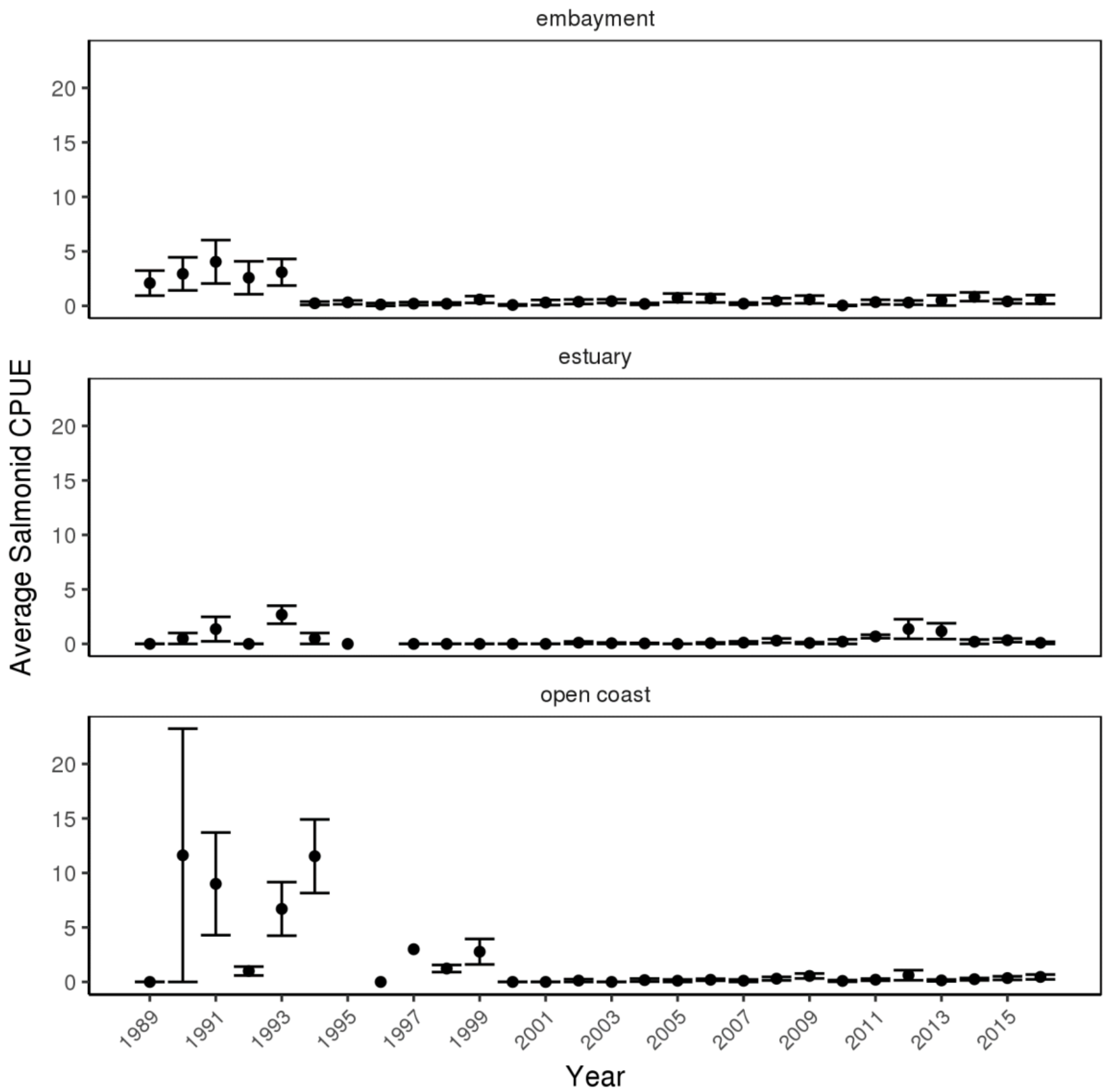

FIGURE 15. AVERAGE ANNUAL CATCH OF SALMONIDS PER 1,000 SECONDS OF ELECTROFISHING (± STANDARD ERROR) FOR EACH HABITAT TYPE IN THE TORONTO WATERFRONT FROM 1989 TO 2016.

