   

THE FISH COMMUNITIES OF THE TORONTO WATERFRONT:

SUMMARY AND ASSESSMENT 1989 - 2005

SEPTEMBER 2008

TORONTO & REGION REMEDIAL ACTION PLAN

TORONTO AND REGION Conservation for The Living City

Ontario

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ABSTRACT

Fish community metrics collected for 16 years (1989 — 2005), using standardized electrofishing methods, throughout the greater Toronto region waterfront, were analyzed to ascertain the current state of the fish community with respect to past conditions. Results that continue to indicate a degraded or further degrading environment include an overall reduction in fish abundance, a high composition of benthivores, an increase in invasive species, an increase in generalist species biomass, yet a decrease in specialist species biomass, and a decrease in cool water thermal guild species biomass in embayments.

Results that may indicate a change in a positive community health direction include no significant changes to species richness, a marked increase in diversity in embayments, a decline in non-native species in embayments and open coasts (despite the invasion of round goby), a recent increase in native species biomass, fluctuating native piscivore dynamics, increased walleye abundance, and a reduction in the proportion of degradation tolerant species.

Electrofishing in the Toronto Harbour

Electrofishing on the night Heron

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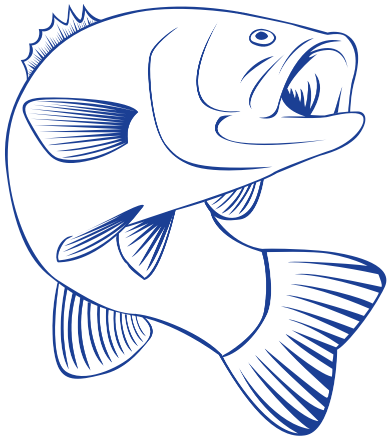


CHAPTER

1

1.0 INTRODUCTION

In 1987, the governments of Canada and the United States ratified the Protocol Amending the Great Lakes Water Quality Agreement (GLWQA) committing them, in cooperation with state and provincial governments, to develop and implement Remedial Action Plans (RAPs) for each Area of Concern (AOC) within the Great Lakes Basin. AOCs are selected geographic areas in which environmental conditions, termed beneficial uses in the GLWQA, are severely impaired, meriting a higher level of attention from the governments to ensure environmental conditions are restored.

The Toronto region was designated as one of the 43 AOCs throughout the Great Lakes basin. Unsatisfactory environmental conditions, namely poor water quality and degraded habitat, prompted the designation. These conditions continue to persist due in large part to the increased urbanization of Toronto and its surroundings.

As of early 2005, only two AOCs in Lake Huron, Severn Sound and Collingwood Harbour, have had environmental conditions restored to allow for a designation of "delisted" or no longer impaired. Of the remaining 41 AOCs, Spanish Bay (Lake Huron) and Presque Isle Bay (Lake Erie) are considered "Areas in Recovery" as all restoration opportunities have been implemented and subsequent monitoring programs have shown improvements to environmental conditions. However, a longer time frame is necessary to ensure these improvements are sustained.

As required in the GLWQA, the boundaries of the Toronto region AOC reflect an "ecosystem approach". Included within the boundaries of the AOC are 45 kilometres of the Toronto waterfront and Toronto Bay, the watersheds of the Etobicoke, Mimico and Petticoat creeks, as well as the Rouge, Humber and Don rivers.

Fourteen beneficial - use impairments are listed in the GLWQA, to reflect the components of the ecosystem. Of these 14, the Toronto region RAP has eight listed beneficial - use impairments, including:

1. Restriction of fish and wildlife consumption
2. Degradation of fish and wildlife populations
3. Degradation of benthos
4. Restrictions on dredging activities
5. Eutrophication or undesirable algae
6. Beach closing
7. Degradation of aesthetics
8. Loss of fish and wildlife habitat

Three beneficial - use impairments are undergoing further assessment to determine their status, these include:

1. Fish tumors and other deformities
2. Bird or animal deformities, or reproductive problems
3. Degradation of phytoplankton and zooplankton populations

As outlined in the GLWQA, the reporting process for the RAP involves three stages: In Stage 1, the problems and causes existing in the AOC are identified and described; the Toronto region Stage 1 Report was released in 1988. *Clean Waters, Clear Choices – Recommendations for Action* was released in 1994 and met the obligations of a Stage 2 Report for the Toronto region AOC. It includes information pertaining to the remedial and regulatory measures selected for implementation and details regarding costs, benefits and responsible lead agencies for

TRCA Night Heron

such activities. The compilation of a Stage 3 Report occurs when monitoring indicates that beneficial uses have been restored and it is no longer accurate to consider the area as an AOC. The area can, at this time, be "delisted". Required for this report is a process for evaluating the remedial measures implemented (e.g., restoration targets) and their effectiveness, as well as a description of the monitoring processes used to track the effectiveness of remedial measures. Therefore, it is important, in the interim, to provide updates and progress reports to ensure the RAP is on track with accomplishing its goals.

1.1 Fish Community Monitoring: Purpose and Scope

Toronto waterfront fish communities may be defined as a combination of different fish species living and interacting with each other at individual sites across the Toronto waterfront (Strus 1994). The fish communities within the watersheds and the Lake Ontario waterfront of the Greater Toronto Area (GTA) are recognized as societal resources that provide recreation, food and income for area residents.

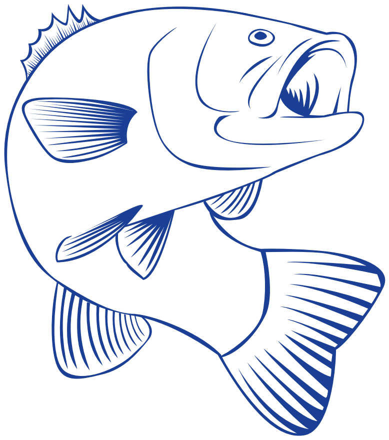
Large Mouth Bass
Photo courtesy of Brent Valere

The Living City initiative, undertaken by the Toronto and Region Conservation Authority (TRCA) and the GTA municipalities, aims to ensure the longevity of fish resources for the future by building a foundation of healthy rivers and shorelines, regional bio-diversity, sustainable communities and business excellence.

Since fish are sensitive to a wide array of environmental variables (Karr 1981; Minns *et al.* 1994; Randall and Minns 2002), long-term assessment of fish communities provides valuable information on the status and health of an urban ecosystem such as the Toronto waterfront. Monitoring changes in fish community structure, population dynamics, growth rates, contaminant loads, reproductive capability and success, and other health characteristics can enable us to better understand the integrated effects of fish community stressors within an ecosystem.

This document and the information herein provides an important update on the Toronto waterfront fish communities; a task previously undertaken in 1994 by the Ontario Ministry of Natural Resources in a report entitled *Metro Toronto Waterfront Fish Communities: Summary and Assessment*–1989–1993 (Strus 1994).

In this report we summarize and assess the changes in the fish community from 1989 to 2005 for open–coast, embayment, and estuary/river mouth habitats of the Toronto waterfront. Included is discussion pertaining to future considerations for the fish resources of the GTA. This information is necessary in order to undertake actions successful at restoring fish and wildlife populations and suitable habitat—two goals essential to the RAP.



CHAPTER

2

2.0 BACKGROUND

2.1 Nearshore Lake Ontario

The modern shoreline of Lake Ontario is situated between two post-glacial abandoned shorelines. The landward abandoned shoreline originally marked the edge of the higher post-glacial Lake Iroquois, resulting in a stranded shoreline bluff and abundant beach material along the present day tablelands.

The Lake Iroquois shoreline influences the morphology of modern streams and focuses the mid-reach recharge of groundwater sources. However it has a minor effect on current aquatic habitats along the shoreline of Lake Ontario.

An off-shore abandoned shoreline created by the lower post-glacial Admiralty Lake has a much greater effect on today's shoreline. The former Admiralty Lake shoreline has left a variety of submerged features including a prominent off-shore bluff, known as the Toronto Scarp, that runs parallel to the Toronto Islands and Scarborough shoreline. Admiralty Lake was also the source of relict sand and gravel deposits still found in deep off-shore waters. The most significant surficial geological features that affect and determine current shoreline conditions are found between the abandoned Admiralty Lake shore and the modern shoreline. Most current and historic habitats were created in this inundated area.

For example, historically, the dynamic movement of littoral material established the peninsula and lagoons of Toronto Bay.

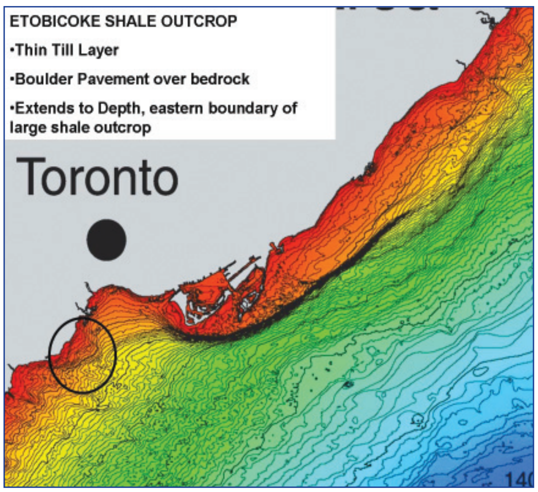
Toronto Harbour 1773

Toronto Harbour Today

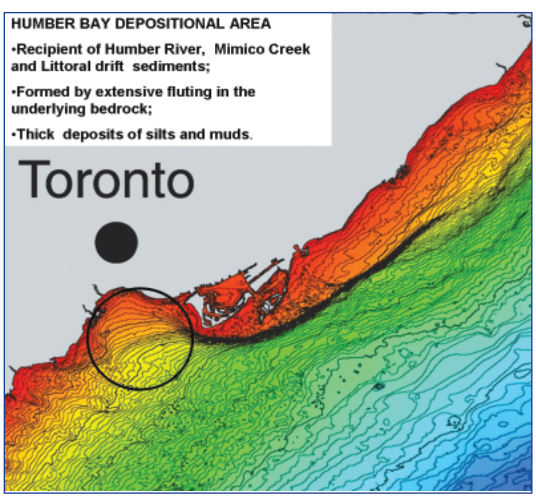
The bulk of this material was supplied from shoreline erosion of significant deposits of sands found in the Scarborough Bluffs and re-worked beach deposits made available during rising water levels. In addition, the Toronto Scarp at the shoreline of the former Admiralty Lake is an important area of congregation for salmonid fish.

