Evaluating the effectiveness of aquatic habitat restoration implemented using the Toronto Aquatic Habitat Restoration Strategy

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EXECUTIVE SUMMARY

Fish populations of the Laurentian Great Lakes are impacted by a variety of stressors. Commercial and recreational fishing directly affect the fishery through harvest while other stressors, such as land use changes and degraded water quality, indirectly affect survival and reproduction through a loss or degradation of habitat. Great Lakes fisheries are also affected by competition and predation by invasive species along with changes in climate such as increasing lake temperatures. An estimated 80% of the approximately 200 fish species found in the Great Lakes use the nearshore areas for some portion of their life and as such, coastal development pressures such as shoreline modifications and watershed urbanization continue to impact the fishery.

The Toronto Waterfront Aquatic Habitat Restoration Strategy (TWAHRS) was developed by the Toronto and Region Conservation Authority with guidance from a committee of subject matter experts to provide practical information for decision-makers, designers and regulatory agencies to ensure that implementation of all waterfront projects incorporate opportunities to improve aquatic habitat. The TWAHRS includes an illustrated compendium of habitat restoration techniques intended to improve waterfront aquatic habitats for a diversity of species - fish, mammals, reptiles, amphibians, molluscs, invertebrates and plants; however, it focuses on fish because they are excellent indicators of the overall health of the ecosystem. In addition to an illustrated compendium of techniques, the TWAHRS proposes a strong framework for inter-agency cooperation prior to the start of waterfront development projects.

The overall goal of TWAHRS was to develop and achieve consensus on an aquatic habitat restoration strategy that will maximize the potential ecological integrity of the Toronto waterfront.

After TWAHRS was finalized and published in 2003, it was immediately adopted by several of the agencies from its stakeholder committee that had contributed to its inception including Fisheries and Oceans Canada, the Ontario Ministry of Natural Resources, City of Toronto, Environment Canada, Ontario Ministry of the Environment, and the Toronto Port Authority. The agency stakeholder committee was tasked with the protection, enhancement and long-term management of waterfront aquatic habitats. These were the first steps toward developing and achieving consensus on an aquatic habitat restoration strategy.

In the spring of 2006, Fisheries and Oceans Canada and its partners developed the governance framework and strategic priorities for the implementation of TWAHRS. The document describes a governance framework to facilitate delivery and to establish evidence-based strategic priorities for implementation. Shortly after, TWAHRS executives met with the Toronto Waterfront Revitalization Corporation and they adopted TWAHRS in their business planning.

Recognizing that the success of TWAHRS would lie in its use, a mechanism to implement TWAHRS would need to be developed among restoration practitioners in the Toronto Region. The establishment of an inter-agency coordinating mechanism would be multi-purposed. It would ensure that: (i) habitat opportunities are incorporated into project planning, (ii) scientific rigour, peer-review and best management practices in experimental habitat management would be used, (iii) cumulative effects of projects are identified through monitoring, and (iv) there is regular reporting on implementation of the Strategy.

The actions described above led to the establishment of Aquatic Habitat Toronto (AHT), a multi-agency partnership charged with implementing TWAHRS. The committee consists of Fisheries and Oceans Canada, Ontario Ministry of Natural Resources and Forestry, Toronto and Region Conservation Authority, Waterfront Toronto, Environment and Climate Change Canada, Ports Toronto and the City of Toronto. AHT works with proponents to facilitate project approvals utilizing an integrated planning approach. This process is guided by TWAHRS with the goal of conserving, restoring and creating aquatic habitat that was historically degraded. AHT also works collaboratively to design aquatic habitat offsetting strategies that contribute to the improvement of

local aquatic habitat supply and support decision-making by advancing scientific research and environmental monitoring. AHT provides crucial information to help decision-makers, designers, and regulatory authorities ensure that waterfront projects incorporate improvements to aquatic habitat along the Toronto Waterfront.

It has been over 15 years since TWAHRS was first implemented and as stated in the strategy document the success would lie in its use and ultimately be measured using scientific rigour to identify the cumulative effect of all projects and report on its success. This evaluation is also timely in that it will contribute to the Toronto Remedial Action Plan habitat beneficial use impairment evaluation currently underway with the goal of de-listing Toronto as an area of concern.

The overall objective of this TWAHRS evaluation project was to evaluate the effectiveness of fish habitat restoration along the Toronto waterfront between 2002 and 2019 by:

1. quantifying the extent of TWAHRS-recommended restoration techniques incorporated into waterfront development and conservation projects, and by
2. examining the response of local fish communities to restoration projects incorporating TWAHRS-recommended restoration techniques.

We examined changes in fish communities pre- and post-restoration at 28 large-scale waterfront restoration projects in open coast, estuary, embayment and coastal wetland habitat types. We used TRCA's long-term waterfront fisheries data set and detailed restoration project information to compare pre- and post-restoration fish communities to offer lines of evidence toward the effectiveness and success of the habitat works.

Between 2002 and 2019, the Strategy served as a resource to direct aquatic habitat restoration by multiple agencies at 44 waterfront projects, totaling approximately 55 ha in area. Fish communities have changed at many of the restored sites across the Toronto waterfront. Even though these changes were often unique to each restored site, some general patterns emerged.

Implementation of TWAHRS techniques at open coast sites generally created habitat for piscivores (fish that eat other fish) and other species that use cobble substrate for spawning (e.g. Smallmouth Bass, Rock Bass). This change in habitat could have also contributed to declines in Spottail Shiner and Emerald Shiner, species that use sandy shorelines, although we also found declines for these species at other restored and unrestored sites.

Restored estuary sites were limited; however, the creation of high estuary hooks and associated back water areas resulted in an increase in piscivores and species richness although these patterns were short-term and the fish community changed again likely responding to changes in substrate. Declines in Common Carp (a TWAHRS fish community objective) occurred across estuary sites.

Embayment restoration was extensive across the waterfront and fish communities consisted of primarily Pumpkinseed, Yellow Perch, Rock Bass and Largemouth Bass in the highest abundance. Many of the restored sites had lower catches for these species compared to the reference site although increasing catches of Yellow Perch and many juvenile piscivores at the restored sites is encouraging. Embayments on the Toronto waterfront continue to represent poor conditions compared to other more pristine embayment habitats of Lake Ontario; however, improvements post-restoration suggest a positive response of fish communities to habitat restoration.

Complex coastal wetland restoration was completed at three sites at Tommy Thompson Park. Restoration included the creation of berms, carp exclusion barriers and extensive aquatic plantings. Fish community response to restoration was dramatic at these sites resulting in a shift from coolwater species to warmwater species. These sites are also providing essential spawning and nursery habitat for several species of piscivore while demonstrating evidence of effective carp exclusion.

After more than 17 years of habitat restoration following the recommendations of TWAHRS, we found that fish communities on the Toronto waterfront have changed over the past 30 years both at restored sites and unrestored sites and these changes varied among habitat type. While restoration projects implemented through TWAHRS create or maintain fish habitat across the Toronto waterfront helping to restore fish communities, restoration efforts need to continue to ensure population persistence in the face of known and emerging threats in the Lake Ontario ecosystem including invasive species and climate change.

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TABLE OF ABBREVIATIONS

AHT	Aquatic Habitat Toronto
CDF	Confined Disposal Facilities
CPUE	Catch-per-unit-effort
DFO	Department of Fisheries and Oceans
HAAT	Habitat Alteration Assessment Tool
HEAT	Habitat Ecosystem Assessment Tool
H_TO	City of Toronto acronym for the chemical element water (H_2O)
IBI	Index of Biotic Integrity
LiDAR	Light Detection and Ranging
MNR	Ministry of Natural Resources
NMS	Non-metric Multidimensional Scaling
RAP	Remedial Action Plan
TRCA	Toronto and Region Conservation Authority
TTP	Tommy Thompson Park
TWAHRS	Toronto Waterfront Aquatic Habitat Restoration Strategy

1 INTRODUCTION

1.1 Background

1.1.1 A Need for Action

Fish populations of the Laurentian Great Lakes are impacted by a variety of stressors. Commercial and recreational fishing directly affect populations through harvest while other stressors, such as land use changes and degraded water quality, indirectly affect survival and reproduction through a loss or degradation of habitat (Randall et al. 1993, Minns et al. 1994). Great Lakes fish populations are also affected by competition and predation by invasive species along with changes in climate such as increasing lake temperatures (Collingsworth et al. 2017). An estimated 80% of the approximately 200 fish species found in the Great Lakes use the nearshore areas for some portion of their life cycle (Chow-Fraser and Albert 1999). The Great Lakes basin is occupied by 31% of Canada's population and as such, coastal development pressures continue to impact fish populations (Great Lakes Stewardship Initiative 2018).

Over the past 200 years, the pressures of colonization, port expansion, industry, transportation and recreation has changed the Toronto and Region waterfront almost beyond recognition. With these changes came serious environmental degradation, to the extent that in 1987, the Toronto waterfront was included on the International Joint Commission's list of 42 Areas of Concern for the Great Lakes. In recent decades, however, considerable work has started the process of restoring natural habitats and improving water quality, with promising results as aquatic and terrestrial communities have begun to show signs of recovery (Kidd 2016). At the same time, there has been renewed emphasis on increasing public access to the lake and ensuring that new development respects and enhances the special conditions and opportunities of the waterfront.

Aquatic habitat along the Toronto waterfront has been subject to major alterations, particularly due to shoreline modifications, watershed urbanization and invasive species introduction. Common historical shoreline modifications included dredging, lake filling and shoreline hardening. In addition to the direct removal of habitat, 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 mussels *Dreissena polymorpha*; quagga mussels *Dreissena rostriformis bugensis*), crustaceans (spiny water flea *Bythotrephes longimanus*) and fish (Round Goby *Neogobius melanostomus*) affected the Lake Ontario food web, and in some cases, water and habitat quality.

1.1.2 The Answer to Habitat Loss

The Toronto Waterfront Aquatic Habitat Restoration Strategy (hereafter "TWAHRS") was developed to provide practical information for decision-makers, designers, ecologists/practitioners and regulatory agencies to ensure that implementation of all waterfront projects incorporates opportunities to improve aquatic habitat. TWAHRS is intended to improve waterfront aquatic habitats for all native species - fish, mammals, reptiles, amphibians, molluscs, invertebrates and plants; however, it focuses on fish because they are excellent indicators of the overall health of the ecosystem (Karr 1981, Fausch et al. 1990, Seilheimer and Chow-Fraser 2006). TWAHRS is an excellent resource for designers and practitioners because it includes the biophysical attributes of the shoreline, an illustrated compendium of habitat restoration techniques and a habitat plan on a shoreline reach and site-specific basis.

The overall goal identified by TWAHRS was to "develop and achieve consensus on an aquatic habitat restoration strategy that will maximize the potential ecological integrity of the Toronto waterfront". The recommendations of TWAHRS were threefold; (1) to endorse the Strategy as the guiding document for the creation and restoration of waterfront aquatic habitats; (2) management to improve the ecological health of the shoreline; and (3) implementation through establishment of an inter-agency coordinating mechanism. The latter objective was successful in that the formation of *Aquatic Habitat Toronto* (AHT), an inter-agency group, was a direct product of publishing TWAHRS. The success of the other two recommendations will be evaluated through this report.

1.1.3 Endorsement, Adoption, and Implementation

The third of the three recommendations of the TWAHRS strategy was Implementation. In recognizing that the success of TWAHRS would lie in its use, a mechanism to implement TWAHRS would need to be developed among restoration practitioners of the Toronto region. The establishment of an inter-agency coordinating mechanism would be multi-purposed. It would ensure that habitat opportunities are incorporated into project planning and that scientific rigour, peer-review and best management practices in experimental habitat management would be used. It would identify cumulative effects of projects through monitoring. And lastly it would report regularly on implementation of the Strategy.

After TRCA finalized and published TWAHRS in 2003, it was immediately adopted by several of the agencies from the TWAHRS agency stakeholder committee, that had contributed to its inception. Initially, the major stakeholders of the agency stakeholder committee were the Department of Fisheries and Oceans (DFO), the Ministry of Natural Resources (MNR), City of Toronto, Environment Canada, Ministry of the Environment, and the Toronto Port Authority (PortsToronto). The AHT committee was tasked with the protection, enhancement and long-term management of waterfront aquatic habitats. It was the first step toward developing and achieving consensus on an aquatic habitat restoration strategy.

In the spring of 2006 DFO and its partners developed the *Governance Framework and the Strategic Priorities for the Implementation of the Toronto Waterfront Aquatic Habitat Restoration Strategy*. The document describes a governance framework to facilitate delivery and to establish evidence-based strategic priorities for implementation. Shortly after, TWAHRS executives met with the Toronto Waterfront Revitalization Corporation (now called Waterfront Toronto). At this time, the Toronto Waterfront Revitalization Corporation adopted TWAHRS in their business planning.

The actions described above led to the establishment of AHT, a multi-agency partnership charged with implementing TWAHRS. The committee comprises three orders of government agencies which include DFO, Ontario Ministry of Natural Resources and Forestry, Toronto and Region Conservation Authority (TRCA), Waterfront Toronto, Environment and Climate Change Canada, PortsToronto and City of Toronto. AHT works with proponents to facilitate project approvals through a streamlined approval process utilizing an integrated planning approach. This process is guided by TWAHRS with the goal of conserving, restoring and creating aquatic habitat that was historically degraded. AHT also works collaboratively to design aquatic habitat offsetting strategies which contribute to the improvement of local aquatic habitat supply and supports decision-making by advancing scientific research and environmental monitoring. AHT provides crucial information to help decision-makers, designers, ecologists/practitioners and regulatory authorities ensure that waterfront projects incorporate improvements to aquatic habitat along the Toronto waterfront.

1.2 Project Purpose

We evaluated the effectiveness of fish habitat restoration undertaken along the Toronto waterfront between 2002 and 2019 by completing the following tasks:

- Quantify the area (m^2) of habitat restored or created, along with the increase in shoreline length (m), on a project basis and by habitat type along the Toronto waterfront.
- Assess the response of fish communities to restoration projects that incorporated TWAHRS techniques.

Fish targets contained within TWAHRS, supplemented by re-designation targets defined by the Toronto and Region Remedial Action Plan (RAP), were used to assess the response of fish communities to restoration projects (Table 1).

Table 1: Fisheries Targets and Success Criteria by Habitat Type and Combined

Habitat Type	Fisheries Targets	Post-Restoration Success Criteria/Metric
Open Coast	• Rehabilitate habitat suitable for populations of cold water fishes	• Increase in cold water fish catch
Sheltered Embayments	• Increase essential habitats for top-order piscivores • Increase and improve habitat suitable for the life cycle requirements of warm and coolwater fishes	• Increase in top-order piscivore catch • Increase in warm and coolwater catch
Coastal Wetlands	• Reduce carp biomass • Increase essential habitats for top-order piscivores	• Decrease in carp catch • Increase in top-order piscivore catch
Estuaries	• Increase essential habitats for top-order piscivores • Increase and improve habitat suitable for resident and migratory fishes	• Increase in top-order piscivore catch • Increase in catch of Walleye, Largemouth Bass, Northern Pike, Smallmouth Bass
All Habitats	• Improve forage base • Native fish communities take a more diverse and stable community structure that includes an assemblage of top-order piscivores • Formerly abundant fish populations are rehabilitated	• Increase in forage base (e.g. Emerald Shiner) catch • Increase in top-order piscivore catch • Increase in formerly abundant fish populations (e.g. Walleye, Atlantic Salmon) catch

We collated available restoration information for 43 projects within the Toronto and Region Area of Concern and five projects outside it. We assigned each project a start and end date, categorized the habitat type as per TWAHRS definitions, and assigned each project the TWAHRS techniques that were used through the restoration process. The project proponent and relevant project details were also captured.