4.7 Simpson's Reciprocal Diversity Index

Diversity scores were highest in embayments (1.98 - 4.14), followed by estuaries (vast majority of scores were between 1.37 and 3.30) and open coast (most scores were between 1.54 and 3.50) (Figure 16). Embayment and open coast diversity scores observed in the 2000's were slightly higher than those of 1990's. Estuary habitat scores showed an overall consistent pattern.

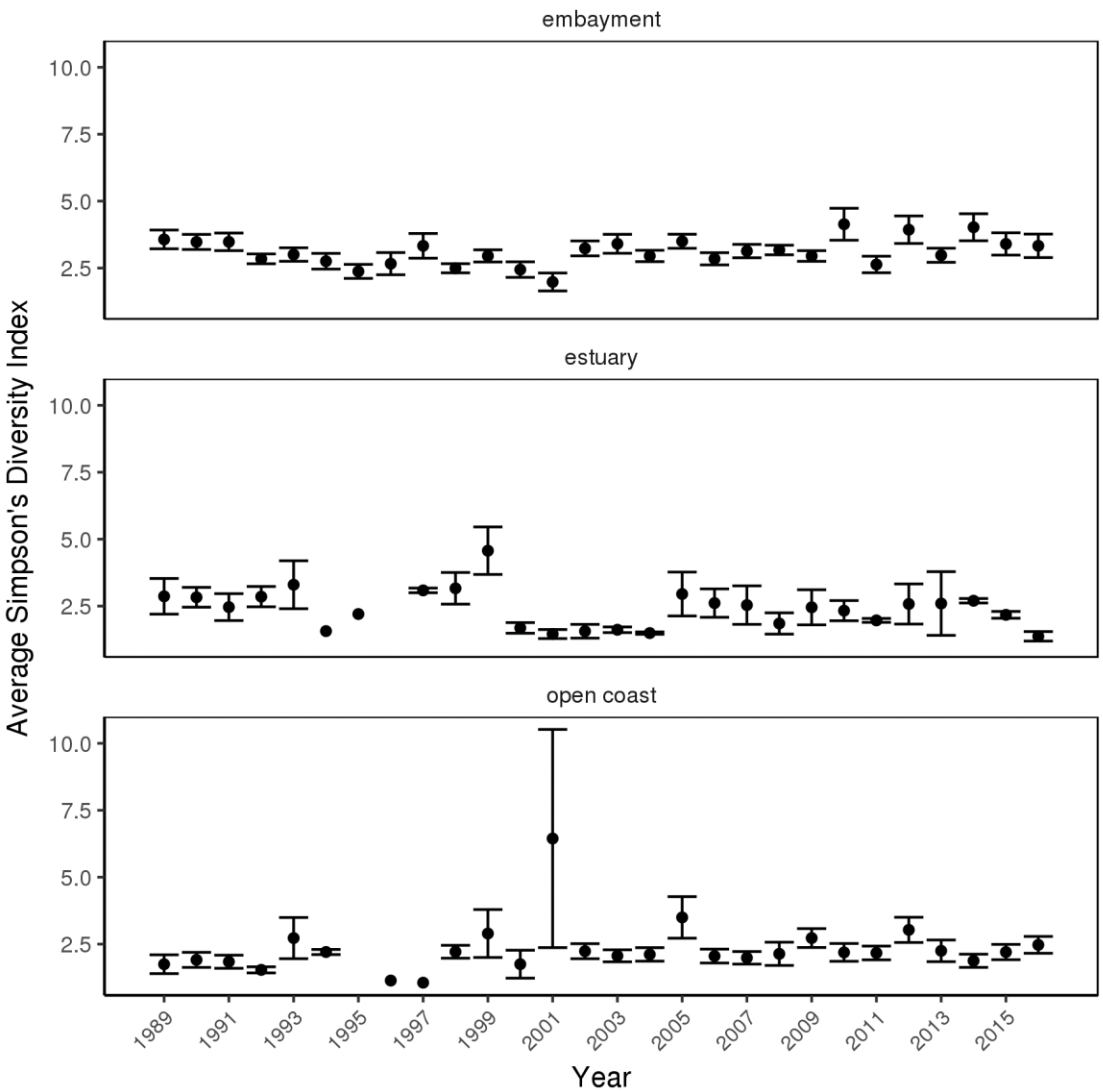

FIGURE 16. AVERAGE ANNUAL PLOT OF SIMPSON'S RECIPROCAL DIVERSITY INDEX (± STANDARD ERROR) FOR EACH HABITAT TYPE IN THE TORONTO WATERFRONT FROM 1989 TO 2016.

NORTHERN PIKE

5 Discussion

The Toronto waterfront aquatic habitats have been extensively sampled from 1989-2016. Embayments remained the most comprehensively sampled habitat type throughout the time period. Both open coast and estuary habitat sampling increased (in the number of sites and transects) starting in the mid-2000's, though estuary habitat remained the least extensively sampled overall. While there are not many estuaries along the Toronto waterfront, an increase in effort in this habitat type would be beneficial.

Stable embayment and estuary native species richness and an increase in the open coast species richness indicates that the fish community health is improving, particularly in the open coast. This habitat supported more native species in the last decade and a half than in the 1990's and early 2000's. The fact that embayments had highest species richness values of all habitat types wasn't unexpected given that these areas are typically the warmest, most sheltered and able to support aquatic plant growth as well as offer diverse habitat. Further investigation into the species richness in the open coast habitats would be beneficial to determine if the species richness increase in this habitat type is linked to an increase in sampling effort.

High diversity scores in embayments are indicative of higher (relative to other habitat types) species richness associated with this habitat. Similarly, an increase in diversity scores observed in the open coast habitat is related to the increase in the number of native species observed in this habitat type. This may indicate a potential increase in open coast habitat conditions quality. While it's not possible to directly attribute this to aquatic habitat rehabilitation efforts associated with many waterfront projects, a further investigation of this trend and the response of fish community to habitat restoration and enhancement in general would be beneficial.