The bathymetry of western Lake Ontario displays a number of features that affect aquatic habitats. Lake Ontario is a deep, cold, oligotrophic (nutrient-poor) lake with relatively steep shorelines, particularly on the northern shore. Shale bedrock is apparent along the shorelines of Niagara Region, Halton Region, Mississauga and Etobicoke. A major depositional zone exists at the Hamilton lakehead. There is an underwater bluff composed of deltaic sands. The geological complex of the Toronto shoreline has five zones:

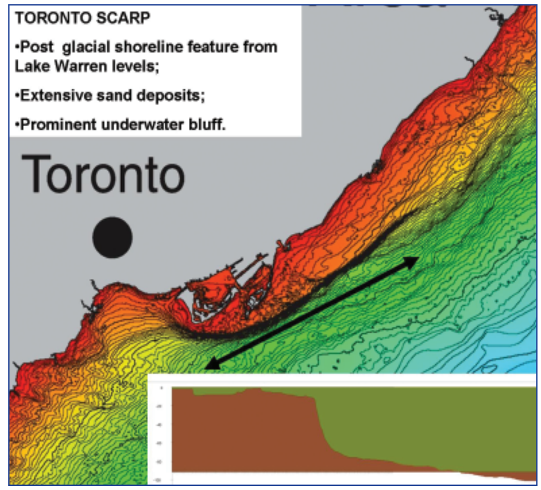
1) Etobicoke Shale Outcrop



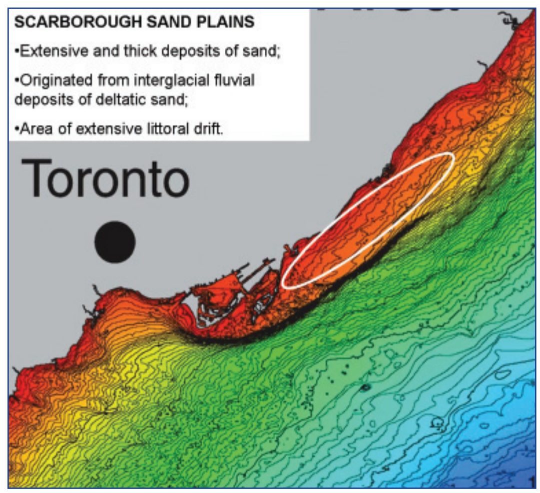
2) Humber Bay Depositional Area



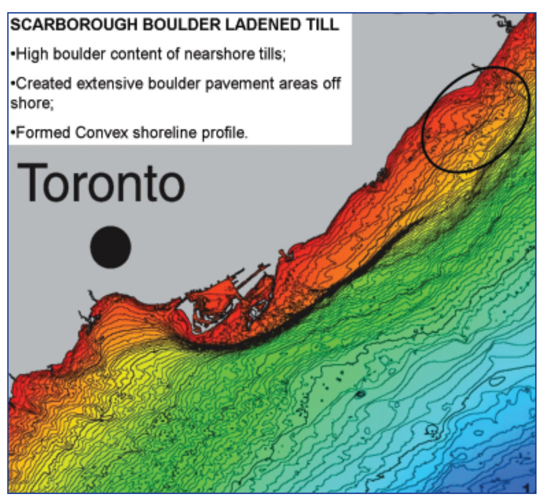
3) Toronto Scarp



4) Scarborough Sand Plains



5) Scarborough Boulder-laden Till



Tommy Thompson Park

Along the wave zone area, bedload sediments from the major rivers have surcharged the shoreline with sand and helped to establish the barrier beaches associated with local coastal wetlands at the mouths of the Rouge and Highland rivers. The boulder-laden till also loaded the wave zone areas with a vast quantity of aggregates.

2.2 Toronto Waterfront Ecosystems

The Toronto waterfront may be subdivided into three essential types of shoreline habitat that may be defined based on physiographic structure and exposure to open lake and watershed conditions.

South Marine Drive

Open coast and embayment habitats vary in the degree to which they are sheltered or exposed to Lake Ontario. River mouth habitats are subjected to the fluvial characteristics that are intrinsic to individual watersheds. However, the ecosystems that are entwined within these habitats are not necessarily discrete, and based on the degree of lake sieche action, watershed discharge, and the mobility of the species comprising the individual ecosystems, differing levels of interaction occur between them.

2.2.1 Open Coast Habitats

Shorelines exposed to the open lake dominate the Toronto waterfront. These are coldwater habitats exposed to extensive wave action, currents and water exchange, resulting in production of biota that are adapted to these conditions. Hypolimnetic upwellings are common occurrences, consisting of wind-generated intrusions of cold subsurface waters upon inshore areas (Bridger and Oster 1981).

Toronto open coast habitats are defined by Paleozoic bedrock outcrops, glacial deposits and lake sediments, as well as bi-coastal processes resulting in erosion of these materials and the subsequent sediment transport and deposition (Rukavina 1969; Lewis and Sly 1971).

Tommy Thompson Park Embayment B

Erosive zones predominate at Scarborough and Etobicoke shorelines where, exposures of boulders, cobble and gravel result from wave action and currents sweeping away finer particles. A central deposition area, consisting of sand and silt eroded from the Scarborough bluffs, dominates the central waterfront. The eastern beaches, Ashbridge's Bay and the Toronto Islands were the major depositional features. Shorelines at Humber Bay consist of inshore sand beaches and fine sediment in deeper waters (soft muds, silts and clays), a result of less current activity and sediment entrapment (Lewis and Sly 1971).

Historically, open coast shorelines provided habitats suitable for spawning coldwater fishes such as lake trout (*Salvelinus namaycush*) and lake white fish (*Coregonus clupeaformis*) (Goodyear *et al.* 1982). Spawning occurred at exposed, wave swept shoals from Scarborough to the Toronto Islands. The extensive use of these exposed shoals by spawning fishes indicates the beneficial effects of storm scouring upon coarse substrates such as gravels, rocks and boulders (Christie *et al.* 1987). The self-cleansing characteristics of exposed open coast shorelines provided essential conditions for over-wintering eggs and larvae.

Most open coast habitats along the Toronto waterfront have been degraded by human interventions. In recent years, the design of shoreline management works has evolved to incorporate more ecological functions. Nearshore benthos may be improved by modifying the substrate, for example by replacing some of the one million cubic metres of rocky materials removed historically from the Toronto shoreline. Another important factor in the open coast is the general lack of debris such as large timbers and woody materials from the upstream watersheds.

2.2.2 Embayment Habitats

Aquatic habitats sheltered from the open lake were formed by coastal deposition processes enclosing bodies of water (e.g., Toronto Islands, Grenadier Pond and Frenchmans' Bay). Embayment formation typically occurred where indentations existed along the shoreline. These were created by lowerland areas being flooded by gradually rising lake levels. The more significant "drowned" areas eventually become partially enclosed by deposited spits and bars (Chapman and Putnam 1966). Lake level increases were caused by varying rates of post-glacial isostatic uplift within the Lake Ontario basin. Isostatic uplift continues to raise the Lake Ontario outlet near Kingston at a rate of about 0.35 metres per century, relative to the western end of the lake (Sly 1991). Within embayment habitats, reduced water exchange with the open lake resulted in warmer water conditions, allowing the establishment of biota adapted to the habitats. The depositional character of embayments favoured wetland formation, and an associated increase in biological production and diversity (Bridger and Oster 1981). Natural wetland

The Mouth of the Rouge River

creation processes were most evident at the mouth of the Don River, within an embayment formed by the Toronto Islands and Ashbridge's Bay. Sheltered embayments in harbour areas, the Toronto Islands and lakefill parks provide thermal refuges, as well as a variety of shoreline conditions and configurations with significant areas of aquatic vegetation. Water currents between sheltered embayments and open waters of the lake attract and hold forage fish, providing a concentrated area for feeding by predators.

2.2.3 Estuary/River Mouth Habitats

Six major rivers and streams enter the Toronto waterfront. Prior to settlement in the late 1700s, the watersheds defining these watercourses were almost entirely forested (Bailey 1973). Extensive tree canopies, absorbent soils, and relatively constant groundwater supply provided coldwater conditions throughout most of the streams and rivers in the Toronto area (Steedman *et al.* 1987). Coldwater fish communities were characterized by self-sustaining populations of brook trout (*Salvelinus fontinalis*) and Atlantic salmon (*Salmo salar*) (Goodyear *et al.* 1982).

Where streams and rivers entered the waterfront, sediment deposition contributed to the formation of wetlands. As in embayments, coastal processes often resulted in the formation of spits and bars across river mouths and estuaries. Being sheltered from open lake effects, embayment and river estuary habitats produced warmwater fishes such as basses (*Micropterus spp.*), northern pike (*Esox lucius*) and muskellunge (*Esox masquinongy*).

Estuaries occur at the lower reaches of streams that are influenced by lake levels (e.g., the Rouge River from Lake Ontario to Highway 401). 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 also represent a physical connection between the lake and watershed for species that need both open waters and riverine habitats.

The environmental quality of the estuaries along the Toronto waterfront varies. Longer estuaries, such as the Rouge River and Highland Creek, still have functional estuarine habitats, albeit degraded. Mimico Creek estuary has benefited from restoration projects in recent years and is showing some signs of recovery. Etobicoke Creek estuary has been considerably shortened and degraded, with little bottom structure or vegetation. The Don River estuary is the most severely altered, with very limited aquatic habitat.

2.3 Habitat Alteration Processes and Aquatic Community Interactions

Like Toronto, the waterfront is by no means a homogeneous entity. A diversity of land uses including parks, residential, industrial and commercial applications are distributed throughout the area. The Toronto Bay area, for example, contains a downtown core that is largely dominated by commercial towers. Outside the commercial core, land use is dominated by light industrial and residential land uses. Overall the per cent of urbanization for the Toronto region AOC as of 2003 was 60 per cent. The 40 per cent designated as rural was located in the headwaters of the watersheds discussed previously (Environment Canada 2003). Typically, three categories of cultural influence have led to degradation of habitat and therefore the ecosystem of the Toronto waterfront: shoreline alteration, water quality and degraded sediments. More recently the arrival of invasive species have altered habitat as well.

2.3.1 Shoreline Alteration

Alterations to the Toronto waterfront have occurred since the 1790s when aquatic plants were removed from Toronto Bay because they impeded navigation. Other early shoreline alterations included filling of wetlands and small streams, hardening of the shoreline, and channelization of watercourses. Toronto Bay in 1813 had shoreline modifications in the form of docks, jetties and filling of small creeks. In the 1820s changes to the substrate were brought about by the dredging of open coast gravel, rocks and boulders by "stone-hooking" ships. By 1913, further alterations included navigable channels such as the Western and Eastern Gaps and the Keating Cut. Filling and armouring of Toronto Harbour shorelines began in the mid-1800s. Much of the alteration consisted of vertical concrete walls and sheet steel pilings, which offered little habitat potential for fish or wildlife. For example, from 1913 to 1928 approximately 6 square kilometres of wetlands were filled at Ashbridge's' Bay to create dry land for industry (Whillans 1982). Also during this period the Don River was diverted to the Toronto Harbour and armoured, thereby creating the Keating Channel. Filling of the shoreline continued into the 1930s, extending to the western beaches. These shorelines were subsequently protected with the construction of several kilometres of concrete breakwaters.

By the 1950s, wetland areas at Etobicoke Creek, the Humber Marshes, the Toronto Islands and Highland Creek were filled so that the marsh area across the Toronto waterfront was reduced from 8.35 square kilometres to less than one kilometre (Whillans 1982).

In 1956, lakefilling began associated with the Leslie Street spit, which was later renamed Tommy Thompson Park. This marked the beginning of the creation of several other lakefill parks. Lakefill park construction during the 1970s and 1980s has created sheltered embayment habitats more favourable to warmwater biota than the previous open coast (Martin-Downs 1988). However, filling buried natural substrates and the result may have been an overall net loss of lake productivity (Christie *et al.* 1987).

By the early 1990s, shoreworks were constructed along the Scarborough waterfront and filled shorelines extended continuously from Mimico Creek to the Eastern Beaches (Strus 1994).

Lakefilling has altered the natural current patterns and coastal erosion dynamics and, therefore sediment supply, transport and deposition processes. Because of this reduction in water exchange and current activity, the levels of turbidity, sediment deposition, nutrients, bacteria, and contaminants were altered near lakefill structures (Bridger and Oster 1981).

Due to the drastic changes in sediment transport associated with both fluvial and coastal processes, dredging has become an unavoidable form of maintenance throughout the waterfront most especially in the Keating Channel. Each year, 35,000 to 40,000 square metres of sediment settle into the Keating Channel. The material comes from runoff and erosion upstream in the Don River. Dredging is undertaken in the channel for flood protection and maintenance of navigable water. The channel is dredged to a depth of 5.8 metres below chart datum and the dredged material is transported by tug and barge to the Toronto Port Authority's Confined Disposal Facility (CDF) within Tommy Thompson Park Endikement. The project is subject to ongoing environmental monitoring by the Port and conservation authorities.