After a careful review of the data, we examined changes in fish communities at 28 large-scale, waterfront restoration projects (Appendix 1) over the past 16 years. This included projects across four habitat types recognized by TWAHRS: estuary, sheltered embayment, coastal wetland and open coast. We examined several specific metrics in each habitat type including:

- Piscivore abundance (catch per unit effort (CPUE))
- Forage base abundance (CPUE)
- Index of Biotic Integrity (IBI; Minns et al. 1994)
- Native species (CPUE)
- Thermal regime (cold, cool, warm; Eakins 2020) (CPUE)
- Fish community composition (CPUE by species)

2 METHODS

2.1 Study Site

The Toronto and Region waterfront area is located along the northern shoreline of Lake Ontario in the Laurentian Great Lakes Region of Canada. The shoreline has been heavily developed and altered over the past 200 years. The geographic scope of the Strategy is the Lake Ontario waterfront from Etobicoke Creek in the west to the Rouge River in the east extending up estuaries of rivers and creeks to the upstream extent of lake effects.

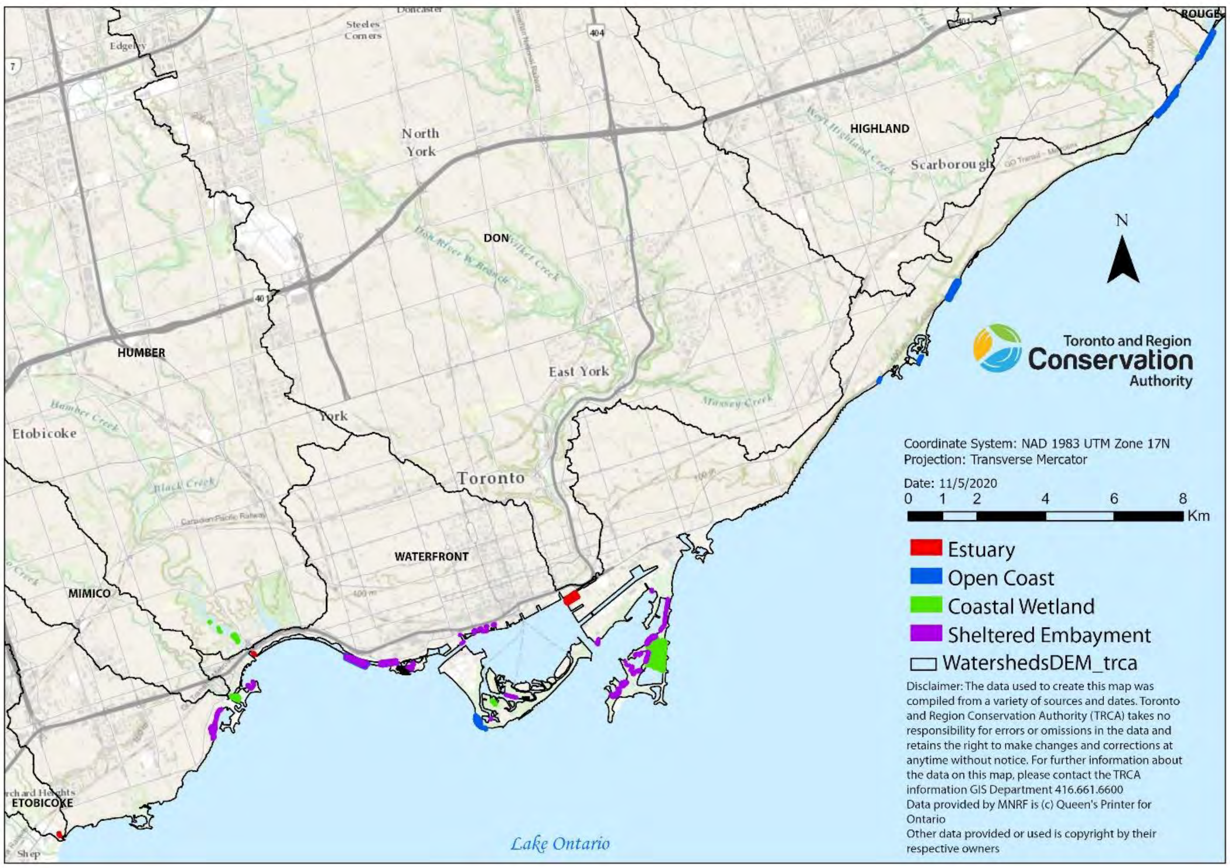


Figure 1: Map of the Toronto and Region Area of Concern with TWAHRS polygons created through this assessment shown across the waterfront.

2.1.1 Estuaries

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.

Freshwater estuary habitats are essential to the function of the waterfront as fish habitat. Healthy estuaries are very productive because they retain nutrients from the watersheds and provide stable thermal conditions. Drowned river mouths and their marshes 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 Largemouth Bass (*Micropterus salmoides*) and Northern Pike (*Esox lucius*).

The primary restoration technique suggested for estuary habitat by TWAHRS is low and high estuary hooks. Estuary hooks provide structural habitat and in-stream cover, connect to riparian habitats, and create quiet backwater areas appropriate for migrating and resident fish. Designing elevation differences in the hooks dictates the primary aquatic benefits obtained from this restoration technique. Marsh areas associated with freshwater estuaries are considered separately under the coastal wetland habitat type.

2.1.2 Coastal Wetlands

Coastal wetlands occur in estuaries at the junction of river and open coast, as well as adjacent to sheltered embayments such as those found in many of the waterfront parks. Coastal wetlands are highly productive environments that offer spawning, nursery, and refuge opportunities for various life cycle processes of fish, insects, and wildlife. Coastal wetlands improve water quality and mitigate flood and erosion impacts through acting as reservoirs or conduits of water, sediment and nutrients.

The TWAHRS suggests four techniques to be used to improve existing coastal wetlands, or to consider in the design of wetlands: 1) shoreline vegetation zones, 2) reptile habitat, 3) log tangles and 4) wetland berms. Shoreline vegetation zones are created by modifying the substrate depths to enhance vegetation growth while installing habitat for reptiles and submerging log tangles provide key preferred habitat for wetland flora and fauna. Creating appropriately sized and sited engineered berms is a critical design consideration for wetland improvements, as it enhances the sheltering benefits of wetlands, protects the nearshore from wave action, and provides the opportunity to install carp exclusion barriers. These barriers are frequently used in coastal wetland design to prevent adult-sized common carp from entering wetlands, while allowing passage of smaller or narrower fish.

2.1.3 Sheltered Embayments

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 times, artificial embayments have developed through the creation of waterfront parks and marinas.

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, including spawning, nursery and foraging habitat. Warm and coolwater species such as Pumpkinseed (*Lepomis gibbosus*), Bluegill (*Lepomis macrochirus*) and Yellow Perch (*Perca flavescens*) are commonly found in embayment habitats.

TWAHRS suggests several restoration techniques for sheltered embayments. Modifying the substrate to depths to be conducive to vegetation growth, creating fluted substrates, and underwater terracing are critical design considerations for shoreline vegetation enhancements. Conversely, modified growth of submerged aquatic vegetation can be used to reduce excessive nearshore growth. Installing log piles and tangles, anchored logs, and underwater reefs all contribute to littoral structural habitat. Shoreline treatments include submerged shoreline shoals, reptile habitats, and the use of aggregate material such as fine fill to adjust the shoreline profile. Improving the lowland riparian wood vegetation community adds structural elements to improve nearshore habitats, while providing a future source for shoreline woody debris. Constructed islands have a multitude of benefits including improving shoreline diversity and length, protecting nearshore environments from wave action, and providing nesting opportunities for birds that are less accessible to subsidized terrestrial predators. Inner harbour shoreline treatments can also introduce habitat heterogeneity to vertical seawalls.

2.1.4 Open Coast

Shorelines exposed to the open lake dominate the Toronto waterfront. These are coldwater habitats subjected to intense wave action, currents and water exchange. Hypolimnetic upwellings of cold sub-surface waters from the offshore zone are common, leading to substantial temperature fluctuations. Warmwater habitat may also occur in the spring if thermal bars are present.

In the past, open coast habitats were extensively utilized by spawning coldwater fishes such as Lake Trout (*Salvelinus namaycush*) and Lake Whitefish (*Coregonus clupeaformis*; Goodyear et al. 1982); however, as habitat quality declined over the last century and a half, and native salmonid stocks were virtually eliminated, this is no longer the case. Nevertheless, open coast shoreline still serves to connect 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.

TWAHRS suggests four techniques to be used in the creation or restoration of open coast shorelines. Repairing boulder pavement increases substrate diversity and, in many cases, replaces substrate that was removed historically through stonehooking practices. Surcharging shoreline revetments (homogeneous retaining walls) and groynes (low walls/barriers) improves shoreline diversity and adds structural elements. Installing underwater reefs enhance underwater structural habitat and may contribute to nearshore spawning opportunities for lake fish by targeting species' preferential spawning substrate.

2.2 Geomatics Layer

2.2.1 General Methods

We used ArcGIS Desktop 10.4.1 to create a layer populated by the extents of restoration projects. Three approaches were used to create this layer:

1. Overlay of existing HEAT (Habitat Ecosystem Assessment Tool)/HAAT (Habitat Alteration Assessment Tool) models.
2. Digitize project polygons using technical design drawings.
3. Digitize project polygons using pre- and post-project shoreline based on ortho images from different year periods.
    i. Year 2002 was used for the pre-project layer;
    ii. Year 2017 was used for the post-project layer; and,
    iii. Years 2018 and 2019 were used in exceptions where projects were implemented post-2017.

All project polygons were categorized to assign one or multiple TWAHRS techniques. Polygons were assigned habitat categories based on the four classes within the original TWAHRS document: Open Coast, Sheltered Embayment, Coastal Wetland, and Estuary. Polygons were assigned a HEAT category based on HEAT methodology (see below). Project polygons are presented along with their fisheries analysis. Brown and orange polygons are terrestrial, whereas green, blue, and yellow are aquatic. Projects also received a start and completion date.

2.2.2 HEAT Model Methods

The HEAT models are represented in shapefile vector format (ESRI Shapefile Format). To develop the HEAT models, users followed the methodology in published HEAT papers and unpublished guidance documents. Briefly, habitat scenario files were prepared for each project. The scenarios are based on surveys of the site before the project and prediction or knowledge of the habitat configuration and conditions proposed or indirectly altered after the development is completed. The project extent includes patches of loss, modification (both direct and indirect) and any offsets (both created and modified):

1) Loss (i.e. no longer aquatic),
2) Modified (i.e. still aquatic habitat) but either,
    i. directly modified by the project footprint, or
    ii. indirectly modified by the project's impacts
3) Offset (previously known as compensation) that has been either,
    i. created (i.e. once terrestrial)
    ii. modified (aquatic habitat that has been improved directly or indirectly as part of an offset plan).

For each habitat patch or grid cell, the area (m^2), project modification class, condition factor, depth range (0-1 m, 1-2 m, 2-5 m, 5-10 m and 10+ m), substrate percent composition (bedrock, boulder, cobble, rubble, gravel, sand, silt, clay and hardpan), and vegetation type by percent cover (submergent, emergent and no cover) are specified. A patch is partitioned by percentage into each habitat feature's intervals so that the percentages within each feature total 100% (e.g. 50% submergent, 50% emergent, 0% no cover) or proportions equal to 1.

For additional information on the published methodology for HEAT, please refer to Minns et al. (2001).

2.2.3 Technical Design Drawings

Technical design drawings are CAD-produced files that are represented in raster format (.jpeg, .png, etc.). Design drawings were compiled for all TWAHRS projects available, where HEAT models were not created. Overhead design schematics were imported into ArcMap and georeferenced to the project location. Project polygons were then created based on design drawing details. Post-project orthophotos were consulted to ensure the project was built to design specifications. Overhead and side profile designs were also used to inform the presence of underwater aquatic habitat. In some cases, as-built drawings were also available, and post-project habitat details such as individual woody material and boulder structures at Tommy Thompson Park's (TTP) restored coastal wetlands were able to be captured. Project polygons were created following the same habitat type categorizations as HEAT methodology prescribes. Projects were designed considering the DFO high-water mark of 75.3 metres above sea level (masl), meaning that all project changes occurring under this elevation were designed and intended to be considered aquatic, as per HEAT methodology guidance. As such, polygons below the 75.3 masl contour were categorized as modified or offset/compensation, and those above were considered loss or unchanged. Polygons above the high-water mark were considered in the majority of cases to be riparian habitat and were assigned a corresponding TWAHRS technique. Attribute tables were populated with as much information, such as substrate type and changes in depth, as feasible.

2.2.4 Orthophoto Interpretation

In cases where HEAT models did not exist, and detailed design drawings were not available, orthophoto interpretation was combined with any additional project information (project reports, aggregate material and plant nursery invoices, personal communication) to create project polygons. The City of

Toronto orthophoto for 2002 was used as the basis for pre-TWAHRS conditions. In most cases, the 2017 orthophoto was used to digitize post-project conditions. Upon starting this analysis, 2017 was the most up-to-date image available, and the 2017 photo had been used by TRCA to digitize the Toronto and Region land use including shoreline to a scale of 1:2,000. In addition, City of Toronto orthophotos are captured via aircraft in the spring, and the 2002 and 2017 orthophotos were flown over periods of time when monthly mean water levels were comparable at 74.98 and 75.18 masl, respectively (DFO 2019). This made pre- and post- digitization of restoration polygons more accurate and comparable.

Project polygons were then finalized as described in above sections, by filling attributes and assigning TWAHRS techniques and HEAT categories. A further step of ensuring the project polygons were categorized appropriately was applied, in the absence of HEAT models and detailed design drawings. A contour layer derived from LiDAR (Light Detection and Ranging; Airborne Imaging, 2014-2015) with accuracy of 0.5 m was applied and all polygons were examined to ensure the delineation between aquatic and terrestrial habitat types fell between the 75 and 75.5 masl contour.

2.2.5 Shoreline Length Determination

Pre- and post-project shoreline lengths were determined using orthophoto interpretation. The 2002 and 2017 City of Toronto orthophotos were used to digitize any changes or differences in shoreline length. For certain projects completed after 2017, for which design drawings were available, the 2018 and 2019 City of Toronto orthophotos were used to estimate post-project shoreline length. For post-project shorelines, which include HEAT models, design drawing and orthophoto interpretation, shoreline lengths were snapped to the outside edges of the project polygons. In cases where HEAT models and design drawings exist, the pre-restoration shoreline was snapped to the inside of the project polygons. It should be noted that the 2002 orthophoto is of lower resolution than 2017, and so the accuracy of this assessment for sites without HEAT and design drawings is impacted. To define the boundary of the shoreline, the extent of the post-restoration polygons was used to determine start and stop points for the shoreline, keeping the extents consistent between pre- and post- analysis.

2.3 Fisheries Analysis

2.3.1 Data Collection

Electrofishing surveys were conducted during the ice-free season from 1989 to 2018 at sites along the 72 kilometres of shoreline that fall within TRCA jurisdiction. Data from only July and October were used in the analysis of this study, in order to control for amount of sampling effort as well as seasonal influences.

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 TRCA for the Toronto and Region Remedial Action Plan (RAP) and other monitoring purposes (Valere 1996). Generally, stations were sampled for approximately 1000 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.

2.3.2 Habitat Restoration

Waterfront restoration projects occurred during various years between the late 1980s and 2019, with the scope of this project focusing on projects implemented after TWAHRS was established. Due to this variability, we assessed each restoration site separately. Habitat restoration techniques at each site varied and considered a number of factors but generally followed the compendium of restoration techniques outlined in the Strategy. A full list of restoration projects by habitat type, the TWAHRS technique used and time periods used are shown in Appendix 1: TWAHRS restoration projects assessed including restoration action/date and reference sites by habitat type.. We compared fish communities pre- and post-restoration at the habitat type scale (estuary, embayment, coastal wetland, open coast). Several sheltered embayment sites were slips and we considered these a sub-category. We examined the dataset to determine what data were available pre- and post-restoration at each site.

In addition to restored sites, we examined temporal trends in fish communities at several “reference” sites. These sites either had no restoration (i.e. a natural sand shoreline) or were restored prior to 1987. This allowed us to control for general changes in fish communities that occurred since the 1980s during restoration site assessments. Reference sites included for this assessment included East Point Park Natural Shoreline (no restoration), Scarborough Shoreline South Marine Drive (armourstone wall 1987), and Colonel Samuel Smith Park Outer Breakwall (armoured shoreline 1975). The main purpose of this initial assessment of reference sites was to determine which fish species are declining or increasing without restoration and to remove these from the assessment. Several additional reference sites were considered and assessed for comparison purposes for each restored site by habitat type. Reference sites only included an analysis of changes in species-specific CPUE (if there were sufficient data).