Both the CPUE and BPUE for the fish community indicated a decrease in fish abundance across all habitat types, though the decrease was least pronounced in the embayment habitat. Native and non-native species CPUE generally followed the same pattern. While this may reflect the fish community responding to environmental degradation, the fact that both CPUE and BPUE remained fairly stable since the early 2000's indicates that the environmental conditions and the fish community health are likely not worsening.

With respect to individual habitat types, CPUE and BPUE data indicate that embayments and estuaries support higher numbers of fish than open coast habitat. This is not surprising given the conditions (temperature, wave action, productivity) in the open coast habitat. Nevertheless, it's important to highlight the importance of the open coast habitat: its historical significance (for example, open coast supported spawning of Lake Whitefish), continued role as a migration corridor for many salmonids (for example, fall migration of Chinook Salmon) and support of the resident warm and cool water fish (for example, foraging habitat for native piscivore Smallmouth Bass). Many fish species also use multiple habitats over the course of their lives: a given fish may spawn in an embayment, and forage in estuaries and along the open coast.

Abundance dynamics of degradation tolerant Common Carp and White Sucker showed a promising trend with respect to fish community health: while the CPUE values of these species followed the general catch trend (decreasing over time), so did their proportion of the total catch, particularly in the 2000's and 2010's. This indicates a decrease in abundance of these species and that the environmental conditions are likely not worsening and fish community health is improving. The decrease in Common Carp abundance, in particular, may be at least partially attributed to the success of Carp exclusion measures implemented as part of rehabilitation projects across the Toronto waterfront. By excluding mature fish from their preferred spawning habitats (warm, typically shallow waters of embayments and coastal wetlands), Common Carp recruitment has been reduced.