Dredging the Keating Channel

Although the majority of sediment from the Don watershed is captured in the Keating Channel, aerial photographs show a plume of sediment moving into the Inner Harbour. When needed, small quantities of material are dredged at berths to maintain required depth. Approximately 3,100 cubic metres are dredged every three to five years. Similar to the Keating Channel dredger, the material is transported to the Toronto Port Authority's CDF.

The East Gap is part of the main shipping channel into Toronto Harbour. Prior to the construction of the Leslie Street Spit, regular dredging of the Gap was required to maintain the navigation depth of 8.2 metres below chart datum. Some sediment continues to intrude into the Gap from western littoral drift and erosion off the Centre Islands. The quantity of this sediment is in the order of 3,500 cubic metres per year. Maintenance dredging is required in the Coatsworth Cut channel in Ashbridge's Bay every two or three years. The design depth of the channel is 1.8 metres below chart datum. The Toronto Port Authority has permitted this dredge material to be transported and disposed in the Toronto Port Authority's CDF.

Dredging drastically increases the level of turbidity in its vicinity, which reduces the depth that light can penetrate in the water column and therefore reduces plant survival and growth (Chambers and Kalff 1985) and, the visual habitat of fish species. Dredging may also re-suspend contaminated sediments that have settled out on the channel bed. This increases the potential for fish to come in contact with toxins and bacteria.

However, modifications have been made to the Toronto waterfront that are positive in relation to the fish community. Modifications to the shoreline changed dramatically with the implementation of the 1967 waterfront plan developed by Toronto. As a result, recent lakefilling activities were directed away from creating port and industrial lands and focused on creating regional waterfront recreational parks. The parks provide waterfront access, local greenspace, boating facilities, and aquatic habitats. Following is a summary of the key projects.

Sam Smith Waterfront Park incorporates many successful habitat creation projects, including wetlands, coastal meadows, shoals and reefs.

Humber Bay Park is the site of a range of intensive habitat restoration works, including a Ministry of Natural Resources habitat project that used woody debris in a sheltered embayment. Test scale wetlands were established in the estuary of Mimico Creek in 1995, and additional wetlands were created in association with the pedestrian bridge over the creek. The estuary now provides an excellent opportunity to recreate a coastal wetland estuary complex. As part of the development of the Humber Bay Shores area, habitat islands, beaches and shoals have been strategically built along the east side of Humber Bay Park, including one of the largest wetland creation projects to date.

The Toronto Bay area was the focus of a study by the Toronto Bay Initiative that outlines many opportunities for habitat regeneration (Kidd 1998). The wetland project and pike spawning habitat at Spadina Quay is an excellent example of created habitats within the harbour and is a useful design template for larger initiatives. The restoration of the lower Don River and the wetland at the mouth of the Don River is one of the largest proposed restoration schemes for the Toronto waterfront, currently undergoing an individual Environmental Assessment.

Within the Toronto Islands at the trout pond, a large wetland complex was enhanced and reconnected to the lagoons. This lacustrine marsh provides critical habitat functions for the fish and wildlife community of the islands. Works undertaken in the mid 1990s on the islands focused on repairing vertical

Sam Smith Waterfront Park

seawalls with a variety of shoals and riparian improvements. Of particular interest is the wetland shoreline that was created at the Queens City Yacht Club that provides vegetated shorelines and improved public access.

The potential for Tommy Thompson Park to act as an aquatic habitat centre for the waterfront is based on the habitat restoration opportunities in the 160 hectares of lagoons and bays associated with the park. The Cell One wetland capping project is the single largest wetland gain to date on the waterfront. Additional wetland creation projects in the park include Triangle Pond, Embayment A and Embayment C.

Ashbridge's Bay and Bluffer's Park are the location of two shoal and reef features within a boat basin on Toronto waterfront. Both parks have potential for additional habitat works.

East of Ashbridge's Bay, the open coast shoreline is characterized by groynes and headland features. Overall, these structures function well as aquatic habitat with the best example being the recent headland structure west of the RC Harris Water Filtration Plant.

East of Bluffer's Park, the Sylvan Avenue project is an example of integrating aquatic habitats into the form and function of an erosion control project. The Port Union Road shoreline improvement project is another example of the integration of aquatic habitats into a shoreline management structure.

2.3.2 Water Quality

Major changes to the land use of the Toronto watersheds have occurred since the turn of the last century. Urban development and agriculture have reduced the quality of water draining into these systems and subsequently into Lake Ontario. The previously forested watersheds have been replaced with extensive urban areas most of which were designed to carry water from the land surface as efficiently as possible. Runoff washes quickly over houses, parking lots and roads, and makes its way to underground sewer systems (City of Toronto 2003). During this process, the runoff incorporates contaminants, nutrients and silt into the load that ultimately ends up at the waterfront (Metro Toronto RAP Team 1988). Lakefill structures and channelization of downstream sections of rivers as mentioned previously does not allow for natural dispersion of effluents.

Humber Bay and the Inner Harbour experience the heaviest sediment deposition rates, due to poor water exchange and dispersion characteristics. During the late 1980s and early 1990s, the Humber was the largest contributor of sediments, carrying 47 per cent of the total load to the waterfront, while the Don River added another 26 per cent (Metro Toronto RAP Team 1988).

Storm events continue to overload combined sewers in older parts of the city. As a result, raw sewage can be transported to the waterfront, greatly increasing bacterial and nutrient levels, as well as increasing algal production. Algal production and subsequent decay can alter oxygen levels within the waterfront, which may adversely affect fish and, in some cases, lead to fish kills. The City of Toronto's 2002 Wet Weather Flow Management Master Plan (WWFMMP) provides important direction for ongoing improvements. The plan proposes a program totalling $1 billion over the next 25 years, including public education, municipal operations, shoreline management, stream restoration, and control measures at the end-of-pipe, during conveyance, and at the source. The shoreline management proposals include structures at the waterfront, near the mouths of Etobicoke Creek and the Humber River, to deflect ongoing inputs of pollutants away from waterfront beaches.

Over the next 25 years, implementation of the WWFMMP will improve waterfront aquatic habitats by reducing inputs of nutrients, sediments and chemical pollutants to the watercourses and Lake Ontario. It will also improve habitat conditions in the rivers and creeks, with benefits to aquatic species that migrate upstream from the lake.

2.3.3 Degraded Sediments and Contamination

Contamination of the water and sediments in the Toronto nearshore were of significant concern upon designation of Toronto as an Area of Concern. In addition to naturally occurring materials, the nearshore sediments are mixed with sediments and compounds often products of anthropogenic activities (e.g., urban runoff, sewage treatment facilities and lakefilling).

Round Goby

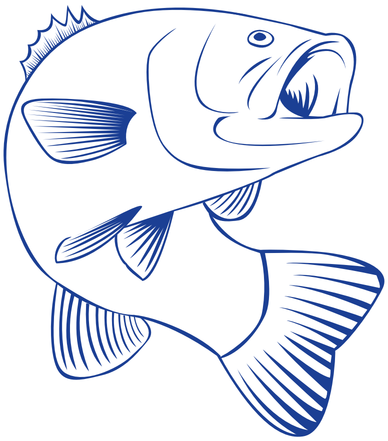
Natural processes such as stream-bank erosion and algal production also can contribute to contaminating compounds within the sediment matrix (Metro Toronto RAP Team 1988; Strus 1994).

Many of the chemical contaminants in the Toronto waterfront are bound to fine grain sediment particles and can, therefore be transported by alongshore currents. As a result, contaminant concentrations may be greater at more complex shorelines where the effects of alongshore currents and water exchange rates are low (Strus 1994). Of course, proximity, magnitude and duration of the source also characterizes the contaminant threat.

The compounds of concern in the Toronto nearshore continue to include polychlorinated biphenyls (PCB), mercury and mirex (Waterfront Regeneration Trust 2001). Bioaccumulation of these compounds produces problems for fish community health and human consumption issues (MOE and MNR 2005). Mercury levels in Toronto fish are generally similar to those found in fish collected in less urbanized areas of the Lake Ontario basin and no sources of mirex exist in the Toronto area. Contaminant levels of these compounds are indicative of lakewide pollution, mainly from Niagara River inputs (Waterfront Regeneration Trust 2001). However, PCB contamination of forage fish has been shown to vary across the waterfront, with higher concentrations in the eastern portion compared to the west (Environment Canada *et al.* 1989).

2.3.4 Invasive Species

Invasive species have also been responsible for major alterations in aquatic communities. Since the 1800s, more than 140 exotic aquatic organisms including plants, fish, algae and molluscs have become established in the Great Lakes. One of the most dramatic recent invasions has been dreissenid mussels (zebra - *D. polymorpha* and quagga - *D. bugensis*) which colonize rocky substrates and other hard surfaces. Dreissenid mussels are highly efficient filter feeders, removing substantial amounts of phytoplankton and zooplankton from the food chain. In doing so they have caused significant improvements in water clarity, which in turn is increasing the diversity and productivity of aquatic plants in the nearshore zone. Invasive crustaceans like the spiny water flea (*Bythotrephes cederstroemi*) and the fishhook waterflea (*Cercopagis pangoi*) have changed the food web of Lake Ontario for native fish species. Meanwhile, invasive fish species have increased in number and biomass in Lake Ontario over the past decade and include the ruffe (*Gymnocephalus cernuus*) and round goby (*Neogobius melanostomous*). The round goby is quickly becoming an integral component of the food chain in Lake Ontario (Dietrich *et al.* 2006a; Dietrich *et al.* 2006b). Asian carp, more specifically grass carp (*Ctenopharyngodon idella*), is also a possible invader to the Lake Ontario fish community. Grass carp are known to have been captured in Ontario as recently as 2003. However, it is believed that captures of grass carp in Lake Ontario were isolated occurrences and that there is not an established population in the lake (TRCA 2008).



CHAPTER

3

3.0 METHODS

3.1 Sample Site Selection

Sites were selected for study based on the availability of long-term fish community data and by habitat type (e.g., open coast vs. embayments vs. estuary/river mouth). Sites that were included in the analyses for this study were those that had been sampled in the majority of years spanning from 1989 to 2005 (Figure 1, Appendix A). Embayments were well represented in the historical database, having broadly similar habitat characteristics (e.g., water depth, macrophyte cover, substrate, etc.) and environmental influences (e.g., wind, temperature and precipitation).

In relation to embayments and river mouth sites, open coast habitats were not sampled as continuously throughout the time series or as extensively geographically (Figure 1, Appendix A).

Open coast habitats may be less productive than sheltered embayments as a result of intense wave action producing harsher habitat conditions dominated by low macrophyte growth and shelter availability (Randall *et al.* 1996; Brind'Amour 2005). However, inclusion of these sites was important for depicting the changes through time in the fish community of the Toronto waterfront. Interactions between nearshore and offshore and fish communities and their habitats are extremely important to the overall function of Great Lakes ecosystems.