2.3.3 Data Analysis

The raw data were exported from a corporate Microsoft Access database to excel for manipulation and analysis. The data used in the analysis were limited to July night-fishing runs to ensure that year-to-year analyses were comparable and due to known variability in fish communities between night and day fishing and among seasons (Sanders 1992, Smith 2017). Night-fishing runs included runs conducted between 17:00 and 04:00. Several issues with sampling time were identified in the database with runs being entered and stored incorrectly. For example, day records could have been night records and vice versa. A sub-set of RunUIDs (unique identifiers) were randomly selected to verify the time with the Fish Collection Record field sheet used to record data at the time of sampling. This verification was isolated to 15% of the runs that occurred between 17:00 and 04:00 but also including runs labelled as occurring at 00:00 for July only. This assessment was restricted to runs that occurred between 1989-1999 and 2008-2018 due to a limited availability of field sheets from 2000-2007. The assessment determined that 100% of runs labelled as night runs or 00:00 were truly collected at night. Coastal wetlands (TTP Cell 1, TTP Cell 2 and TTP Embayment D) were analyzed using daytime electrofishing data because they were only surveyed during the day post-restoration. Any other deviations from the use of July night-fishing data are explicitly stated in the results for the site.

We calculated CPUE for each species for each electrofishing run as the number of individual fish per 1000 shocking seconds. Top-order piscivores selected for analysis include Northern Pike, Walleye (*Sander vitreus*), Largemouth Bass, Smallmouth Bass *(Micropterus dolomieu*) and Bowfin (*Amia calva*). These species were selected based on their occurrence in the Toronto area and their inclusion in the *Fish communities of the Toronto waterfront: summary and assessment 2006-2016* report (TRCA 2018) along with comments received on that document. Atlantic Salmon (*Salmo salar*), Chinook Salmon (*Oncorhynchus tshawytscha*), Coho Salmon (*Oncorhynchus kisutch*), Brown Trout (*Salmo trutta*) and Rainbow Trout (*Oncorhynchus mykiss*) were chosen as species that migrate into lentic systems in the fall season. The thermal regime (cold, cool, warm) was determined for each fish species using information from the Ontario Freshwater Fishes Life History Database (Eakins 2020). Water temperature changes are also reported for each site since water temperature has been shown to be more important than habitat structure in predicting species presence (Creque et al. 2006).

Forage fish were considered to be those that remain small for their entire life cycle and occur in large numbers (McCullough and Stegemann 1992). Common forage fish of New York State include Alewife (*Alosa pseudoharengus*), Rainbow Smelt (*Osmerus mordax*), Slimy Sculpin (*Cottus cognatus*), Gizzard Shad (*Dorosoma cepedianum*) and Trout-perch (*Percopsis omiscomaycus*; McCullough and Stegemann 1992). Northern Pike are opportunistic feeders although Gizzard Shad, Alewife, Yellow Perch and Trout-perch are especially common in its diet (Inskip 1982). In Lac Ste. Anne, Alberta, Northern Pike consumed primarily perch, Spottail Shiner (*Notropis hudsonius*), Burbot (*Lota lota*) and White Sucker (*Catastomus commersoni*; Diana 1979). Smallmouth Bass prey species include Bluntnose Minnow (*Pimephales notatus*), Central Stoneroller (*Campostoma anomalum*), Northern Creek Chub (*Semotilus atromaculatus*) and Fantail Darter (*Etheostoma flabellare*; Lachner 1950). The diets of Smallmouth Bass and Largemouth Bass are similar with Largemouth Bass consuming sunfish, crappies, shiners, minnows, goldfish, silverside, bullhead and shad among others (Lasenby and Kerr 2000). Walleye consume an enormous variety of fish including sucker (*Catostomus* sp.), crappie (*Pomoxis* sp.), Alewife, Gizzard Shad, sculpin (*Cottus* sp.), shiners, Yellow Perch, White Bass (*Morone chrysops*), Rainbow Smelt, trout and salmon, Bluegill, Burbot and Freshwater drum (*Aplidonotus grunniesns*) among many others (Hartman 2009). Based on this brief literature review, a forage fish species list was created from species captured in embayment, open coast, estuary and wetland habitats in Toronto and adjusted based on expert opinion (Appendix 2). Some of these species grow to larger sizes during their development (e.g. Gizzard Shad, Freshwater Drum, White Perch (*Morone americana*), Yellow Perch) and were only considered forage fish if they were less than 150 mm in length. We determined this limit by first calculating the average size of each piscivore species in our data set (Largemouth Bass, Smallmouth Bass, Northern Pike, Walleye and Bowfin) then determining the prey size consumed at that body length using Mittelbach and Persson (1998). We averaged the prey size consumed by these species, at these average lengths, to determine the cut-off length of 150 mm. Bowfin were not available in Mittelbach and Persson (1998) so Northern Pike was used as a surrogate. Data that were collected in bulk were not qualified to be included in the forage analysis, as only smallest and largest lengths were recorded, and it is not possible to discern which of these fish fall below the selected size threshold.

We calculated IBI scores for each electrofishing run based on Minns et al. (1994). This IBI was developed using data from electrofishing transects conducted in the littoral zones of Lakes Ontario and Huron within Areas of Concern (Minns et al. 1994). The IBI uses three groups of information to calculate a single IBI value for each site including species composition, trophic composition and abundance/condition (Minns et al. 1994). In general, a higher IBI value represents a site with more native species and individuals, a higher biomass of native species, more Centrarchid species, more native Cyprinid species, more intolerant species, a higher % piscivore and specialist biomass, fewer non-indigenous species and individuals, a lower % non-indigenous species biomass and a lower % biomass of generalist species. All species were considered in the IBI calculations including species showing lake-wide temporal trends that were removed from all other analyses. We used the converted and adjusted IBI as recommended by Minns et al. (1994) for the assessment. The adjusted IBI calculation removes offshore species since their presence likely only represents sporadic incursions into nearshore habitat (Minns et al. 1994). Considering the removal of offshore species, the species that remain in the analysis that are removed from examination of other metrics include White Sucker, Round Goby and American Eel. We only examined the final IBI value for each individual site assessment, and not the individual IBI metrics.

We used Non-metric Multidimensional Scaling (NMS) to examine changes in fish communities pre- and post-restoration. NMS is an ordination technique that can be used for non-normal data and is generally considered one of the most effective ordination techniques used for ecological community data (McCune and Grace 2002). We used the metaMDS function from the vegan package in R statistical software with the default Bray-Curtis distance measure (R Core Team 2018). We report the stress and results only for the first two axes. Pre-restoration years and post-restoration years were grouped and compared using 95% confidence interval ellipses. We also examined the correlation between each species' CPUE and year at each site using non-parametric Spearman correlation (rho). For correlations, those with $p<0.05$ were considered significant and those with a $p<0.10$ were considered approaching significance.

IBI scores were not reported for all years for boat slips because sampling alternated between 500 and 1000 electrofishing seconds. We reported adjusted IBI values for Peter and Rees Slips for a limited number of years that all were sampled using 1000 second runs. Adjusted IBI scores for Spadina and Simcoe Slips were not reported due to limited data and variability in sampling effort. The North West and South East footpad electrofishing runs in Embayment C at TTP were assessed using only runs that were 500 seconds or close to 500 seconds (e.g. 508). This makes these individual site assessments not comparable to other individual site assessments reporting IBI values.

A pooled assessment by habitat type was conducted after each individual site was assessed independently. The pooled assessment used only the IBI and its associated metrics. The goal of this assessment was to pool the data from each habitat to examine the overall effectiveness of restoration. Changes in the IBI and its associated metrics were examined based on years since restoration. This is a generalized scale related to the number of years pre- or post-restoration. For example, if a site was restored in the year 2000 and data were available for 1998 and 2002, these time points would be marked as -2, 1 and +3. This creates a relatable scale across restoration sites that often had variable restoration dates. Only July night-fishing data were used for this assessment. We standardized for sampling effort (# electrofishing seconds) by only including electrofishing runs that were between 900 and 1100 seconds. Most electrofishing transects were 1000 seconds and using this range resulted in the removal of 57 runs. If there were several years considered to be "during restoration" in the individual site assessments, these years were removed from the analysis. Boat slips were not included in this assessment due to a lack of pre- and/or post-restoration data or limited data in general. The number of electrofishing runs by year were examined to ensure that only one site (or a few) were representing a year and influencing the overall results. The adjusted IBI along with each of the IBI metrics were compared pre- and post-restoration using paired t-tests after testing for any deviations from normality.

3 RESULTS

3.1 Geomatics Summaries (quantities of area restored - areas and shoreline lengths)

Table 2: TWAHRS Restoration Projects Summary with Restored Areas, within TRCA's Jurisdiction (Etobicoke Creek to Carruthers Creek)

Habitat Type	Project Name	TWAHRS Techniques	Restoration Period	Area - Aquatic & Riparian (m^2)	Area – Terrestrial (m^2)	Total Project Area (m^2)	Change in Shoreline Length (m)
Coastal Wetland	Embayment D (Inside)	Wetland Berms; Exclusion Barrier; Complex Shoreline Profile Improvements; Aquatic Vegetation; Shoreline Vegetation Zones	2012-2014	59668	2413	59668	*+1355 (includes Emb D outside)*
	Humber River Marsh #1	Wetland Berm; Exclusion Barrier; Shoreline Vegetation Zones	2012-2013	13020	413	13433	-35
	Humber River Marsh #2	Reptile Habitat; Anchored Logs; Log Tangles	2012-2014	368	-	368	0
	Humber River Marsh #3	Reptile Habitat; Anchored Logs; Log Tangles	2012-2015	1583	-	1583	0
	Mouth of Mimico	Wetland Berm; Exclusion Barrier; Complex Shoreline Profile Improvements; Wetland Shoreline Profile; Shoreline Vegetation Zones; Anchored Logs	2010	19155	1323	20478	+332
	Toronto Island Site 3	Wetland Shoreline Profile; Shoreline Vegetation Zones	2011-2012	1156	-	1156	+341
	Toronto Island Site 4	Wetland Shoreline Profile; Shoreline Vegetation Zones	2012-2013	354	-	354	+194

Habitat Type	Project Name	TWAHRS Techniques	Restoration Period	Area - Aquatic & Riparian (m^2)	Area – Terrestrial (m^2)	Total Project Area (m^2)	Change in Shoreline Length (m)
	TTP Cell 1	Wetland Berm; Exclusion Barrier; Shoreline Shoal; Log Tangles; Anchored Logs; Reptile Habitat; Shoreline Vegetation Zones; Lowland Riparian Woods	2004-2007	50950	63870	114820	+242
	TTP Cell 2	Wetland Berm; Exclusion Barrier; Shoreline Shoal; Log Tangles; Anchored Logs; Reptile Habitat; Shoreline Vegetation Zones; Lowland Riparian Woods	2015-2017	67353	69568	136921	+1450
Estuary	Etobicoke Creek Recreation Node 1	Shoreline Shoal	2011	217	200	417	0
	Etobicoke Creek Recreation Node 2	Shoreline Shoal	2017-2018	427	301	728	0
	Humber Estuary Hooks	High Estuary Hooks	2007-2008	459	519	978	+62
	Essroc Quay	Complex Profile Shoreline Improvements; Exclusion Barrier; Wetland Berm; Shoreline Shoal; Log Tangles; Log Piles Shoreline Vegetation Zones	2017-2019	9788	449	10237	-193
Open Coast	Bluffers Beach	Surcharged Groyne	2018	5536	-	5536	0
	Fishleigh	Surcharged Revetment	2017	1307	799	2106	+2
	Frenchman's Bay Outside*	Surcharged Revetment	2012-2014	5074	3214	8288	0
	Gibraltar Point	Underwater Reef	2018-Present	34542	643	35185	+83
	Meadowcliffe	Surcharged Groyne	2011-2013	50109	19739	69849	+537

Habitat Type	Project Name	TWAHRS Techniques	Restoration Period	Area - Aquatic & Riparian (m^2)	Area – Terrestrial (m^2)	Total Project Area (m^2)	Change in Shoreline Length (m)
	Port Union Phase I	Surcharged Groyne	2001-2006	27005	44896	71902	+605
	Port Union Phase II	Surcharged Groyne	2008-2012	21721	37898	59619	+606
	Western Beaches Rowing Facilities (Outside)	Surcharged Revetment	2006-2007	17371	5304	22675	*+214 (includes inside)*
	Marksbury Road*	Boulder Pavement Repair; Shoreline Shoal	2009	1621	-	1621	0
Sheltered Embayment	Bathurst Slip	Shoreline Shoal	2017	57	-	57	0
	Western Beaches Rowing Facility (Inside)	Surcharged Revetment, Log Tangles	2006-2007	60008	-	60008	*+214 (includes outside)*
	Embayment A	Wetland Berms; Wetland Shoreline Profile; Reptile Habitat; Anchored Logs; Complex Shoreline Profile Improvements; Shoreline Vegetation Zones; Shoreline Shoal; Lowland Riparian Woods	2009-2010	9832	4577	14409	+566
	Embayment B	Wetland Berm; Shoreline Shoal; Complex Shoreline Profile Improvements; Anchored Logs; Log Piles; Log Tangles	2011	1010	1262	2272	+732
	Embayment C	Log Tangles; Log Piles; Anchored Logs; Shoreline Shoal; Wetland Berms; Exclusion Barrier; Shoreline Vegetation Zones; Complex Shoreline Profile Improvements; Wetland Shoreline Profile; Lowland Riparian Woods	2008-2011	13670	2031	15700	+822

Habitat Type	Project Name	TWAHRS Techniques	Restoration Period	Area - Aquatic & Riparian (m^2)	Area – Terrestrial (m^2)	Total Project Area (m^2)	Change in Shoreline Length (m)
	Embayment D (Outside)	Constructed Islands, Shoreline Vegetation Zones, Wetland Shoreline Profile, Shoreline Shoal, Log Tangles	2012-2014	11942	1720	13662	*+1355 (includes Emb D inside)*
	Frenchman's Bay (Inside)*	Surcharged Revetment; Log Tangles	2012-2014	22473	181	22654	+782
	Hearn Recreation Node	Shoreline Shoal; Anchored Logs	2015	81	580	661	-7
	Humber Bay East Fishing Pier	Shoreline Shoal; Log Piles; Log Tangles; Shoreline Vegetation Zones; Lowland Riparian Woods	2018	2150	146	2297	-2
	Mimico Linear Phase I (Superior Avenue)	Constructed Islands; Complex Shoreline Profile Improvements; Shoreline Vegetation Zones	2006-2008	13606	24972	38578	+401
	Mimico Linear Phase II (Marina Del Ray)	Complex shoreline profile improvements; Shoreline Shoal; Shoreline Vegetation Zones	2011-2012	3847	-	3847	
	Long Pond	Wetland Shoreline Profile; Shoreline Vegetation Zones; Anchored Logs, Shoreline Shoal; Constructed Islands	2014-2015	1821	36	1857	+124
	Ontario Place (Inside)	Exclusion barrier; Shoreline Shoal; Anchored logs	2006	5501	104	5605	+18
	Peter Slip	Shoreline Shoal; Inner Harbour Quay Treatments	2007	864	-	864	0
	Rees Slip	Shoreline Shoal; Log Tangles; Inner Harbour Quay Treatments	2009	572	-	572	0
	Simcoe Slip	Shoreline Shoal; Log Tangles; Inner Harbour Quay Treatments	2009	821	364	1184	-10
	Spadina Slip	Shoreline Shoal; Aquatic Vegetation; Anchored Logs; Inner Harbour Quay Treatments	2008	2245	-	2245	0

Habitat Type	Project Name	TWAHRS Techniques	Restoration Period	Area - Aquatic & Riparian (m^2)	Area – Terrestrial (m^2)	Total Project Area (m^2)	Change in Shoreline Length (m)
	Trout Pond Recreation Node	Shoreline shoal, anchored logs	2017	183	97	279	0
	Tommy Thompson Park West Shore	Anchored Logs, Shoreline Shoal, Log Tangles; Lowland Riparian Woods	2016-2018	5397	25	5423	0
	Ontario Place West Channel	Shoreline Shoal	2014-2015	3585	1713	5298	+1
	Lakefront Promenade	Shoreline Shoal; Inner Harbour Quay Treatments	2006	440	-	440	0
	Western Gap Shoals	Shoreline Shoal; Inner Harbour Quay Treatments	2014	53	-	5	0

*Denotes project is outside of the Toronto Region Area of Concern

3.2 Fisheries Analysis - Project Scale

3.3 Open Coast Projects

3.3.1 Reference Site – East Point Park Natural Shoreline

Changes in fish community were examined at a reference site, East Point Park Natural Shoreline. This site has not received any anthropogenic corrective restoration action and is considered relatively natural for the Toronto region landscape. Likely, stonehooking activities took place in the nearshore environment, but these influences are historic, and no changes were made during the time frame examined here.