Trophic group dynamics examination showed a number of opposing trends: the proportion of piscivores in embayments increased (sign of improving fish community health), the proportion of generalists in embayments showed a small increase (sign of declining fish community health), and the proportion of piscivores in open coast habitat declined (sign of declining fish community health). Note that piscivores CPUE in the open coast may have been largely driven by salmonid species which showed high CPUE in the 1990's relative to 2000's and 2010's. As salmonids are largely a reflection of stocking efforts, their abundance is not a reliably accurate reflection of environmental conditions or fish community health. At the same time, some species-specific trends in piscivore abundance constituted positive trends in fish community health. In particular, Largemouth Bass CPUE in embayments, though variable, showed an overall upward trend from 1989-2016, and catches of Northern Pike and Smallmouth Bass, though lower than Largemouth Bass, were stable overall throughout the 2000's and 2010's. Based on these observations, further investigation into the Toronto waterfront fish trophic dynamics (where a more specific trophic classification is used, for example) would be beneficial.

While the native species CPUE did not show sustained substantial changes, non-native CPUE observed in the 2000's and 2010's was lower than in the 1990's, specifically in estuary and open coast habitats. This decrease was likely driven primarily by a decrease in Alewife. Alewife is a highly abundant schooling species and their numbers may fluctuate quite substantially from year to year. The decline in Alewife catch has both positive and negative implications. Alewife is the main prey species for salmonids and therefore a decline in Alewife populations can negatively affect salmonid species (OMNRF, 2000). However, if Alewife declines give way to a native species that fill the same niche (e.g., Emerald Shiner), the impact on salmonids are unlikely to be as significant. Further investigation into the dynamics of these fish species and consideration of lake-wide trends would be useful.

The Round Goby, a small invasive fish, has been captured consistently since its first detection in 2013. It is important to note that electrofishing is not the most effective method of monitoring Round Goby populations, as they are bottom-dwelling fish and remain on the lake bottom when electroshocked. Round Goby eat fish eggs, such as those of Smallmouth Bass, and in turn the goby become prey for the Smallmouth Bass that do survive past the juvenile stage (Lyderson, 2011). They are also a favorite of many fish-eating birds such as Double-crested Cormorants (*Phalacrocorax auritus*) (Madura and Jones, 2016), which has taken some predation pressure off native species. However; their consumption has contributed to botulism in piscivorous birds, as Round Goby have a tendency to spread the bacteria. Despite their integration into the Lake Ontario foodweb, and their top-down control of invasive dreissenis, the proliferation of Round Goby is more known for their negative ecological consequences. Round Gobies have been captured in other locations in the Lake Ontario on a similar timeframe as the Toronto region (Dietrich *et al.,* 2006), therefore, their appearance in the Toronto region is a reflection of a lake-wide trend.

ROUND GOBY

Non-native Common Carp CPUE has likely declined as indicated by the tolerant species CPUE, but it hasn't been examined in isolation from the White Sucker CPUE. Overall, these observations are not conclusive and the non-native species dynamics need to be examined further.

Biomass of both cool- and coldwater species has decreased since the late 1990's in embayments and open coast habitat, while warmwater species biomass values remained fairly consistent throughout the 1989-2016 period. At the same time, BPUE of cool- and cold-water species in estuaries did not show a similar decrease while warmwater species BPUE did decrease since the early 2000's. These observations are not conclusive as changes in biomass by habitat type may be driven by changes in biomass of individual species or groups of species rather than temperature itself. A comprehensive investigation of how overall fish biomass responds to different themal conditions would be beneficial.

Walleye

Data from Hamilton Harbour, a developed site similar to the Toronto waterfront, showed a decline in total catch and total biomass during the 1988-2016 time period. Likewise, the Bay of Quinte also experienced a decrease in total catch, despite being considered a relatively unaffected (i.e., less environmentally degraded) site in Lake Ontario. This indicates that the fish community trends observed in Toronto waterfront reflects lake-wide conditions. It should be noted that the DFO does not break down the data by habitat type, and catch per unit effort is based on area surveyed as opposed to time (total fish caught per 100 m transect as opposed to total fish caught per 1,000 seconds of electrofishing). Additionally, the sites were sampled from approximately May to August, whereas TRCA sampled seasonally from spring to fall. The differences in these datasets and data analysis prevent direct comparison between sites. Nevertheless, it provides a point of reference for the Toronto waterfront fish communities, and may be worth investigating further (DFO, 2018a, 2018b).