3.2 Fish Community Sampling

Sampling occurred in summer (mid-July to late August) in each year. Electrofishing surveys were conducted at each site using a 5.5-metre Smith-Root electrofishing boat. Sampling was conducted using the Toronto and Region Conservation Authority standardized electrofishing procedure established by the TRCA for RAP and other monitoring purposes. One thousand (1,000) second transects were generally run at each sampling site. A five-person crew performed the sampling with one person driving and operating the electrofisher, while two people netted fish and two people emptied the nets into the boat's live-well. Once the transect was complete, the fish were transferred from the electrofishing boat's live-well, to another boat for processing. Fish were separated by species and measured for total length (millimetres) and weight (grams). Environmental conditions at the site and details about the electrofishing procedure used were also collected. These data included: start time

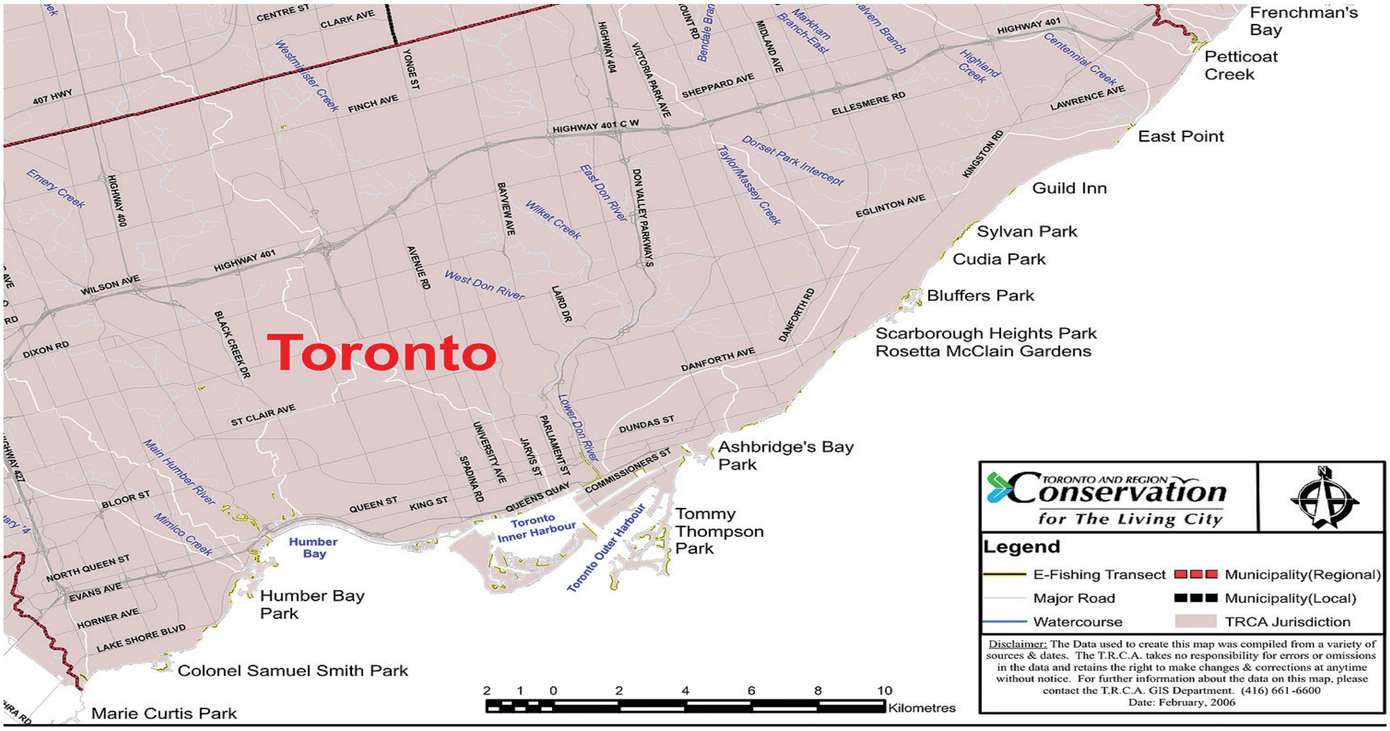


Figure 1 - Map of the Toronto waterfront illustrating the locations of the electrofishing transects conducted by the Toronto and Region Conservation Authority took place from 1989 to 2005.

of sample, electroshocking duration (seconds), amperage, voltage, off-shore distance (metres), water temperature (°C), air temperature (°C), substrate (visual inspection; sand, boulder, cobble, gravel etc.) and depth (metres).

3.3 Data Treatment

Species-specific data were grouped according to whether they were indigenous to Lake Ontario (Scott and Crossman 1998) or if they were non-indigenous and/or invasive species. A second grouping of species-specific data occurred based on thermal guild (cold, cool or warm) based on Coker *et al.* (2001).

Fausch *et al.* (1990) identified nine primary assumptions relating to the response of fish community structure to environmental degradation. Of these nine, a total of six were investigated for the Toronto waterfront. They include:

1) Overall fish abundance generally declines.
2) The number of native species declines.
3) The proportion of degradation-tolerant species increases.
4) The proportion of top-piscivores and trophic specialists declines.
5) The proportion of trophic generalists increases.
6) The proportion of non-native species increases (e.g., invasive species).

To understand the fish community dynamics of abundance; overall (all species included) and species-specific catch in numbers and biomass per 1,000 of electrofishing effort. Catch per unit effort (CPUE) and biomass per unit effort (BPUE) was calculated as an average (± the standard error) for each habitat type and for each year from 1989 to 2005. In cases where sampling effort varied, data were corrected to standardize the effort across all years.

Standardization involved multiplying the catch data by the reciprocal of the ratio of 1,000 to the number of sampling seconds. Salmonid species were not included in these analyses as they are not indigenous to the Toronto waterfront and totally dependant on stocking efforts, or their populations are greatly enhanced by such practices. A complete list of the salmonid species stocked into Lake Ontario in 2005 is shown in the Ministry of Natural Resources, Lake Ontario Management Unit Annual Report (OMNR 2006).

To assess fish community diversity, the reciprocal form of Simpson's diversity index (D) was used. Simpson's reciprocal index was calculated using Species Diversity and Richness version 2.65 (Pisces Conservation Ltd. 2001). The Simpson's diversity index is a non-parametric test that makes no assumptions about the community (Ludwig and Reynolds 1988; Southwood and Henderson 2000). Simpson's diversity index incorporates species richness and equitability and describes the probability that a second individual chosen at random from a population will be the same as the first (Ludwig and Reynolds 1988; Southwood and Henderson 2000; Magurran and Phillip 2001; Ponce-Hernandez 2004). The reciprocal form, Simpson's D, is a measure of the very abundant species in the sample, with a higher D-value indicating higher species diversity (Ludwig and Reynolds 1988; Southwood and Henderson 2000; Magurran and Phillip 2001; Ponce-Hernandez 2004) and is given by Southwood and Henderson (2000) as:

$D = 1/C$ Equation 2.1

where:

$C = p_i^2$ Equation 2.2

and where p_i is the proportion of individuals of the i^{th} species in the sample and:

$p_i^2 = N_i (N_i - 1) / N_T (N_T - 1)$ Equation 2.3

where N_i is the number of individuals of the i^{th} species and N_T is the total number of individuals in the sample.

To further illustrate the change in native vs. non-native dynamics, CPUE was calculated as an average (± the standard error) for each habitat type and for each year from 1989 to 2005. Non-native prey fish (alewife and smelt), as well as non-indigenous salmonids were not included in comparative analyses but are shown separately. Excluding alewife and smelt from such analyses was done to allow a more comprehensive look and the changes to the non-native fish community. Alewife makes up a large proportion of the catch by number of non-natives but are misleading due to their life history, which is that of a highly reproductive schooling species.

Biomass per unit effort (BPUE) was calculated as an average (± the standard error) for each habitat type and for each year from 1989 to 2005 for resident piscivores, generalists, and specialists. Healthy piscivore populations create a "predation dominant" fish community (Regier *et al.* 1979) and Hurley and Christie (1977) contended that abundance of piscivores was a key factor in maintaining a balanced fish community in eastern Lake Ontario, where environmental stresses (eutrophication) inhibited the ability of piscivores to compete successfully. In the absence of piscivores, planktivores and benthivores may dominate. Healthy piscivore populations are indicative of healthy fish communities (Fausch *et al.* 1990).

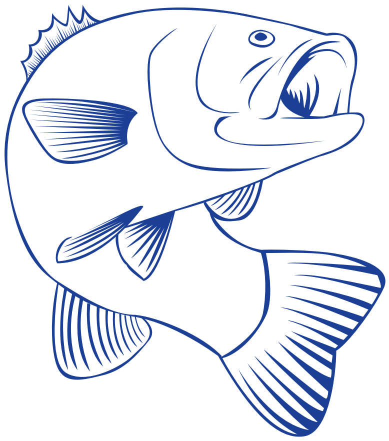
A community shift from specialized trophic species to generalist indicates a reduction in water quality or physical habitat degredation (Karr *et al.* 1986; Leneord and Orth 1986; Ohio EPA 1987). The dominance of generalist feeders increases as specific food sources become less reliable, e.g., when degraded conditions reduce the abundance of particular prey items. An opportunistic foraging strategy makes generalists more successful than specialized foragers, because they are better suited to a shifting food base (common with degraded conditions) than are more specialized feeders (Karr *et al.* 1986).

Degration tolerant benthivores, which have dominated the Toronto waterfront (Strus 1994), include the white sucker and common carp and are often associated with degraded environments (Karr 1981; Miller *et al.* 1988; Scott and Crossman 1973; Fausch *et al.* 1990). Benthivore proportion was calculated annually using the following:

> Benthivore proportion (%) = benthivore biomass total community biomass where: benthivore biomass is the total of white sucker and common carp biomass and total community biomass is the total biomass calculated for a given year estimated from the electrofishing samples.

It has been hypothesized that climate change may be responsible for changes in fish community structure in lacustrine environments (Casselman 2002; Casselman *et al.* 2003; Chu *et al.* 2003; Chu *et al*. 2005). The average annual biomass of indigenous species for each thermal guild was calculated for each habitat to investigate changes in community structure with respect to temperature preference.

TRCA Aqualab



CHAPTER 4

4.0 RESULTS AND DISCUSSION

4.1 Results

The total number of electrofishing transects that were incorporated into the analysis for the Toronto waterfront fish community summary was 425. The embayment habitat type was sampled more extensively than open coasts and estuaries. The period between 1995 and 1997 saw a general reduction in sampling effort. In relation to embayments and river mouth sites, open coast habitats were not sampled as continuously throughout the time series or as extensively geographically (Table 1, Appendix A).

The total number of fish species that were captured by electrofishing from 1989 to 2005

SITE HABITAT TYPE			
Year	Embayment	Estuary	Open Coast
1989	14	7	5
1990	13	5	7
1991	14	5	8
1992	15	6	5
1993	16	5	6
1994	15	1	1
1995	9	2	2
1996	10	0	4
1997	11	3	7
1998	19	3	7
1999	13	2	12
2000	19	3	13
2001	10	2	5
2002	20	3	4
2003	18	6	10
2004	14	3	10
2005	15	2	13
TOTAL	245	58	119

Table 1 - Number of electrofishing transects (n) done in each year in each habitat type on the Toronto waterfront from 1989 to 2005.

was 50, of which 40 were native species and 10 were non-native or invasive (Table 2). Cold, cool and warm thermal guild species were present in the Toronto waterfront, with the majority belonging to the cool guild, followed by the warm guild. Fish species typically associated with the coldwater guild were less frequently captured by the sampling programs.

Trophic group representation was variable throughout the study period, but all groups were well represented. Ten generalist species, 12 piscivore species, and 28 specialist species were observed during the study period (Table 2).