Figure 2: East Point Park Natural Shoreline, 2018. *(Source: City of Toronto)*

This site was also used for the initial assessment to identify species with lake-wide species population trends. Due to a limited amount of night electrofishing data, only data from 1991, 1996, 1997 were compared to data from 2017, 2018, 2019. These comparisons identified several species undergoing temporal changes in CPUE and were subsequently removed from all further analyses within this document (Appendix 3). This analysis included only July night electrofishing data and has had the species showing temporal trends removed.

After removing species showing temporal trends, there were very few species left at this site. Two Rainbow Trout, one Brown Bullhead (*Ameiurus nebulosus*) and two Lake Chub (*Couesius plumbeus*) were caught in 1991. One Common Shiner (*Luxilus cornutus*) and one Gizzard Shad were caught in 1996. In 1997, 1 Common Carp (*Cyprinus carpio*) and 13 Emerald Shiner (*Notropis atherinoides*) were caught (note that sampling effort was 300 sec in 1997 compared to 1000 sec in other years). In 2017 and 2019, no species were caught other than Alewife. In 2018, two Gizzard Shad were caught.

3.3.2 Port Union Waterfront Improvement Project

We examined changes in fish communities at an open coast system comprising three electrofishing transects: Port Union Armourstone West, Port Union Armourstone East and Port Union Natural Shoreline East. These sites formed the Port Union Waterfront Improvement Project, which is considered in this study one of the first TWAHRS implementations.

The design of this shoreline erosion control structure is a modification of the surcharged open coast groynes from the TWAHRS compendium of techniques. This technique promotes that aquatic habitat is implemented in tandem with critical erosion control structures. The clusters of large armourstone provide structural habitat and offshore protection and anchoring of smaller aggregates. A mixture of aggregates is placed at the end of the groynes or headlands and within the beach cells. Aggregates form shoals along the beach and act as important wave zone and shallow water habitat. This site also received the technique boulder pavement repair. Large aggregate is placed at the toe of the beach to anchor surcharged stone and to replace historically depleted lakebed stone.

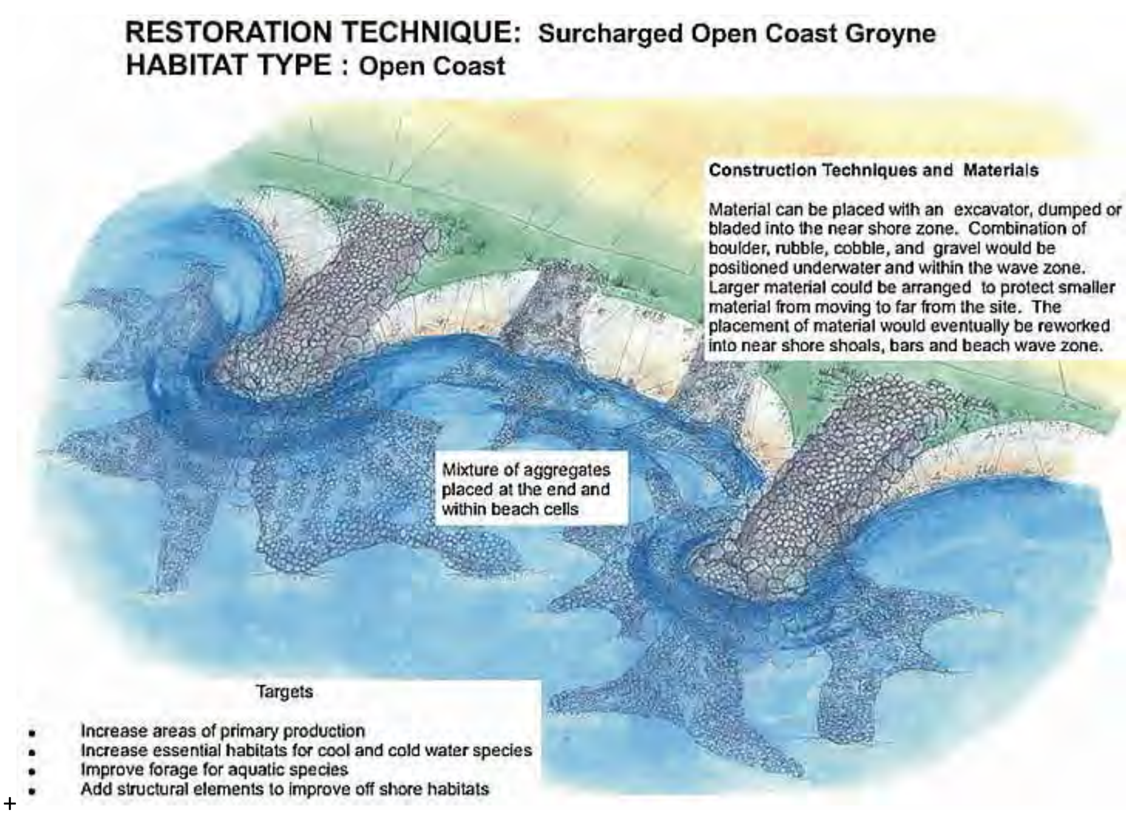


Figure 3: Habitat technique concept from the TWAHRS compendium of techniques (TRCA 2003)

The location of this project is centered around Port Union Road. It's bound by Lake Ontario to the south, Highland Creek to the west and Rouge River to the east. The waterfront improvements included lakefilling for a waterfront corridor to accommodate two pedestrian tunnels, to provide safe public access to the waterfront, and to mitigate shoreline erosion. Pre-restoration conditions varied across the 3.6 km shoreline. From west to east, the shoreline was formed by a dynamic sand and gravel beach at most 50 m from the waterline to the toe of a railway embankment. Adjacent to Port Union Road, the shoreline consisted mainly of an armourstone revetment, as well as a cobble beach retained by a vertical seawall sheetpile enclosure. The nearshore of this area consisted of a sand, cobble and gravel pavement with some boulders interspersed. The centre reach was characterized by a moderately high and continually eroding bluff, fronted by a narrow sand and gravel beach. This configuration gave way to the confluence of Adam's Creek, flanked by a narrow sand and cobble beach. The nearshore was populated with cobbles from the eroding shoreline drumlin. The shoreline west of Rouge beach was primarily armourstone revetment, with a few exceptions of sand and gravel beaches (TRCA 2002).

Restoration addressed waterfront erosion and introduced some heterogeneity to the nearshore environment. A preferred option was chosen through the Port Union Waterfront Improvement Environmental Assessment. The proposed shoreline included two headland beach systems, a larger headland promontory which functions as a pedestrian node, and two existing dynamic beaches at the western and eastern ends of the project. Prior to restoration, Adam's Creek emptied into the lake through a sewer conduit. Through this project it was opened and restored to a small seasonally inundated coastal wetland, providing habitat for frogs and other marsh wildlife. Chesterton Shores, the area between Phase I and Phase II, was estimated to take between 30 and 50 years to erode to the pedestrian trail and railway tracks, leaving future erosion control measures on an as-needed basis. To compensate for the 17.5 ha of lakefilling, gravel and cobble beaches were installed between the headlands, and two coastal wetlands at Adam's Creek and Highland Creek were restored. These elements comprised the on-site Fish Habitat Compensation Plan. Additional offsite compensation at TTP Cell 1 was required. TRCA was the proponent of this restoration project. Construction of Phase I (westernmost headland beach system) spanned from 2002 to 2006, with Phase II scheduled to begin in 2003. In actuality, Phase II was constructed between 2008 and 2012.

Figure 4: Port Union Phase II detail: Armourstone headland, cobble beach, and Adam's Creek mouth (TRCA 2013)

Figure 5: Cobble beach natural sorting and recruitment of woody debris at Port Union Phase I (TRCA 2009)

The expected TWAHRS outcomes of this project were as follows. Both the offshore boulder pavement repair technique and the surcharged groyne technique targeted increasing areas of primary production, increasing essential habitats for cool and coldwater species, improving forage for aquatic species, and adding structural elements to improve offshore habitats.

Table 3: Restoration Summaries for Port Union Phase I and Phase II.

Area Restored	TWAHRS Techniques Used	Aquatic Area (m²)	Terrestrial Area (m²)	Increase in Shoreline Length (m)
Phase I: Port Union Armourstone West	Surcharged Groynes, Boulder Pavement Repair	27,005	44,895	605 (52% increase)
Phase II: Port Union Natural Shoreline East		21,720	37,900	606 (60% increase)
Port Union Waterfront Park	Surcharged Groynes, Boulder Pavement Repair	48,725	82,795	

3.3.3 Phase I: Port Union Armourstone West

This shoreline received the TWAHRS treatment type of surcharged open coast groynes between 2002 and 2006. Constructed groynes took the form of armourstone headland systems, with a cobble beach extending underwater among headlands to a depth of approximately 1.5 metres. Over time, wave conditions and beach sorting resulted in a stable shoreline condition with some cobbles and larger aggregate contributing further offshore to pavement repair.

1999 2018 2018

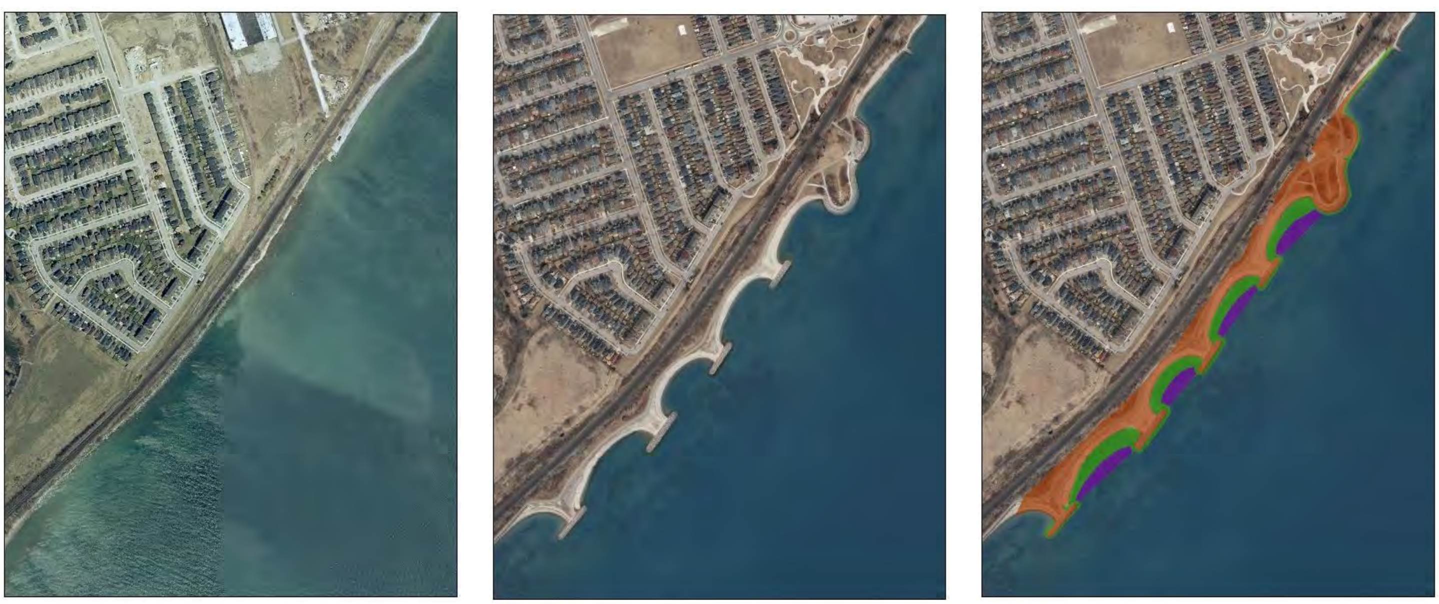


Figure 6: Port Union Phase I project before (left) and after (centre). Project polygons are shown on the far right. (Photos: Triathlon Mapping 1999; City of Toronto 2018).

With only two years of pre-restoration data (1999 and 2000), it was difficult to draw conclusions about the effectiveness of restoration at this site. Piscivore CPUE ranged from zero in both 2000 and 2018 to 13 individuals in 2016. Native piscivores using this site included primarily Smallmouth Bass although one

Northern Pike was caught in 2015. Smallmouth Bass CPUE may be higher post-restoration but again, with only two years of pre-restoration data, it is difficult to know if these high catches could have occurred in other years pre-restoration and there was no significant increase in Smallmouth Bass CPUE ($p>0.211$). Forage and native CPUE also appeared to have several years that were higher post-restoration, but high catches of forage and native species again may have happened in pre-restoration years but were missed. Adjusted IBI scores were generally lower than other habitat types and variable at this site over the entire time period ranging from 55 in 2009 to 19 in 2014. This site is approximately 1 km east of the mouth of Highland Creek and is likely being used as a staging site by fall migratory species including Chinook Salmon caught in 1998 and several Rainbow Trout caught in 2013, 2014 and 2015.

The fish community consisted of primarily cool and coldwater species with few warmwater species. Coolwater species included primarily Smallmouth Bass, Emerald Shiner and Rock Bass (*Ambloplites rupestris*). Coldwater species were relatively numerous here compared to other sites and included mostly Chinook Salmon but also many Rainbow Trout and Brown Trout. One Atlantic Salmon, one Lake Chub and one Trout-perch were also caught. Warmwater species were few but included Brown Bullhead, Logperch (*Percina caprodes*) and Common Carp. Brown Bullhead and Spottail Shiner (*Notropis hudsonius*) CPUE decreased significantly between 1999 and 2019 ($r=-0.609$, $p=0.027$ and $r=-0.620$, $p=0.024$, respectively) although Spottail Shiner were only found in low abundance in 1999 and 2000. Changes in fish communities were also difficult to interpret in the ordinations due to limited pre-restoration sampling. Community ordination suggests that Brown Bullhead, Spottail Shiner and Trout-perch had higher catches in pre-restoration years. Both short-term and long-term post-restoration fish communities appeared more similar than those pre-restoration with the most commonly occurring species including Yellow Perch, Smallmouth Bass, Rock Bass, Emerald Shiner and Chinook Salmon.