The IBI scores rated open coast of Toronto Harbour as Poor (score of >20-48), and Toronto Harbour embayment as Fair (score of >40-60). Hamilton Harbour and Bay of Quinte only contain embayment sites, which were rated as Poor (score of >20-48) and Good (score of >60-80), respectively. When scores excluded offshore or coastal schooling species such as Alewife, White Perch, and Gizzard Shad, Toronto Harbour embayment IBI score became Poor, and open coast habitat became Very Poor. Hamilton Harbour and Bay of Quinte were not affected by excluding offshore or coastal schooling species to the same degree. These coastal schooling species are considered indicators of ecosystem impairment, and their presence in an IBI assessment may decrease precision by increasing the IBI score unjustly (Boston *et al*., 2018). When examining electrofishing data in multiple nearshore sites of Lake Ontario, overall IBI scores from nearshore areas of Hamilton Harbour and Toronto Harbour were Fair, whereas the Bay of

Quinte sites scored as Good (Hoyle *et al.*, 2018). Hamilton and Toronto Harbour, both considered developed (and degraded) sites, have similar scores, and rank much lower than the well-functioning Bay of Quinte ecosystem. Further examination of temporal trends in Toronto waterfront's IBI scores may prove valuable for resource managers by providing insight into how the system has changed since 1989.

Collectively, these results did not indicate any significant changes in terms of the fish community health. However, there were more positive or neutral trends than negative trends. An increase in species richness and diversity scores in the open coast and a decrease in tolerant species abundance are indicators of improving fish community health. Stable overall catch and biomass values observed in the 2000's and 2010's indicate that these aspects of fish community health are not deteriorating. Inconclusive observations concerning the trophic and thermal group dynamics need to be investigated further. Increase in invasive Round Goby, while a marker of declining fish community health, is a reflection of a lake-wide trend.

It's worth noting that a number of substantial changes detected took place in the late 1990's-early 2000's. These include a decrease in salmonid CPUE, a decrease in overall fish catch and biomass, several habitat-specific trends in thermal and trophic group dynamics. It would be useful to examine these further, particularly together with the physical and chemical variables, or in the context of lake-wide fish community trends and habitat alteration or rehabilitation.

Continued fisheries data collection is recommended to track fish community health over time. Long -term data are useful in detecting subtle or complex phenomena, tracking slow ecological processes and add context to short-term changes (Dodds *et al.*, 2012). Next steps could include further investigations described above, a detailed examination of temporal trends in the Toronto waterfront fish community using the IBI approach, and statistical modelling of fish abundance fluctuations incorporating physico-chemical variables. Should any of these be undertaken, the results could provide further insights into the overall fish community health and environmental conditions change, and inform management actions.

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Appendices

Appendix 1. Species caught from 1989 to 2016. Their presence in a given year is indicated by an "X". The absence of a species in a reporting period is indicated by greyed-out boxes.