ORIGIN	THERMAL GUILD	SPECIES	COMMON NAME	TROPHIC GROUP
NATIVE	Cold	*Acipenser fulvescens*	lake sturgeon	Generalist
		Salvelinus namaycush	lake trout	Piscivore
		Prosopium cylindraceum	round whitefish	Specialist
		Cottus bairdi	mottled sculpin	Specialist
		Percopisus omiscomaycus	trout-perch	Specialist
	Cool	*Anguilla rostrata*	American eel	Piscivore
		Rhinichthys atratulus	blacknose dace	Generalist
		Labidesthes sicculus	brook silverside	Specialist
		Culaea inconstans	brook stickleback	Specialist
		Luxilus cornutus	common shiner	Specialist
		Semotilus atromaculatus	creek chub	Generalist
		Notropis atherinoides	emerald shiner	Specialist
		Notemigonus crysoleucas	golden shiner	Generalist
		Etheostoma exile	Iowa darter	Specialist
		Etheostoma nigrum	johnny dater	Specialist
		Couesius plumbeus	lake chub	Specialist
		Percina caprodes	logperch	Specialist
		Rhinichthys cataractae	longnose dace	Specialist
		Lepisosteus osseus	longnose gar	Piscivore
		Esox lucius	northern pike	Piscivore
		Moxostoma macrolepidotum	shorthead redhorse	Specialist
		Notropis hudsonius	spottail shiner	Specialist
		Gasterosteus aculeatus	threespine stickleback	Specialist
		Sander vitreum	walleye	Piscivore
		Catostomus commersoni	white sucker	Specialist
		Perca flavescens	yellow perch	Specialist
	Warm	*Pomoxis nigromaculatus*	black crappie	Specialist
		Lepomis macrochirus	bluegill	Specialist
		Pimephales notatus	bluntnose minnow	Generalist
		Amia calva	bowfin	Piscivore
		Ameiurus nebulosus	brown bullhead	Generalist
		Pimephales promelas	fathead minnow	Generalist
		Aplodinotus grunniens	freshwater drum	Specialist
		Dorosoma cepedianum	gizzard shad	Specialist
		Micropterus salmoides	largemouth bass	Piscivore
		Lepomis gibossus	pumpkinseed	Specialist
		Ambloplites rupestris	rock bass	Specialist
		Micropterus dolomieu	smallmouth bass	Piscivore
		Morone chrysops	white bass	Specialist
		Ameiurus natalis	yellow bullhead	Generalist
NON-NATIVE	Cold	*Salmo trutta*	brown trout	Piscivore
		Oncorhynchus tshawytscha	chinook salmon	Piscivore
		Oncorhynchus kisutch	coho salmon	Piscivore
		Oncorhynchus mykiss	rainbow trout	Piscivore
	Cool	*Alosa pseudoharengus*	alewife	Specialist
		Osmerus mordax	rainbow smelt	Specialist
		Neogobius melanostomus	round goby	Specialist
	Warm	*Cyprinus carpio*	common carp	Generalist
		Carassius auratus	goldfish	Generalist
		Morone americana	white perch	Specialist

Table 2 - Species name, common name, origin, thermal guild and trophic group for all species present in Toronto waterfront electrofishing database from 1989 to 2005.

Average catch per 1,000 seconds. of electrofishing showed a general decline in all habitat types since the early 1990s. The CPUEs of near 200 fish per 1,000 seconds in 1996 and 1997 were reduced to approximately 100 fish per 1,000 seconds in 2004 and 2005 in embayment habitats. An even greater reduction in CPUE was observed in the open coast habitats where, since 2002, less than 100 fish per 1,000 seconds were caught. The same general trend was observed in estuary habitats, however, with a greater magnitude of variation. The years 2002 and 2004 both had mean CPUEs less than 50 (Figure 2).

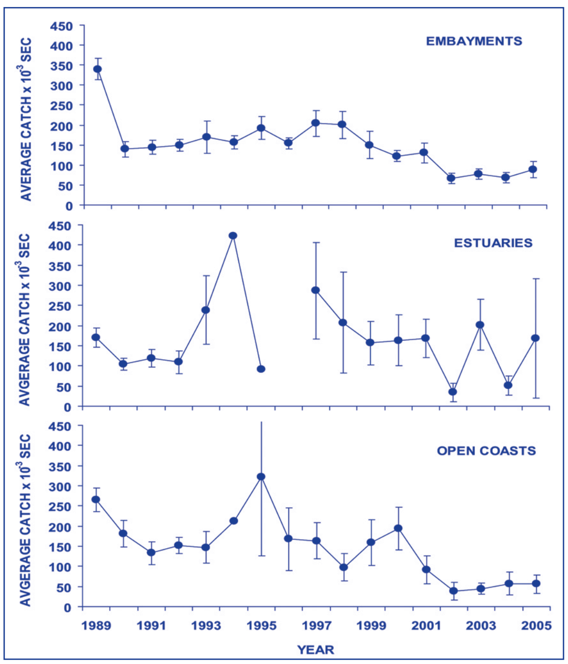


Figure 2 – Average annual catch per 1,000 seconds (± standard error) of electrofishing effort for all species combined for each habitat type in the Toronto waterfront from 1989 to 2005.

Similar to CPUE, biomass per unit effort was generally reduced since the early 1990s. However, this trend was much less pronounced in embayment habitats (BPUEs varying between 20 and 40) in comparison to estuaries and open coasts where mean BPUEs were below 10 (Figure 3).

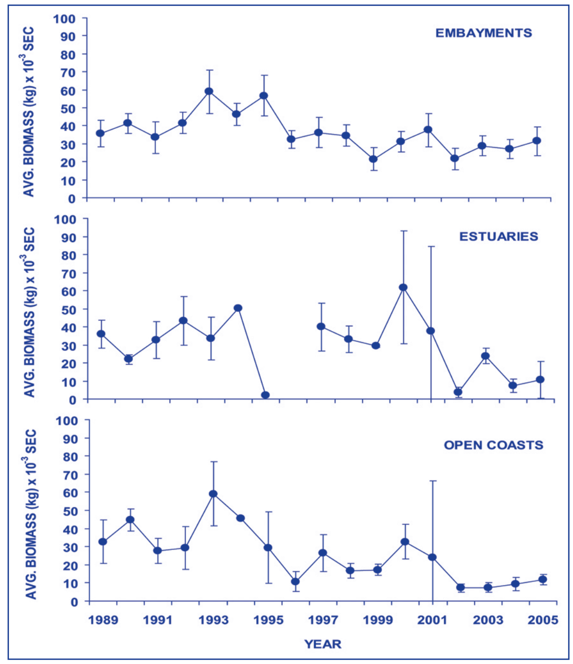


Figure 3 – Average annual biomass in kilograms per 1,000 seconds (± standard error) of electrofishing effort for all species combined for each habitat type in the Toronto waterfront from 1989 to 2005.

The reciprocal form of Simpson's diversity index markedly increased in embayment areas from 1989 to 2005. The greatest index of diversity was observed in the last year of the time series 2005 at a value of 8.3. In estuaries the index of diversity was markedly decreased and generally lower than in embayments. Diversity in the open coast habitats was lower than in estuaries and embayments throughout most of the early to mid-90s. However, diversity in the open coasts generally increased throughout the time series (Figure 4).

Walleye

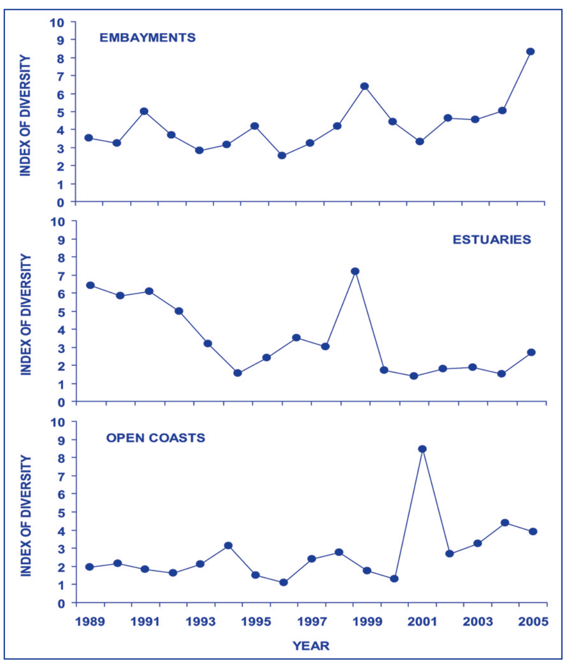


Figure 4 – Annual plot of Simpson's reciprocal index for each habitat type in the Toronto waterfront from 1989 to 2005.

The composition by biomass of the Toronto waterfront fish community remained relatively stable during the 16 year period. In embayment habitats the most dominant group were the catastomids (41per cent), which were almost exclusively represented by white sucker (Figure 5).

Second to the catastomids were the cyprinids (33 per cent), which included the common carp. Esocids (pike), clupeids (gizzard shad and alewife), ictalurids (bullheads), scaenidae (freshwater drum), and percids (perches), and centrarchids (basses and sunfish) are also representative groups (three to seven per cent each) within the embayment habitats (Figure 5).

In estuaries and river mouths cyprinids (predominantly carp) dominated the biomass (63 per cent) and catastomids (white sucker) were secondary (18 per cent). The same families as mentioned above for embayment habitats completed the community composition within estuaries and river mouths (Figure 5).

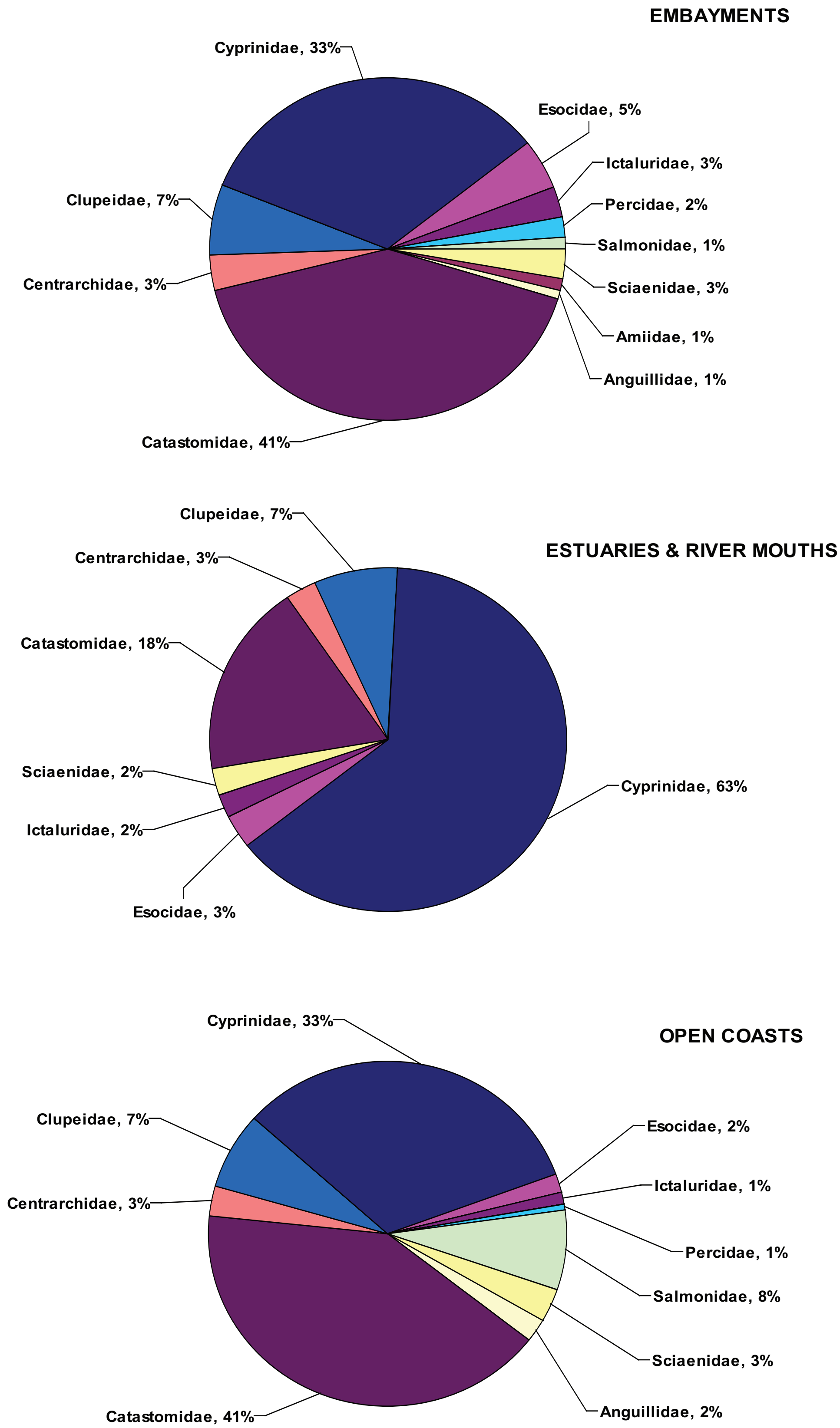


Figure 5 – Species-specific percent (%) composition of the Toronto waterfront fish community based on biomass (kilogram) for each habitat type pooled from 1989 to 2005.