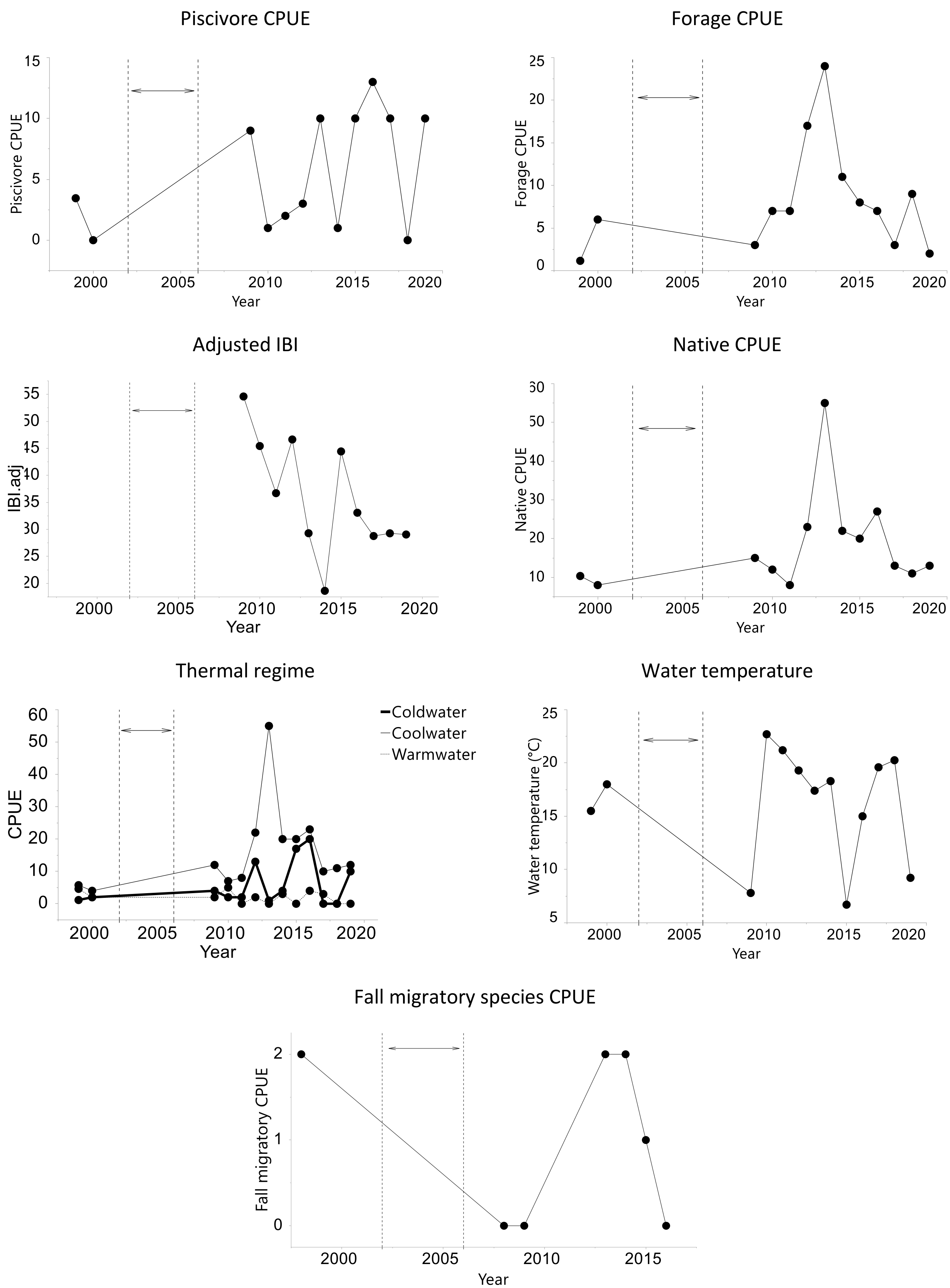


Figure 7: Port Union Phase I TWAHRS Assessment Metrics

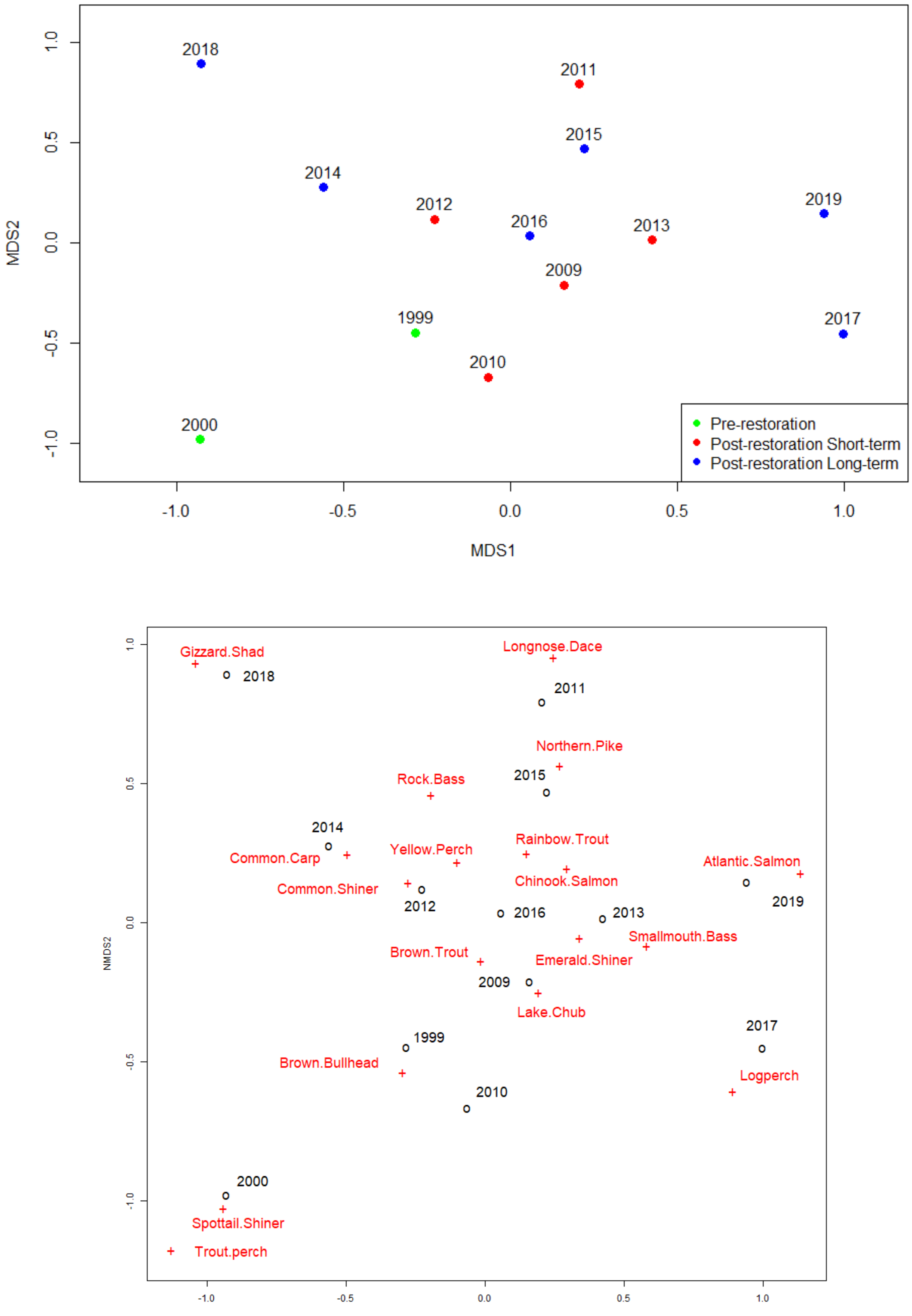


Figure 8: Port Union Phase I Community Ordination (Stress = 0.13)

The targeted fisheries objectives of the TWAHRS techniques used here were accomplished. The site is shown to be used by primarily cool- and coldwater fish in the post-restoration timeframe. Notably, an Atlantic Salmon, a coldwater species undergoing recovery in Lake Ontario, was captured at this site in 2019. Foraging opportunities varied and peaked in 2013, primarily attributed to Emerald Shiner using the site. Although the low amount of pre-restoration data prevents determining significance of species CPUEs using the community ordination, it is clear that Brown Bullhead, Spottail Shiner and Trout-perch are associated with pre-restoration years. All other fish mentioned, including the native piscivores and coldwater species are found to be associated with post-restoration years. The addition of structural elements to improve offshore habitats appears to have created suitable habitat for rock-loving species, such as Rock Bass, Smallmouth Bass, and Logperch, which use the site post-restoration. Smallmouth Bass in particular may be using this site to forage for Round Goby, a species that was removed from the analysis due to increasing lake-wide populations trends and the poor fidelity of electrofishing as a method of capturing this species (Appendix 3).

3.3.4 Chesterton shoreline (Port Union Armourstone East)

There was no restoration along the shoreline for the majority of this electrofishing run although it is located between Port Union Armourstone West and Port Union Natural Shoreline East (two sites with surcharged open coast groynes). The east end of the run does intersect with the most western groyne of Port Union Phase II, including the restored confluence of Adam's Creek mouth. Restoration actions occurred in 2002-2006 to the west (Phase I) and in 2008-2012 to the east (Phase II). We examined this site to discern if there are any co-benefits of the flanking restoration work to this shoreline. This site has the longest record of electrofishing monitoring (1996-2019), so a long-term look at any shifts in the fish community is possible here. This site may also serve as a reference source of pre-restoration fisheries conditions to compare the adjacent restored areas.

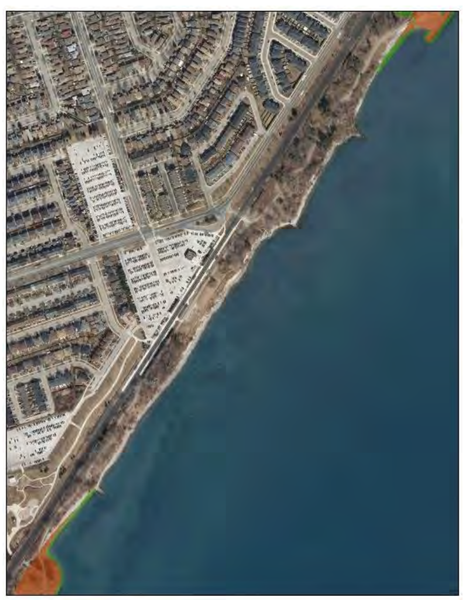


Figure 9: Chesterton Shoreline, between Port Union Phase I and Phase II. (Photo: City of Toronto 2018)

There was no restoration directly at this site but we may expect changes in fish communities related to nearby restoration projects. Piscivore CPUE was variable but stable and was completely represented by Smallmouth Bass since it was the only piscivore at this site. Smallmouth Bass have become more common at this site occurring in every year since 2013 although increasing temporal trends in CPUE were not statistically significant (p=0.122). Rock Bass were also found more frequently in later years and the occurrence of these species could be due to increases of this species at nearby restored sites. Forage CPUE appeared to have declined since 2013 and this pattern reflects forage CPUE patterns at Port Union Armourstone West (approximately 500 m west of this site). At this site, the potential decrease appears to be related to Emerald Shiner CPUE which peaked in 2012 and 2013 then declined post-2013. Native species CPUE also appeared to have declined post-2013 but this may just be reflecting the inter-annual variation at this site. Adjusted IBI values were variable ranging from 10 in 2007 to 57 in 2010. October night-fishing data were lacking at this site (only three years) and only captured one Chinook Salmon in 1998. One Rainbow Trout was captured during a day-fishing run in 2004.

The fish community consisted of primarily cool and coldwater species with few warmwater species. Coolwater species included primarily Smallmouth Bass, Emerald Shiner and Threespine Stickleback (*Gasterosteus aculeatus*). Coldwater species were relatively numerous at this site also compared to other sites and included mostly Chinook Salmon but also many Rainbow Trout, Brown Trout and Lake Chub were caught. One Trout-perch was also caught. Warmwater species were few but included primarily Logperch with fewer Brown Bullhead, Common Carp and Freshwater Drum caught. Fish communities were similar when comparing pre-restoration and post-restoration time periods from nearby Port Union restoration projects.

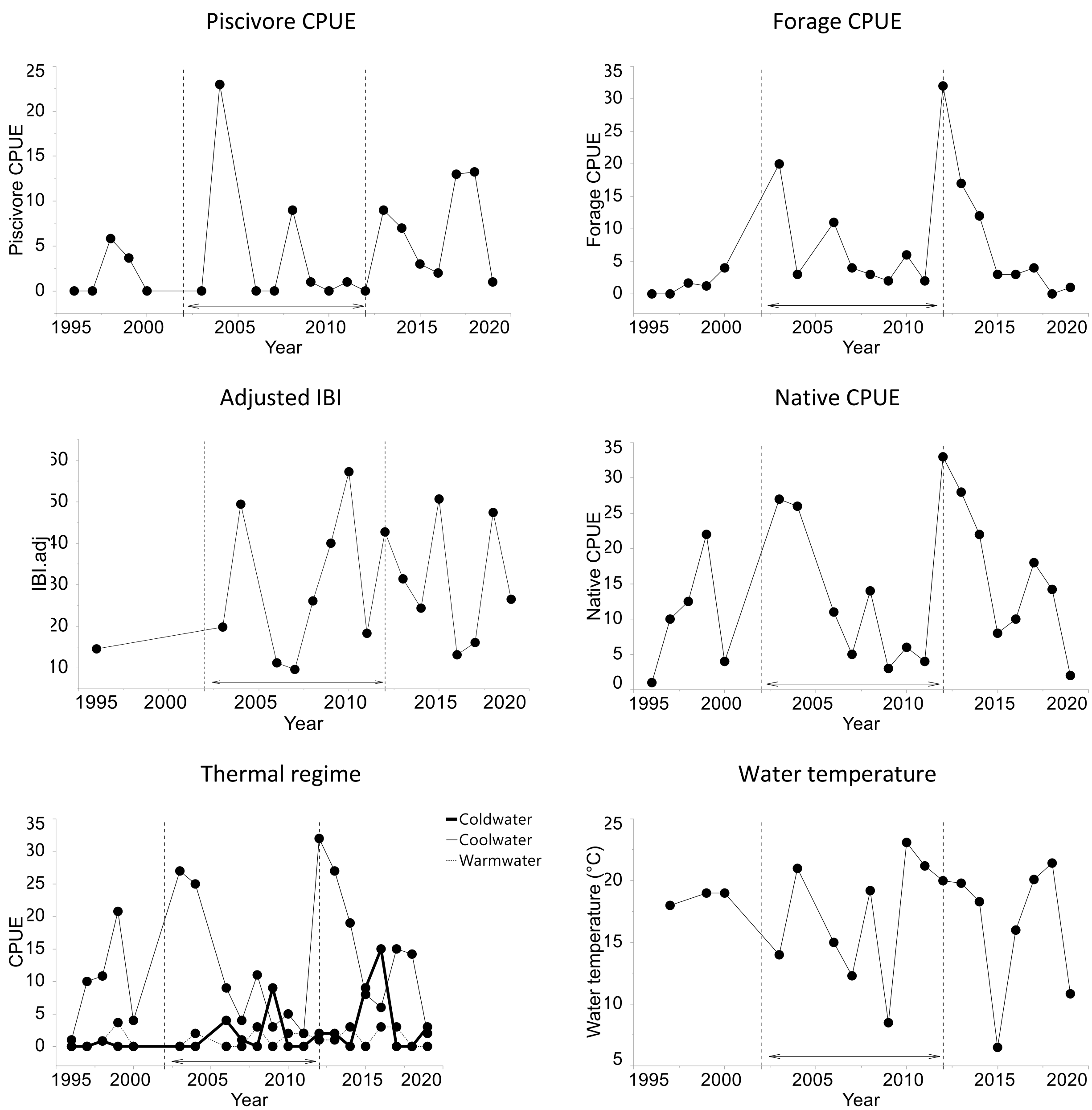
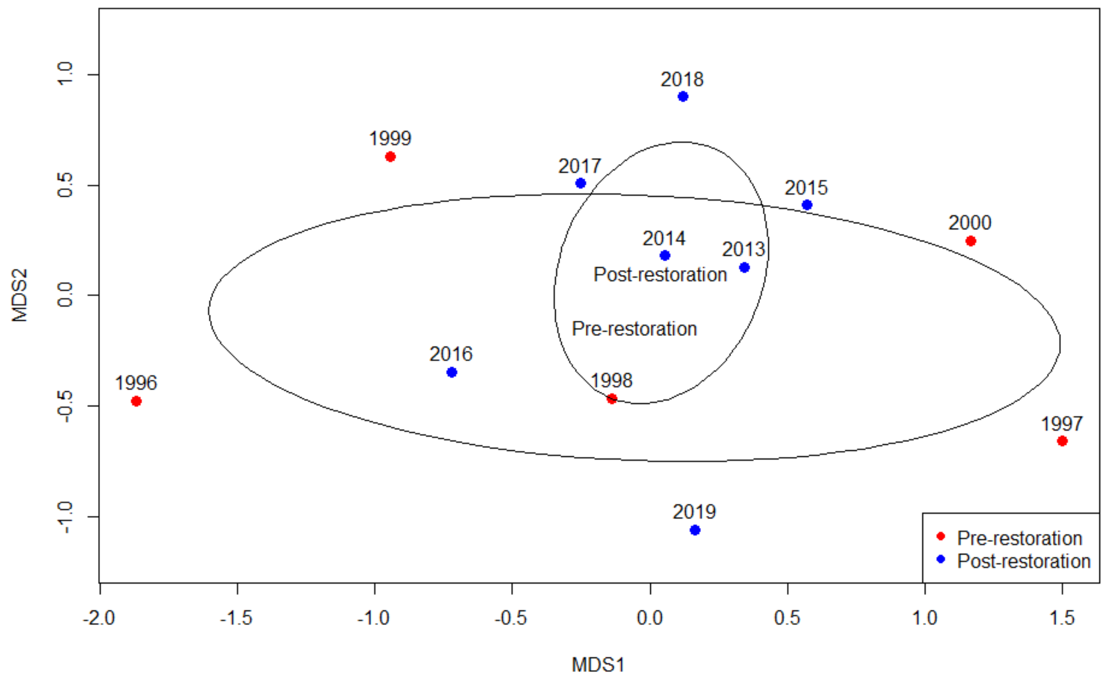