Species	Sampling Year																												
	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total
Alewife	X	X	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**26**
American Eel	X	X	X	X	X	X	X	X	X	X	X	X	X		X				X			X		X	X	X	X	X	**21**
Atlantic Salmon																												X	**1**
Banded Killifish																										X	X	X	**3**
Black Crappie	X	X	X	X	X					X		X	X	X	X	X	X	X			X		X	X	X	X			**18**
Bluegill	X	X	X		X	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**24**
Bluntnose Minnow	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**28**
Bowfin	X	X	X	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**26**
Brook Silverside														X	X	X	X	X		X	X	X	X		X		X	X	**12**
Brook Stickleback	X	X					X		X	X	X	X	X	X	X	X				X	X	X				X	X	X	**17**
Brown Bullhead	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**28**
Brown Trout	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	**25**
Burbot																										X		X	**2**
Chinook Salmon	X	X	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**26**
Coho Salmon		X			X													X								X	X		**5**
Common Carp	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**28**
Common Shiner	X		X	X				X		X	X	X		X			X	X	X	X	X	X		X	X	X	X	X	**19**
Creek Chub	X		X		X						X													X	X	X		X	**8**
Emerald Shiner	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**28**
Fathead Minnow	X				X						X	X				X	X	X	X	X		X		X	X		X	X	**14**
Freshwater Drum	X		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**26**
Gizzard Shad	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**28**
Golden Shiner					X		X	X	X	X				X	X	X	X	X	X			X	X	X	X	X	X	X	**18**
Goldfish	X	X	X	X	X	X				X	X	X	X			X		X		X	X		X	X	X	X		X	**19**
Goldfish x Common Carp hybrid																												X	**1**
Green Sunfish																						X		X				X	**3**
Hornyhead Chub																												X	**1**
Johnny Darter	X	X			X	X	X		X	X	X	X	X	X	X	X	X	X											**15**
Johnny/Tesselated Darter																X													**1**
Lake Chub			X		X	X					X				X		X	X	X		X	X	X	X		X	X	X	**15**
Lake Trout	X	X	X	X	X	X			X		X						X												**9**
Lake Whitefish	X																												**1**
Largemouth Bass	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**28**
Logperch										X	X		X			X				X		X	X	X	X	X	X	X	**12**
Longnose Dace					X												X	X	X	X				X	X	X			**8**
Longnose Gar						X					X	X						X		X		X	X	X	X			X	**10**
Mottled Sculpin	X	X	X	X	X	X				X	X		X	X		X	X		X										**13**
Northern Pike	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**28**
Pearl Dace																	X												**1**
Pumpkinseed	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**28**
Rainbow Darter																								X					**1**
Rainbow Smelt	X	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**26**

Rainbow Trout	X		X	X	X	X	X			X	X			X	X	X		X	X	X	X	X	X	X	X	X		X	**21**
Rock Bass	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**28**
Round Goby												X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	**15**
Rudd																											X		**1**
Sea Lamprey															X			X				X							**3**
Shorthead Redhorse	X	X	X	X				X	X			X	X	X		X	X		X	X	X	X	X	X	X		X		**19**
Smallmouth Bass	X	X	X		X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**25**
Spotfin Shiner																								X					**1**
Spottail Shiner	X	X		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**26**
Threespine Stickleback	X					X		X	X		X	X	X	X	X	X	X	X	X	X				X	X	X	X	X	**19**
Trout-perch	X			X	X					X	X			X			X	X											**8**
Walleye	X	X				X		X		X		X	X	X		X	X	X	X	X		X	X		X		X	X	**18**
White Bass	X	X			X		X												X		X		X	X	X	X	X	X	**12**
White Perch	X	X	X	X	X	X	X	X	X	X	X	X									X	X	X	X	X				**17**
White Sucker	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**28**
Wiper																							X						**1**
Yellow Bullhead					X																								**1**
Yellow Perch	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**27**
Total	**38**	**31**	**30**	**26**	**37**	**31**	**21**	**23**	**24**	**33**	**36**	**32**	**29**	**32**	**31**	**35**	**36**	**37**	**33**	**33**	**31**	**35**	**34**	**40**	**38**	**37**	**36**	**42**	

APPENDIX 2: SPECIES RICHNESS OF NATIVE FISH BY HABITAT TYPE FROM 1989 TO 2016.

Year	Open Coast	Embayment	Estuary	Total
1989	9	29	11	30
1990	7	23	7	24
1991	9	25	9	27
1992	5	23	7	25
1993	11	23	7	28
1994	4	23	2	24
1995	2	22	2	23
1996	2	19	0	19
1997	3	20	2	22
1998	15	22	8	26
1999	15	23	13	28
2000	6	23	8	25
2001	14	22	6	24
2002	9	25	6	26
2003	11	22	11	23
2004	14	26	9	27
2005	24	23	13	31
2006	16	24	16	28
2007	15	22	10	26
2008	13	22	10	25
2009	11	21	9	22
2010	14	24	11	27
2011	13	22	6	25
2012	20	24	10	32
2013	17	25	13	29
2014	16	23	11	28
2015	17	24	5	28
2016	20	28	5	33

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