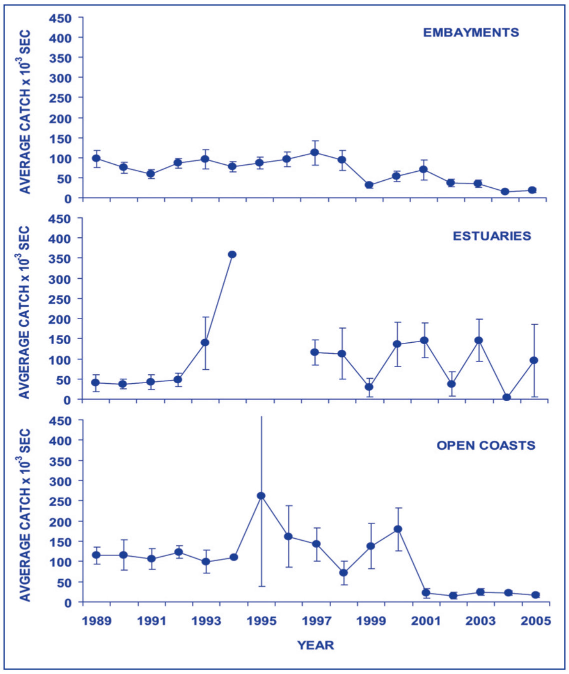


Figure 6 – Average annual catch per 1,000 seconds (± standard error) of electrofishing effort for non-native species excluding alewife, smelt and salmonids for each habitat type in the Toronto waterfront from 1989 to 2005. For a detailed list of species included as non-natve, refer to Table 2.

The open coast habitats were dominated by catastomids (41 per cent) and cyprinids (33 per cent). The same families as mentioned for embayments and estuaries completed the composition in open coasts with the exception of salmonids (8 per cent) that were present in the open coast habitat with a relatively noticeable proportions in comparison to the other two habitat types.

Non-native species CPUE (excluding alewife, smelt and salmonids) has declined in the past 16 years in embayments and open coasts. The CPUE of non-native species in estuaries has been variable and not necessarily indicative of a decline in non-native species (Figure 6). The incidence of capture of round goby increased from its first detection by electrofishing in 2003 at Cherry Beach north shore. By 2005, round goby was captured in greater numbers and at more locations, and from Humber Bay to Port Union (Table 3).

		CATCH	
Year	**Site Name**	**Embayment**	**Open Coast**
2003	Cherry Beach north		1
TOTAL		**0**	**1**
2004	Colonel Sam Smith Park boat basin	4	
	Port Union Armour Stone East		1
	Tommy Thompson Park Embayment B	4	
TOTAL		**8**	**1**
2005	Cherry Beach north		5
	Colonel Sam Smith outer breakwall		6
	Hern Gereating Station		3
	Humber Bay East East Island		10
	Humber Bay East West Island	9	
	Humber Bay West Marina Del Ray	12	
	Tommy Thompson Park Cell 3	3	
	Tommy Thompson Park Embayment A	2	
	Tommy Thompson Park Embayment B	25	
	Toronto Islands Lighthouse Bay	1	
	Toronto Islands Sunfish Cut	6	
TOTAL		**58**	**24**

Table 3: Catches of round goby by electrofishing in embayment and open coast sites in the Toronto waterfront from 2003 to 2005.

Northern Pike

The BPUE of alewife in all habitat types has declined. Alewife BPUE has successively declined since 2001 in embayments (0.08 kilogram per 1,000 seconds in 2005) and has remained low since 2001 in open coasts (approximately 0.5 kilogram per 1,000 seconds). Alewife BPUE showed a slight in increase in 2005 from 2004 in estuary habitats. The BPUE in embayments and estuaries was typically lower than in open coast habitats (Figure 7).

The BPUE of smelt relatively small in the Toronto waterfront throughout the time series in all habitats, and showed a general decline. The most notable decrease occurred in open coast habitats where in 1997 BPUE was approximately 0.7 and by 2001 BPUE was less than 0.1 (Figure 8).

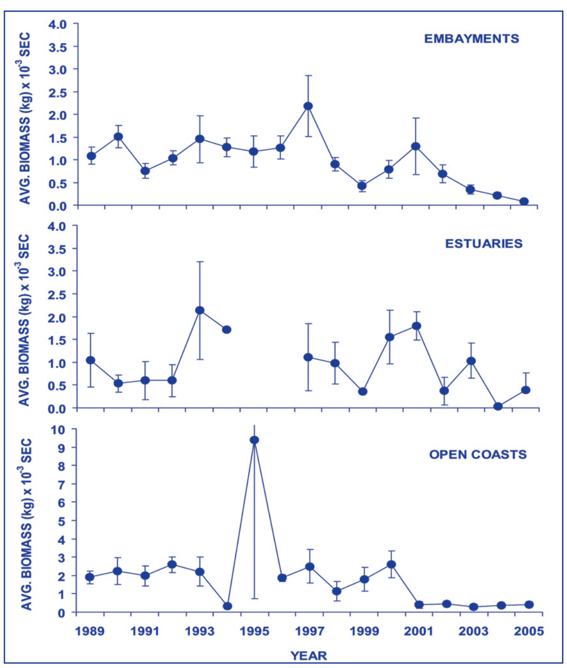


Figure 7 – Average annual biomass per 1,000 seconds (± standard error) of electrofishing effort for alewife for each habitat type in the Toronto waterfront from 1989 to 2005.

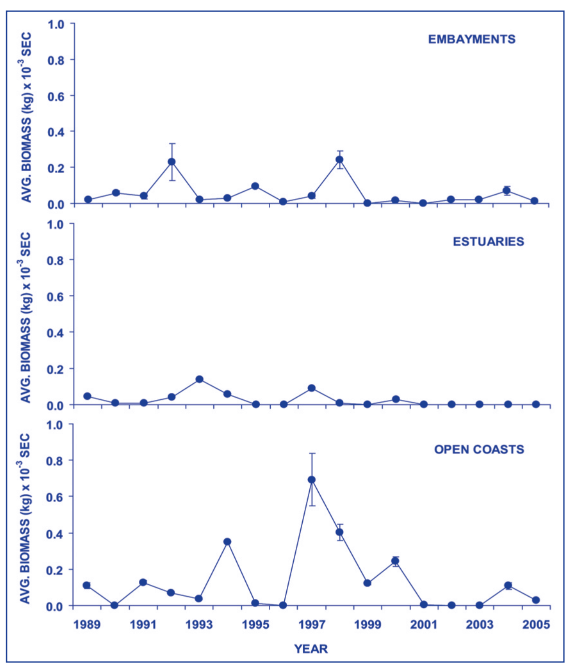


Figure 8 – Average annual biomass per 1,000 seconds (± standard error) of electrofishing effort for rainbow smelt for each habitat type in the Toronto waterfront from 1989 to 2005.

Yellow Perch

The BPUE of salmonids (rainbow trout, brown trout, lake trout, chinook salmon, coho salmon) has declined in open coast habitats since 1998. In embayments, the BPUE of salmonids has been variable although in 2004 and 2005 it was very low. The BPUE in estuary habitats remained low throughout the study period (Figure 9).

The CPUE of native species although reduced from the mid to late 1990s in embayments has gradually increased in since 2002. A similar trend occurred in estuary habitats, while in the open coasts native species CPUE has remained relatively stable since an increase from mid to late 1990s levels in 2001 (Figure 10).

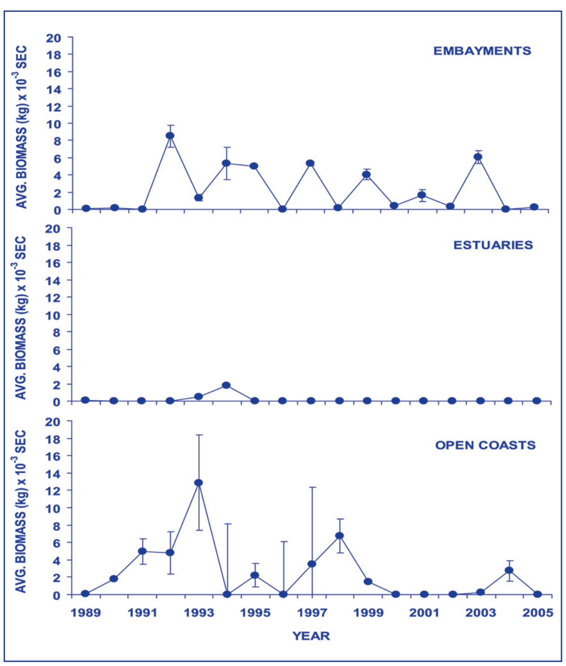


Figure 9 – Average annual biomass per 1,000 seconds (± standard error) of electrofishing effort for salmonids (Rainbow Trout, Brown Trout, Lake Trout, Chinook Salmon, Coho Salmon) for each habitat type in the Toronto waterfront from 1989 to 2005.

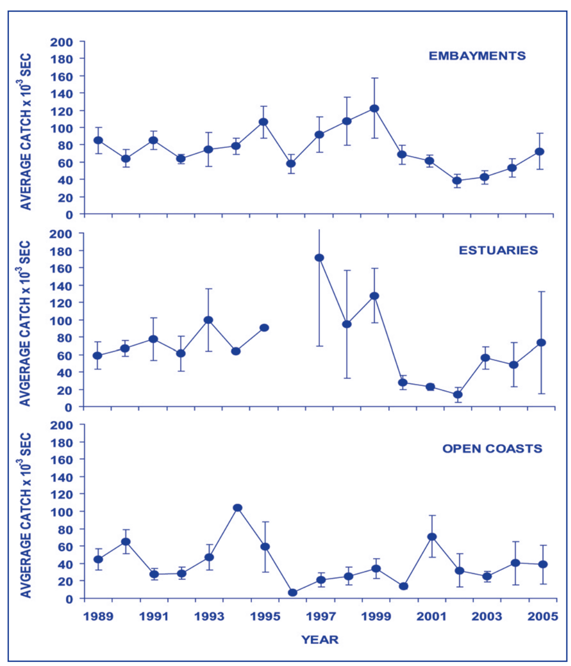


Figure 10 – Average annual catch per 1,000 seconds (± standard error) of electrofishing effort for native species for each habitat type in the Toronto waterfront from 1989 to 2005. For a detailed list of species included as native refer to Table 2.