Figure 10: Chesterton Shoreline TWAHRS Assessment Metrics



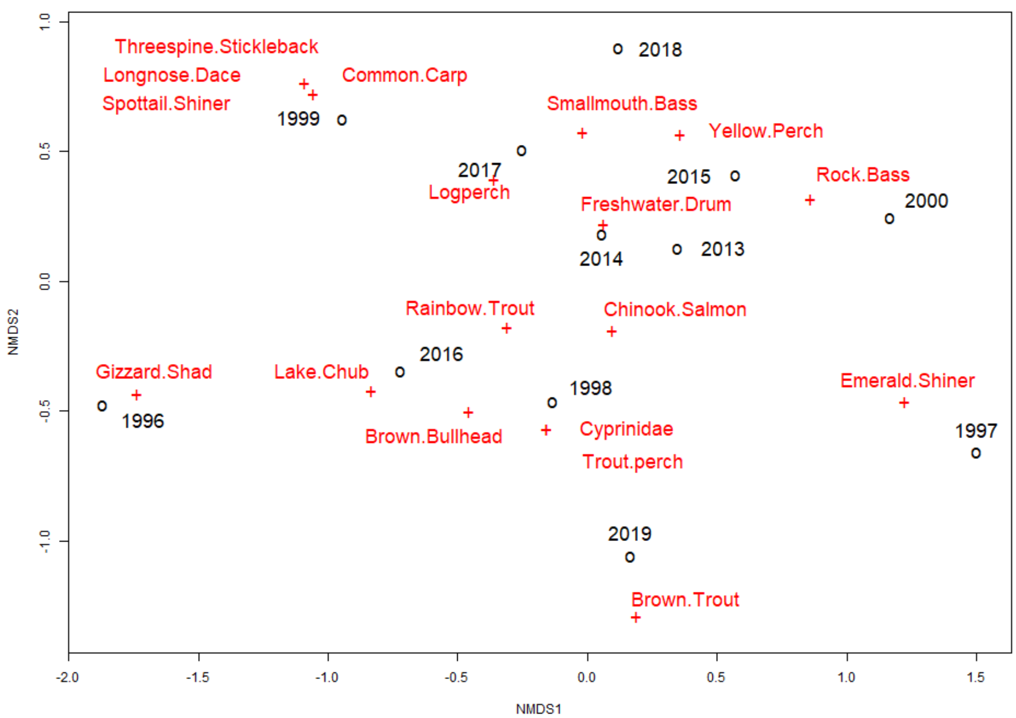


Figure 11: Chesterton Shoreline Community Ordination (Stress = 0.17)

The community in pre-restoration years did not differ significantly from the community in post-restoration years, indicating that the flanking restored sites may not have influenced a shift in species composition or catch rates at this transect. This is in line with the ordinations from the two restored transects, although there are fewer pre-restoration data available at these sites. There were no significant increases or decreases in individual species CPUE over time, although the site is used heavily by Smallmouth Bass. Coolwater species dominate the catches, and coldwater fish use of the site peaks after Phase I and Phase II restoration, as does native and forage catches, although these can be attributed to schooling Emerald Shiners. The local benefit of this site may be the variability in habitat it provides among the cobble beaches, ensuring fish using this shoreline originating from Highland Creek, Adam’s Creek or the Rouge River have access to nearshore sand substrate.

3.3.5 Phase II: Port Union Natural Shoreline East

Completion of this site culminated the Port Union Waterfront Project. This stretch of shoreline received a similar treatment as Port Union Phase I, with groynes receiving cobble surcharging. Constructed groynes took the form of headland systems, with a cobble and gravel beach extending underwater among headlands to a depth of approximately 1.5 metres. Wave action was attenuated among the headlands, creating localized shelter along the open coast. Over time, wave conditions and beach sorting resulted in a stable shoreline condition with some cobbles and larger aggregate contributing further offshore to pavement repair. Construction took place from 2008 to 2012.

Figure 12: Port Union Phase II project before (left) and after (centre). Project polygons are shown on the right. *(Photos: Triathlon Mapping 1999; City of Toronto 2018)*

With only one year of pre-restoration data (1999), it was difficult to draw conclusions about the effectiveness of restoration at this site. This site was used heavily by piscivores with CPUE ranging from 2 in 2016 to 23 in 2013 (10 individuals on average). Smallmouth Bass was the dominant native piscivore using this site although one Northern Pike was caught in 1999. Forage and native CPUE was the highest in 2013 immediately post-restoration. Adjusted IBI scores were only available post-restoration and were variable ranging from 62 in 2015 to 18 in 2019. This site is approximately 700 m west of mouth of the

Rouge River and may provide staging habitat for fall migratory species. Rainbow Trout were the only fall migratory species using this site in October. Two adults were caught in 2009 and two juveniles in 2014.

The fish community consisted of primarily coolwater species with lower numbers of both cold and warmwater species. Coolwater species included primarily Smallmouth Bass, Yellow Perch, Rock Bass and Emerald Shiner. Catch of coldwater species was lower here compared to the other Port Union sites although remained higher than other habitat types (estuaries, wetlands, embayments). Coldwater species included mostly Chinook Salmon but also many Rainbow Trout, Brown Trout and Lake Chub were caught. Warmwater species were few and included primarily Logperch with lower numbers of Brown Bullhead, Common Carp and Freshwater Drum.

Changes in fish communities were also difficult to interpret in the ordination due to limited pre-restoration sampling. Fish communities were similar during restoration and post-restoration with Chinook Salmon, Yellow Perch, Smallmouth Bass and Rock Bass found throughout the time period. These species also consistently had the highest CPUE at this site. Johnny Darter (*Etheostoma nigrum*), Mottled Sculpin (*Cottus bairdii*), Northern Pike and Spottail Shiner were found primarily pre-restoration (in 1999). Spottail Shiner CPUE may have decreased although results were only approaching significance ($r=-0.539$, $p=0.087$). Logperch were only found post-restoration in 2014, 2017 and 2019.

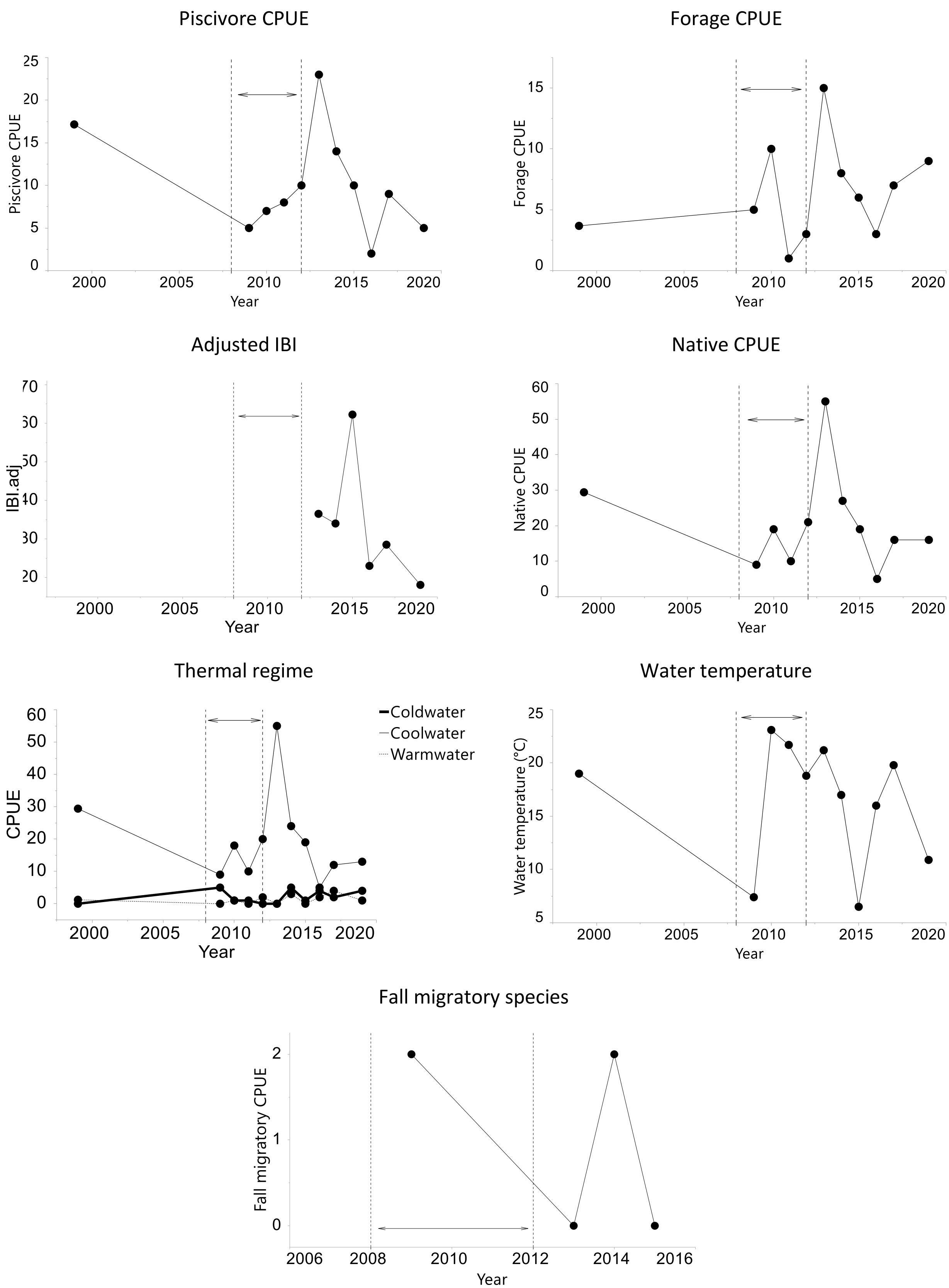


Figure 13: Port Union Phase II TWAHRS Assessment Metrics

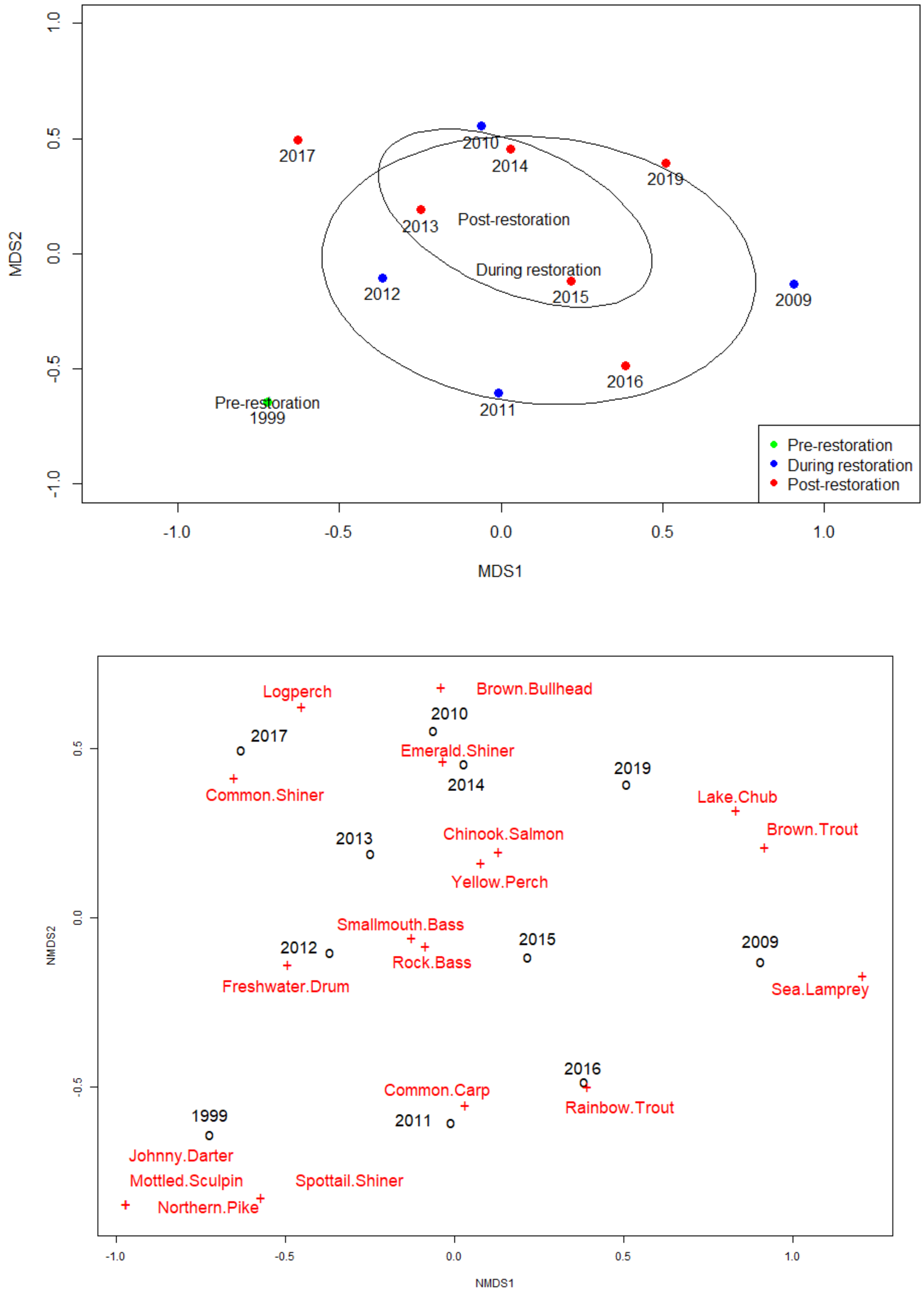


Figure 14: Port Union Phase II Community Ordination (Stress = 0.22)

The site appears to be used by species whose foraging strategy centres primarily around rocky substrates, such as Smallmouth Bass, Rock Bass and Logperch, with catches of the latter increasing significantly. These species are associated more closely with post-restoration years, after the substrate shifted from sand and rubble to cobble and boulder. The site is also used by warmwater, vegetation-associated species that may be originating from the Adam's Creek mouth wetland or from within Rouge Marsh, such as Common Shiner and Yellow Perch. Although confidence ellipses were not available to compare communities pre- and post-restoration, it is evident that species such as Johnny Darter, Mottled Sculpin and Spottail Shiner were replaced at this site with others targeted through substrate choice.

3.3.6 Scarborough Shoreline Meadowcliffe

Following the effectiveness of beach headland systems for erosion control at Port Union Waterfront Park, a similar design was enacted at the site of an eroding beach bluff further west, near a street named Meadowcliffe Drive. The pre-restoration conditions consisted of a continually eroding bluff comprised primarily of fine glacially deposited sand and silt. The erosion of this bluff contributed to the recruitment of Bluffers beach, following the construction of Bluffers Park headland in the early 1980s. By 2011, the bluff's erosion was encroaching dangerously on several homeowners at the crest of the bluff. A significant amount of landfill was required to create the landform where the habitat concept, surcharged headlands, would be attached. Cobbles and gravels were used to surcharge the armourstone headlands in a similar configuration to Port Union. The construction occurred from 2011 to 2013.

2002 2018 2018

Figure 15: Meadowcliffe project before (left) and after (centre). Project polygons are shown on the right.
(Photos: Triathlon Mapping 1999; City of Toronto 2018)

This restoration site has a long-term data set including six years of pre-restoration data (1990-1993, 2007, 2010) and six years of post-restoration data (2014-2019). Piscivore CPUE at this site was very low with only one Smallmouth Bass caught in 1990 and one Northern Pike caught in 2013. There was a decrease in both forage and native species CPUE starting in approximately 2013-2014. Emerald Shiner were the most abundant forage and native species at this site comprising 88% of the total catch over the 15 years surveyed. Emerald Shiner are a very important food item for numerous species and populations are known to fluctuate widely (Scott and Crossman 1998). Further monitoring at this site should continue to determine if the lower catches of forage and native species (driven primarily by Emerald Shiner) continue. Adjusted IBI scores also reflect this drop post-restoration. The most recent low IBI scores were due to several low scoring IBI metrics including native species richness/counts, no Centrarchid species or intolerant species and low/no native Cyprinids.

The fish community consisted of primarily coolwater species with lower catches of both coldwater and warmwater species. Coolwater species included primarily Emerald Shiner. Catch of coldwater species was lower here compared to the other open coast sites, although was higher than other habitat types (estuaries, wetlands, embayments). Coldwater species included mostly Brown Trout but multiple Chinook Salmon, Rainbow Trout and Lake Chub were also caught. One Coho Salmon was caught in 1993. Warmwater species were few but included Common Carp, Brown Bullhead, Logperch and White Perch.

Fish communities did not differ significantly pre- and post-restoration. Species only found pre-restoration included Brown Bullhead, Coho Salmon, Common Shiner, Smallmouth Bass, Spottail Shiner, White Perch and Yellow Perch. Species only found post-restoration include Chinook Salmon, Rock Bass and Threespine Stickleback. The CPUE of these species were low with only 1-3 individuals caught in any one year (and often only caught in one or two years).

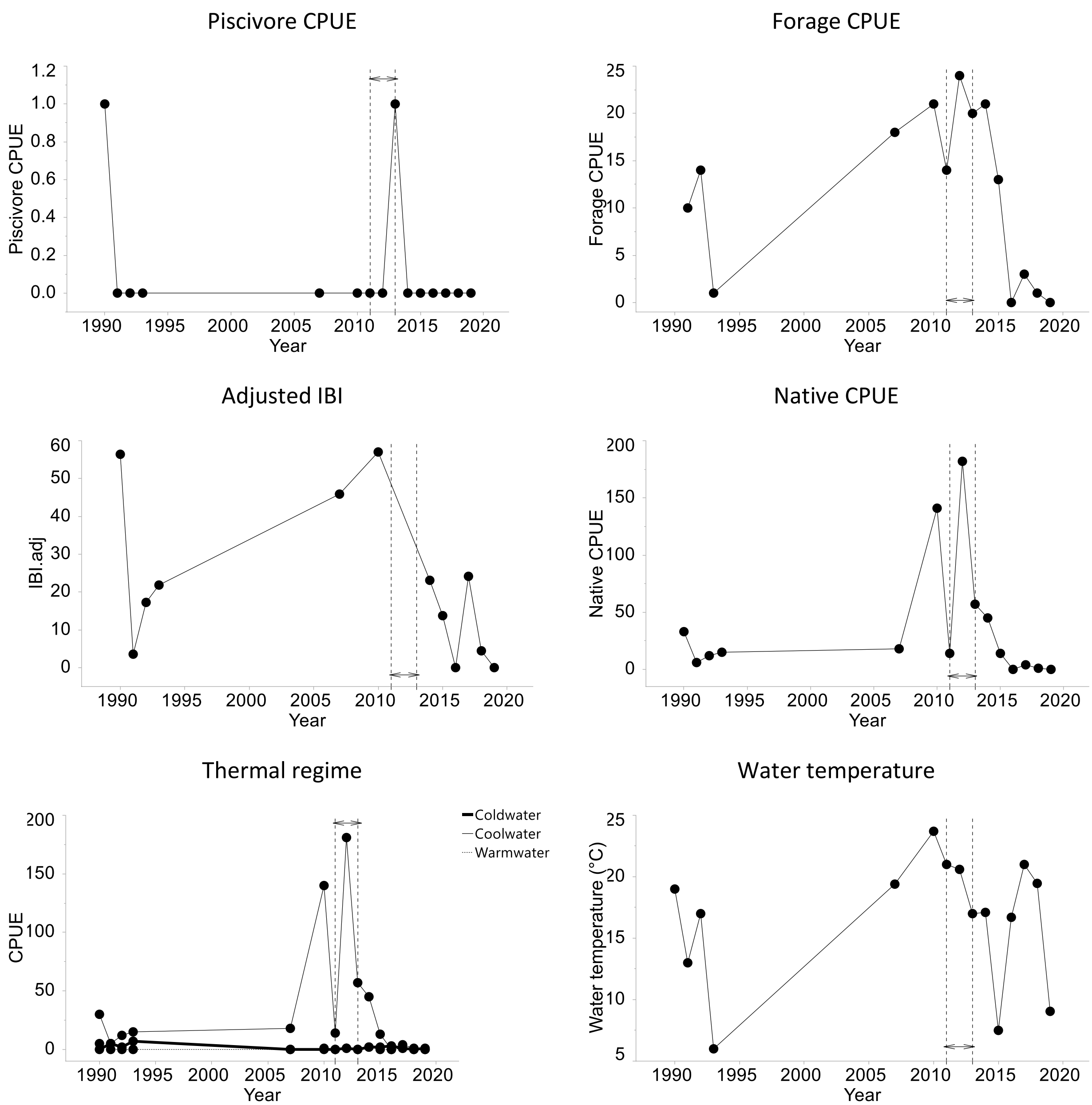
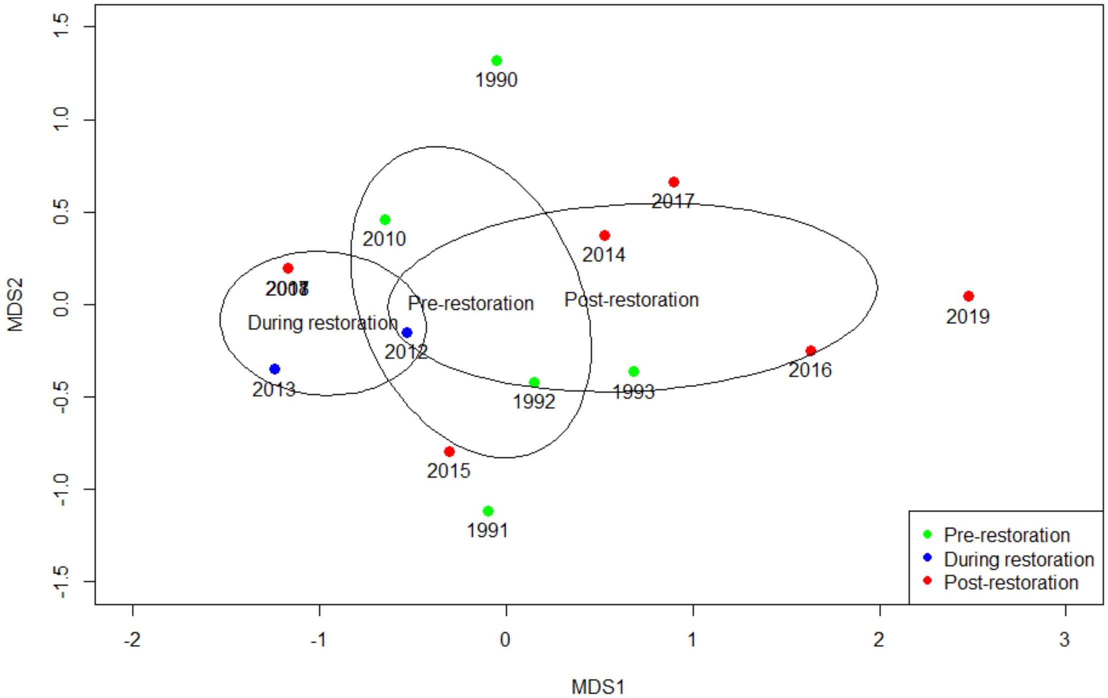


Figure 16: Scarborough Shoreline Meadowcliffe TWAHRS Assessment Metrics



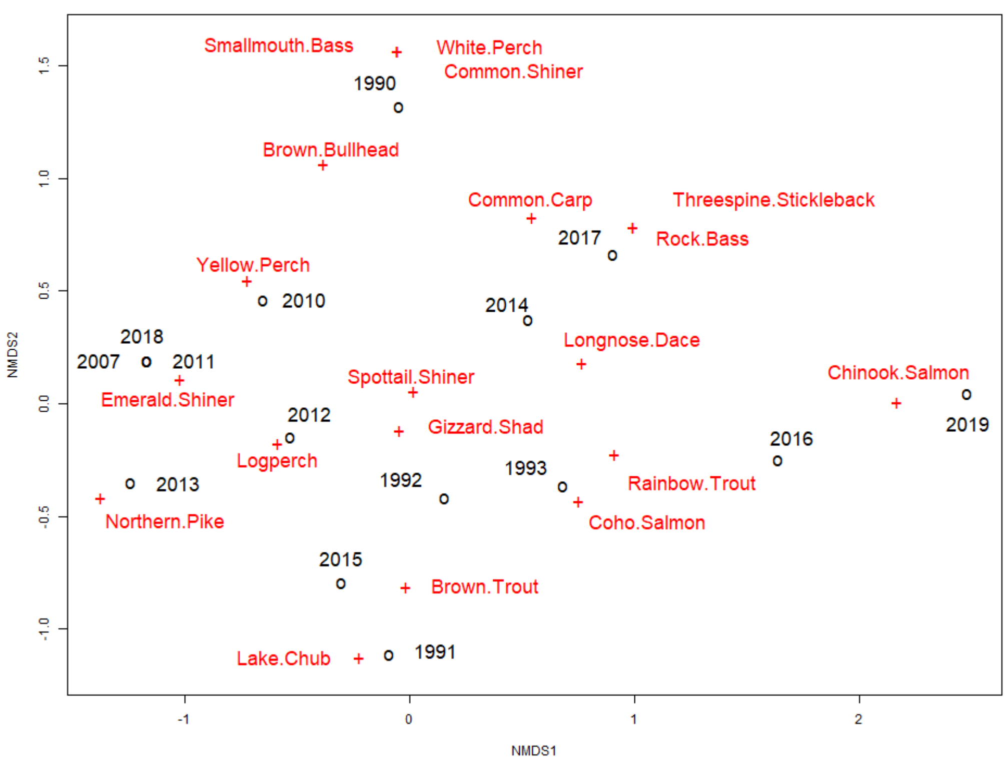


Figure 17: Scarborough Shoreline Meadowcliffe Community Ordination (Stress = 0.11)

TWAHRS objectives for this site included creating habitat suitable for cool and coldwater species, and to increase forage availability. Of the restored area, 20,805 m^2 is considered aquatic and 49,045 m^2 is terrestrial, above the high-water mark. 50,110 m^2 of area contributes to the habitat addition of a cobble beach headland system created through this restoration project, whereas the supporting area of 19 740 m^2 was planted with riparian species through typical site finishing practices. Having grown in since 2013, this vegetated bank provides greater stability in the slope of the previously eroding bluffs. In total the project footprint was 69,850 m^2, encompassing both aquatic and the supporting terrestrial habitat. The shoreline was lengthened by 537 m, resulting in an increase in shoreline length of 76%.

This site achieves a portion of the TWAHRS restoration objectives. The site continues to be used by coolwater species post-restoration. Although there is strong overlap in the community ordination ellipses, Chinook Salmon and Rock Bass were seen to be more closely related to the post-restoration time period. Interestingly, Threespine Stickleback, a species commonly associated with woody material, were found post-restoration. The nearby Bluffers Park embayment system may be a local source of these warmwater, wood-associated species. They may be drawn to the site due to the entrapment and recruitment of drifting woody material transported by the open waters of Lake Ontario.

3.4 Estuary Projects

3.4.1 Estuary Reference - Lower Don River South

This site was examined as a reference site for Toronto area estuaries. The site received no restoration actions during the time frame examined. All data were collected after an area below the rail bridge was excavated in early 2006 to mitigate localized flooding and boulders were added at this site as habitat. Most of this site is bordered by a vertical sheetpile wall (left) and a naturalized vegetated clay bank (right). Flows and shear are high at this site, often scouring any useful fish habitat downstream.

2017

Figure 18: Lower Don River South reference site. (Photo: City of Toronto 2017)

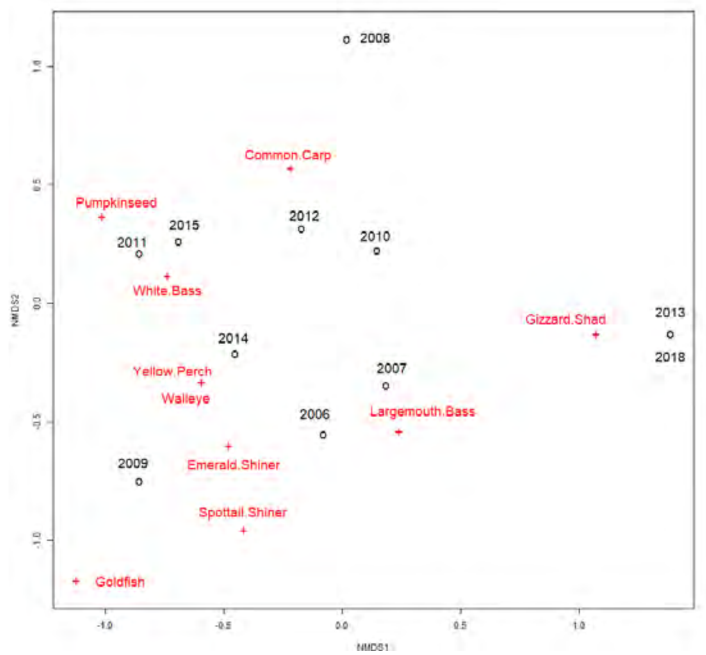


Figure 19: Lower Don River South community ordination.

This site had 11 years of July night electrofishing data between 2006 and 2018. Few species were using this site compared to other habitat types. Species with a moderate CPUE included Emerald Shiner (253), Gizzard Shad (61), Common Carp (33) and White Bass (*Morone chrysops*; 10). These species were found in most of the years and did not appear to be caught more, or less, during a certain time period. Other species occurring in only one or two years in low numbers included Goldfish (*Carassius auratus*), Largemouth Bass, Pumpkinseed, Spottail Shiner, Walleye and Yellow Perch. Spottail Shiner CPUE may have been declining between 2006 and 2018 although the correlation was only approaching significance (r=-0.525, p=0.087).

This site had a moderate fall migratory species CPUE in many years although only day electrofishing data were available. Fall migratory species included Chinook Salmon with 1-5 individuals caught in most years, 13 individuals caught in 2004 and 14 individuals caught in both 2007 and 2015. One Brown Trout was caught in 2007 and one Rainbow Trout was caught in 2014.

3.4.2 Humber River Estuary

The high estuary hooks at the Humber River Estuary were constructed in the winter of 2007-2008 as partial compensation for the Western Beaches Rowing Facility project. The pre-restoration linear shoreline was composed of rubble placed informally for the purpose of shoreline protection. Stone hooks consisting of armourstone, boulder and cobble were placed at the mouth of the Humber River, following the compendium of recommended restoration techniques in TWAHRS.