The BPUE of native piscivore species (northern pike, smallmouth bass, largemouth bass, bowfin, walleye and longnose gar) have shown a fluctuating trend in embayment habitats. Lower levels of BPUE of approximately 20 kilograms per 1,000 seconds of electrofishing effort during the early 1990s, 1997 and 2002 were typically followed by substantial increases (50 to 70 kilograms per 1,000 seconds). The BPUE of resident piscivores in estuaries has remained relatively low in more recent years (zero to three kilograms per 1,000 seconds) in comparison to levels observed in the early 1990s (six to 34 kilograms per 1,000 seconds) and also in comparison to that of embayments. Open coast habitats have shown the opposite trend to estuaries and have shown an increase in BPUE since the early 1990s. Although at low levels the BPUE from 2003 to 2005 (eight to 12 kilograms per 1,000 seconds) has remained relatively stable in open coasts (Figure 11).

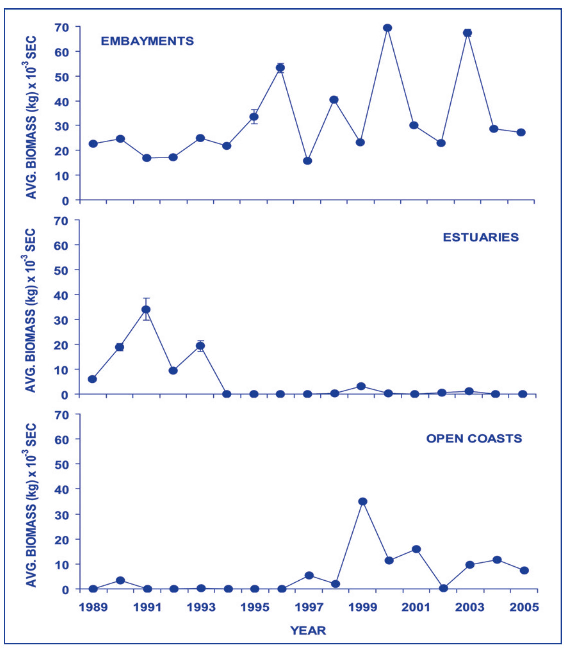


Figure 11 – Average annual biomass per 1,000 seconds ± standard error) of electrofishing effort for resident piscivore species for each habitat type in the Toronto waterfront from 1989 to 2005. For a detailed list of species included as resident piscivores, refer to Table 2.

The average CPUE of walleye in embayment habitats of the Toronto waterfront remained at low levels from 1989 to 2003 (one or two fish per 1,000 seconds of electrofishing effort), however in 2004 and 2005 Walleye CPUE showed a marked increase (nine and 14 fish per 1,000 seconds) (Figure 12).

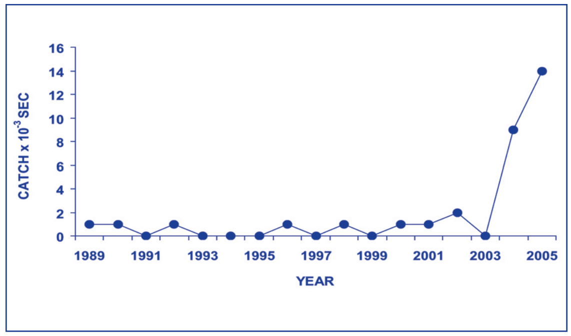


Figure 12 – Average annual catch per 1,000 seconds (± standard error) of electrofishing effort for walleye in the Toronto waterfront embayments from 1989 to 2005.

Walleye

In embayment habitats, the average BPUE of generalists has increased since 1999, while the average BPUE of specialists has decreased. In estuaries and open coasts, the average BPUE was relatively similar for both generalists and specialists from 2002 to 2005 (Figure 13).

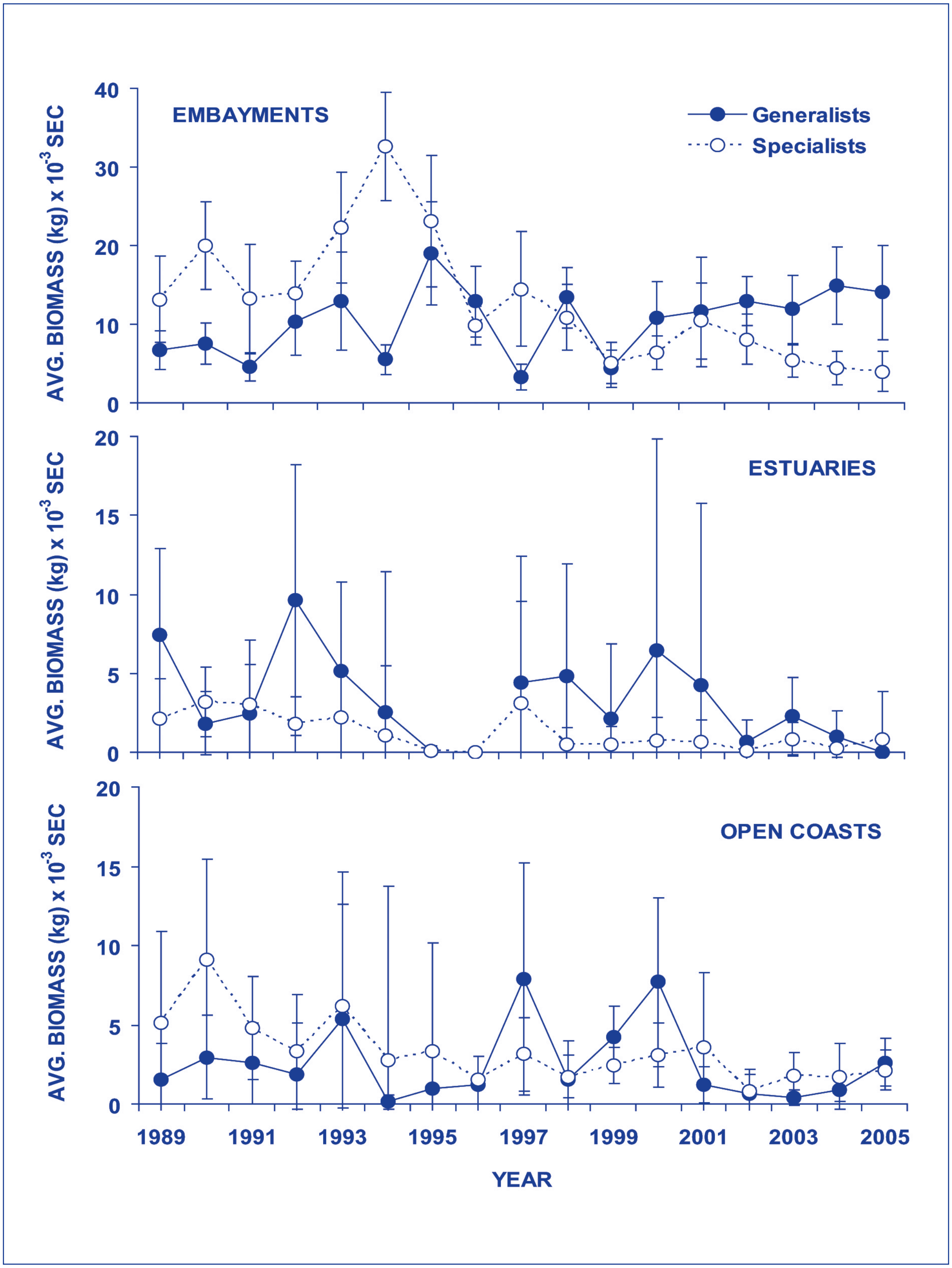


Figure 13 – Average annual biomass per 1,000 seconds (± standard error) of electrofishing effort for generalist and specialist species for each habitat type in the Toronto waterfront from 1989 to 2005. For a detailed list of species included as generalists and specialists, refer to Table 2.

The proportion of degradation-tolerant species by CPUE to the rest of the fish community has shown a general decline in embayments from 1989 to 2005 (62 per cent in 1993 compared to eight per cent in 2005). In estuaries, an overall decline in benthivores has occurred since 1997 (58 per cent), with 2004 showing the lowest proportion of degradation-tolerant species since 1997 at 12 per cent. Open coast habitats, although having showed more variability in the proportion of benthivores, has shown a marked decline since 2003 from 32 per cent to 10 per cent in 2005 (Figure 14).

White Sucker

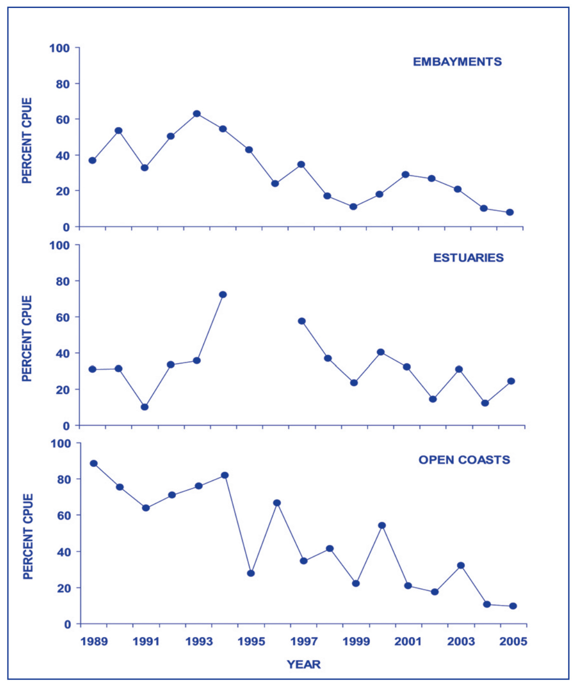


Figure 14 – Annual percent composition by catch per 1,000 seconds (CPUE) of degration-tolerant species (white sucker and common carp) of all species excluding alewife and smelt for each habitat type in the Toronto waterfront from 1989 to 2005.

Only cool and warm thermal guild species were sufficiently captured in the electrofishing surveys to allow for analysis of biomass per unit effort. In embayments warm guild average BPUE has remained relatively stable at approximately six kilograms per 1,000 seconds throughout the time series while the cool guild average BPUE has shown a gradual but marked decrease from 37 kilograms per 1,000 seconds in 1994 to levels similar to that of the warmwater guild (approximately five kilograms per 1,000 seconds) in 2005. In estuaries the average BPUE of warmwater species has been variable, but from 1998 to 2004 averaged approximately two kilograms per 1,000 seconds and slightly increased to seven kilograms per 1,000 seconds in 2005. Coolwater-tolerant species in estuaries showed higher BPUEs in the early and late 1990s and were at similar levels to that of the warmwater tolerant species.

In open coasts, the average BPUE of cool water species has been greatly reduced from level observed in the early 1990s and since 2002, BPUE has remained relatively stable (between three and six kilograms per 1,000 seconds) through to 2005. However, the average BPUE of the warm guild has shown a slight increase since 2002 to 2005 from less than one to five kilograms per 1,000 seconds of boat electrofishing effort (Figure 15).

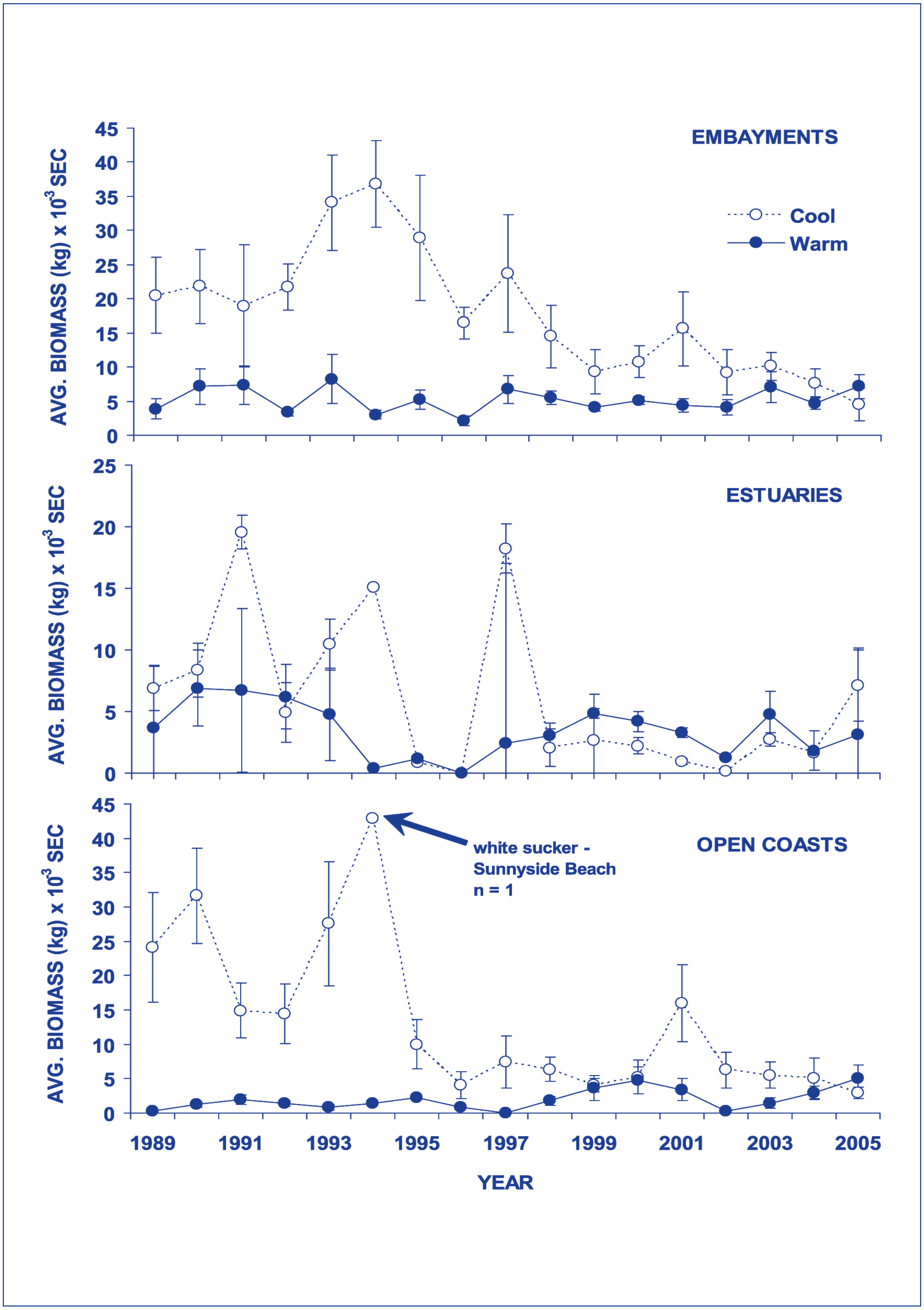


Figure 15 – Average annual biomass per 1,000 seconds (± standard error) of electrofishing effort for cool and warm thermal guilds for each habitat type in the Toronto waterfront from 1989 to 2005. For a detailed list of species included in cool and warm thermal guilds, refer to Appendix A.

4.2 Discussion

Toronto and Region Conservation Authority carried out extensive standardized electrofishing surveys along the Toronto waterfront in three habitat types; embayments, estuaries & river mouths, and open coasts. However, site transects were not fixed at all sites throughout the time series and the embayment habitats were sampled more extensively, mostly due to logistic simplicity and interest through the Remedial Action Plan process. To gain a better understanding of community dynamics in estuaries/river mouths and open coast areas, an increase and continuity in effort in these habitats is needed.

Both CPUE and BPUE for the fish community indicated a decrease in fish abundance in the Toronto waterfront which could be indicative of an environment that is degraded or has experienced further degradation (Fausch *et al.* 1990). A decrease in fish abundance may signal an increase in degradation or an increased response by the fish community to an already degraded system. This is most pronounced in embayment areas where the extent of water movement is more limited. The BPUE would be expected to be reduced as it is directly related to the CPUE. A more rigorous investigation of changes to size, growth and fecundity of declining species populations may further ellucidate the factors causing the decline in overall abundance.

The species richness observed from 1989 to 2005 through electrofishing was equal to that observed by Strus (1994). However the composition of species was not identical since the earlier report also included fish species that were captured using summer and fall seining methods. Round goby, brook silverside and longnose gar were all included in the species list in this report and were absent from assessments prior to 2003 (Strus 1994). The invasive round goby has been reported in many areas of Lake Ontario (Charlebois *et al.* 1997; Hoyle *et al.* 2003a; Dietrich *et al.* 2006) and likely has become an important prey species for many predators in the Great Lakes (Steinhart *et al.* 2004; Truemper & Lauer 2005; Dietrich *et al.* 2006a; Dietrich *et al.* 2006b).

Diversity has similarly increased in the embayments indicative of this increase in species richness. Since diversity also takes into account the proportion of each fish species in the community, it can be said that the community in the Toronto waterfront embayments is also represented by a greater abundance of fish species that were previously present in smaller numbers. The same can be said for the open coast environment. However in the estuaries and river mouths species/richness is reduced and the proportion that dominant species (white sucker and common carp) comprised increased.

Composition of the Toronto waterfront fish community has changed relatively little in the 16 years between 1989 and 2005 (also see Strus 1994). The benthivorous common carp and white sucker continue to dominate the biomass of the waterfront with other species being of lesser proportion. The proportion of these two species combined (e.g. proportion of degradation tolerant species) has shown a negative trend over the duration of the time series (1989 to 2005) in embayments, although the magnitude of reduction has been small. The reduction of benthivores in the open coast habitats has been substantial in the past four years, and in the estuary habitats in the past six years. This reduction in the per cent biomass of benthivores in these habitats may indicate a less degraded environment to previous years (Karr 1981; Miller *et al.* 1988; Scott and Crossman 1973; Fausch *et al.* 1990).

Common Carp

Coming to a conclusion regarding whether the health of the fish community of the Toronto waterfront has improved over time is not simple. The series of metrics that were used to describe the fish community were used due to their inherent ability to indicate aquatic health within an ecosystem (see section 3.2). However in this study, recent results for each metric do not collectively corroborate a direction in terms of fish community health. The results continue to indicate a degraded or further degrading environment including an overall reduction in fish abundance, a high composition of benthivores, an increase in invasive species, an increase in generalist species biomass, yet a decrease in specialist species biomass, and a decrease in coolwater thermal guild species biomass in embayments.

Results that may indicate an improvement in community health include no significant changes to species richness, a marked increase in diversity in embayments, a decline in non-native species in embayments and open coasts (despite the invasion of round goby), a recent increase in native species biomass, fluctuating native piscivore dynamics, increased walleye abundance, and a reduction in the proportion of tolerant species.

Next steps should include an analysis of the metrics applicable to the goals of the RAP. A more site-specific analysis may allow managers to make decisions regarding the effects of recent habitat improvement efforts.

Further investigation of species-specific CPUE and BPUE at individual sites within habitat types with clear hypotheses pertaining to fish community health is possible with the data summarized here and may assist managers in decision-making processes. Statistical modelling with respect to indicator species and physical and chemical data may prove useful for predicting future community dynamics and, therefore fish community health.

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APPENDIX A - Site Specific Sample Summary

SITE ID	SITE NAME	HABITAT	SITE TYPE	NUMBER OF SAMPLES
169	Ashbridge's Bay Boat Basin	embayment	RAP	14
170	Ashbridge's Bay Coatsworth Cut	embayment	RAP	11
173	Bluffer's Park Boat Basin	embayment	RAP	12
172	Bluffer's Park Marina	embayment	Project	10
154	Colonel Sam Smith Park Boat Basin	embayment	RAP	14
156	Humber Bay East Fishing Pier	embayment	RAP	13
25	Humber Bay East West Island	embayment	DFO	13
157	Humber Bay West Marina Del Ray	embayment	RAP	15
164	Tommy Thompson Park Cell 1	embayment	RAP	13
165	Tommy Thompson Park Cell 2	embayment	RAP	17
166	Tommy Thompson Park Cell 3	embayment	RAP	14
167	Tommy Thompson Park Embayment A	embayment	RAP	14
190	Tommy Thompson Park Embayment B	embayment	Project	12
168	Tommy Thompson Park Embayment C	embayment	RAP	16
98	Toronto Harbour Spadina Quay	embayment	Project	11
161	Toronto Islands Donut Island	embayment	RAP	9
160	Toronto Islands Lighthouse Bay	embayment	RAP	14
162	Toronto Islands Sunfish Cut	embayment	RAP	13
123	Toronto Islands Trout Pond	embayment	Project	12
163	Don River Keating Channel	estuary	RAP	13
152	Etobicoke Creek Marie Curtis Park	estuary	RAP	16
155	Humber Bay Park Mimico Creek Mouth	estuary	RAP	14
159	Humber River Estuary - West shore at mouth	estuary	Project	4
180	Rouge River Estuary - Main channel	estuary	Project	7
179	Rouge River Estuary - South of bridge	estuary	Project	5
184	Adams Creek mouth	open coast		1
249	Bluffers Park Fishleigh	open coast	Project	6
171	Bluffers Park outer breakwall	open coast	Project	5
182	Cherry Beach north shore	open coast	Project	6
254	Colonel Sam Smith outer breakwall	open coast	Trout Run	4
153	Colonel Sam Smith Park Filtration Plant	open coast	Project	6
262	East Point natural shoreline	open coast	Project	3
317	Hern Generating Station	open coast	Project	5
20	Humber Bay East East Island	open coast	DFO	9
24	Humber Bay East West Beach	open coast	DFO	1
320	Humber Bay West Superior Ave	open coast	Project	1
1736	Luety Lifeguard Station	open coast	Project	3
58	Pickering Shoreline Ngs Revetment - east	open coast	Project	6
59	Pickering Shoreline Ngs Revetment - inlet to discharge	open coast	Project	3
60	Pickering Shoreline Ngs Revetment - west	open coast	Project	6
61	Port Union Armour Stone East	open coast	Project	10
62	Port Union Armour Stone West	open coast	Project	3
63	Port Union Nat. Shoreline East	open coast	Project	3
64	R.C. Harris Filtration Plant Eastern Beaches	open coast	Project	3
1732	Rouge Beach West of Mouth	open coast	Project	4
175	Scarborough Shoreline Groynes - Hunt Club	open coast	Project	2
177	Scarborough Shoreline Meadowcliffe	open coast	Project	5
178	Scarborough Shoreline South Marine Drive	open coast	Project	9
176	Scarborough Shoreline Springbank	open coast	Project	5
66	Sylvan Ave Bellamy Rd.	open coast	Project	4
72	Tommy Thompson Park Trout Run	open coast	Trout Run	2
96	Toronto Harbour Eastern Gap	open coast	Project	1
110	Toronto Islands Gibraltar Point	open coast	Project	1
128	Western Beaches Sunnyside Beach	open coast	Project	2




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