The proposed function of the hooks is to provide staging areas for fish by deflecting and concentrating flows, creating eddy pools (e.g. slack water areas) and to encourage productivity of both fish and vegetation. The design creates backwater pools and eddies, which are beneficial as refuge to fish during periods of high flow. The design provides vertical relief from the scoured riverbed mouth. The hooks also function to better connect the aquatic habitat to nearshore riparian vegetated habitats.

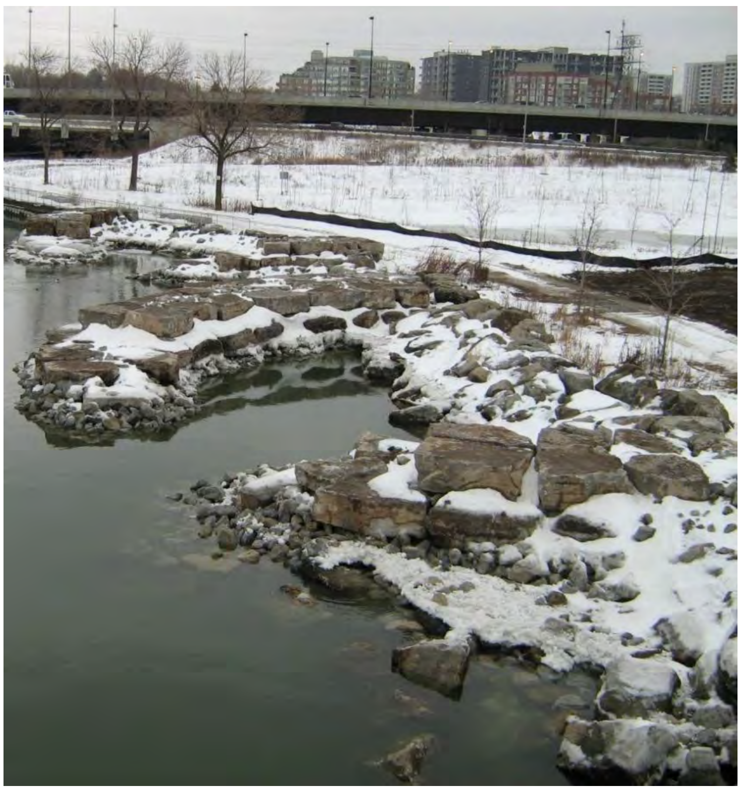


Figure 20: Humber River high estuary hooks after completion. (TRCA 2008)

Figure 21: Estuary hooks in high spring flows. Woody material has been captured in back eddy pools. (TRCA 2008)

Through this project, a wetted area of 460 m^2 of was restored with a further 520 m^2 of supporting terrestrial area. Shoreline complexity was increased, and the shoreline length was increased by 79%. The shoreline was also softened and diversified by replacing homogeneous larger sized material with smaller and more diverse substrate.

Table 4: Summaries for Humber River Estuary.

Restored Area	TWAHRS Technique	Aquatic Area (m^2)	Terrestrial Area (m^2)	Increase in Shoreline Length (m)
Humber Estuary East Side	High Estuary Hooks	460	520	62 (79% increase)

2005 2018

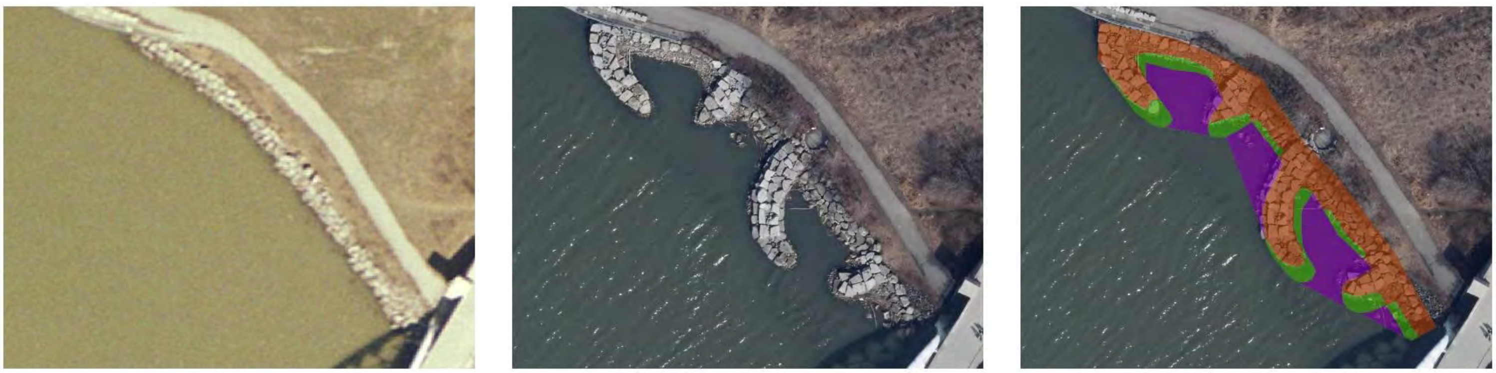


Figure 22: Before and after views of restoration at the mouth of the Humber River. The project polygons are shown on the right. (Photos: First Base Imagery 2005; City of Toronto 2018)

There were changes in the fish community using the Humber River Estuary between 1989 and 2018. Several species were only found post-restoration including Bluntnose Minnow, Fathead Minnow (*Pimephales promelas*), Golden Shiner (*Notemigonus crysoleucas*), Goldfish, Northern Pike, Rock Bass, Spotfin Shiner (*Cyprinella spiloptera*), White Perch and Yellow Perch. Fathead Minnow CPUE increased significantly between 1989 and 2018 (r=0.524, p=0.045). Most of these species occurred fairly infrequently (in only 2 or 3 years) so their presence pre-restoration could have been affected by limited surveys pre-restoration. The presence of Rock Bass post-restoration was strongly related to the restoration with no individuals found pre-restoration and between one and seven individuals found in almost every year post-restoration. Smallmouth Bass may have also benefitted from this restoration found only in one year pre-restoration, but consistently one to two individuals were found in the five years immediately post-restoration. Unfortunately, this species has not be found at this site since 2012. Brown Trout and Trout-perch were the only two species found pre-restoration but not post-restoration and this could be due to various factors that may or may not be related to the restoration.

Piscivore CPUE increased immediately post-restoration and this was related to the presence of Smallmouth Bass and Northern Pike during these years. Forage fish CPUE was variable both pre- and post-restoration. Native species CPUE peaked immediately prior to restoration primarily due to a catch of 215 Emerald Shiners. The adjusted IBI score was quite variable ranging from 60 in 2012 to 14 in 2015. Coolwater species had the highest CPUE consisting of primarily Common Shiner and Emerald Shiner while warmwater species CPUE was lower and consisted of primarily Common Carp. The CPUE of fall migratory species was generally low with two individuals caught in two years post-restoration including

Rainbow Trout and Chinook Salmon. Fish communities changed among pre-restoration, early post-restoration and later post-restoration years. The community pre-restoration had more Emerald Shiners, Brown Trout and Common Carp. Common Carp CPUE decreased significantly at this site between 1989 and 2018 ($r=-0.719$, $p<0.01$). Immediately post-restoration the community consisted of Golden Shiner, Smallmouth Bass, Northern Pike, Yellow Perch, Freshwater Drum and Bluegill. Five to ten years post-restoration the community consisted of Goldfish, Fathead Minnow, Common Shiner, White Perch and Gizzard Shad. These changes in community structure may represent changes in the substrate post-restoration including sedimentation (silting in) that may have occurred in later years.

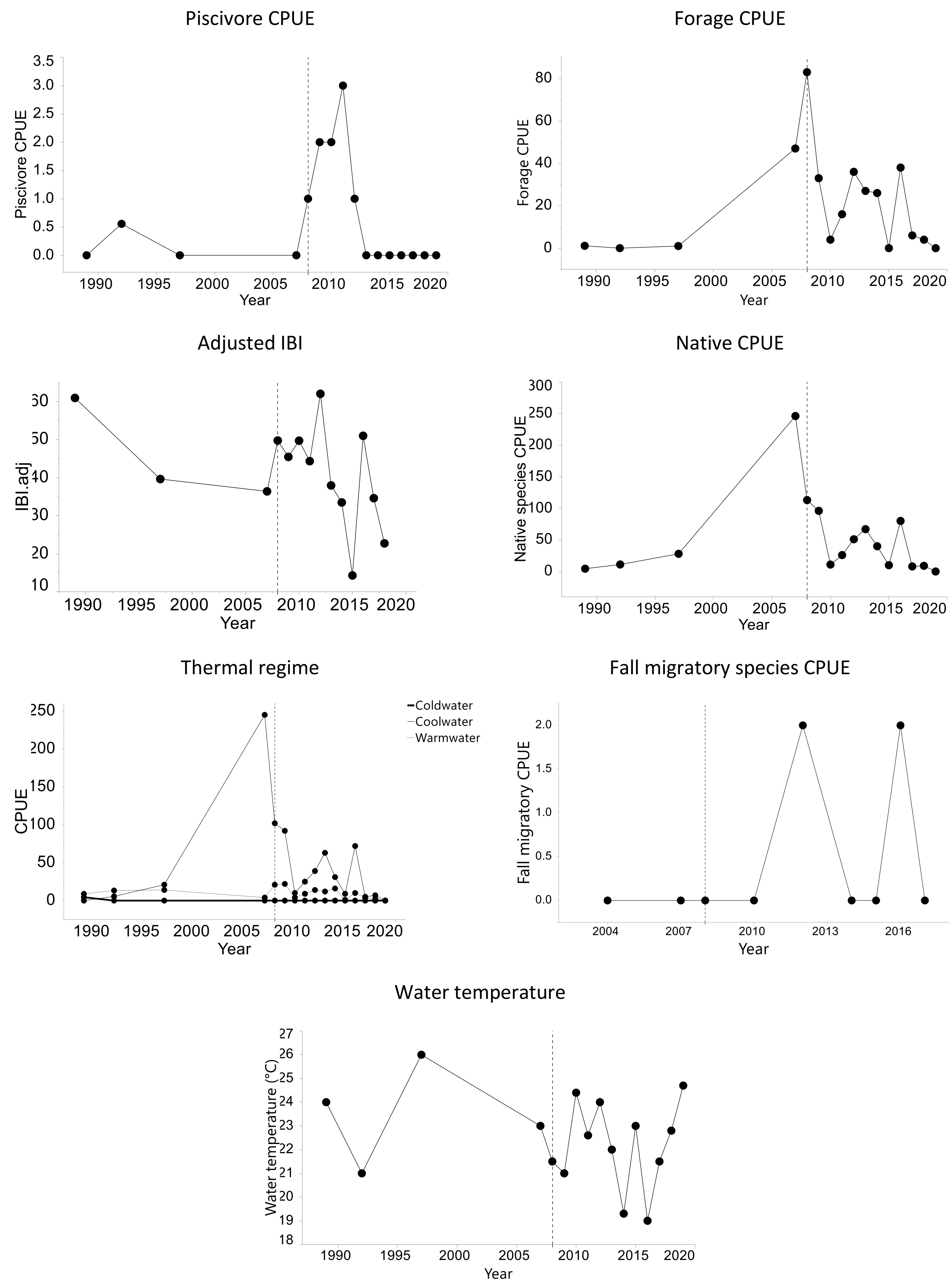


Figure 23: Humber Estuary Hooks TWAHRS Assessment Metrics

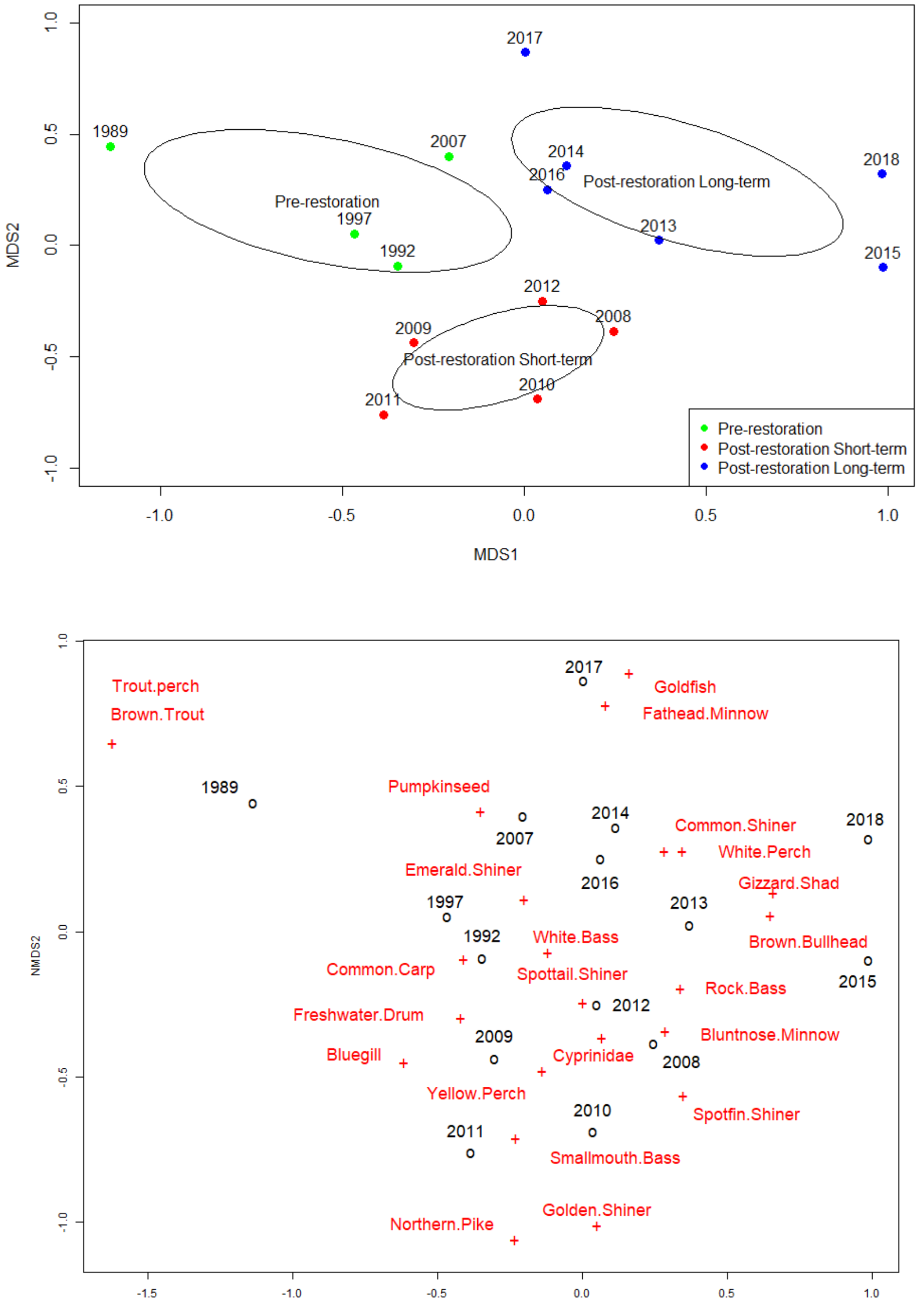


Figure 24: Humber Estuary Hooks Fish Community Ordination (Stress = 0.23)

This site achieved many of the intended goals as described in TWAHRS, notably creating suitable habitats for fish of all body size and condition, creating staging habitat for migrating fish, and increasing habitat for predatory fish. In addition, rock-loving species were selected for through substrate choice. This project illustrates the dynamic nature of projects post-restoration and fish community response.

3.4.3 Etobicoke Creek - Marie Curtis Park

Historically, the area anterior to the outlet of Etobicoke Creek in Marie Curtis Park was restored from vertical sheet pile wall to hardened armourstone revetment in the late 1990s. It is unclear which agency conducted this work. The rivermouth remained in this state until 2012, when TRCA undertook a small restoration project on the east (right) bank. A recreation node was constructed, with round riverstone placed or flung 6-10 m into the river at the base of the armourstone node, in an act of surcharging. Additionally, in 2017 a restoration project was initiated on the west (left) bank. A second recreation node was constructed from a derelict boat launch, with natural round riverstone placed in a similar manner at the base of the node and along the shoreline using an excavator bucket.

2009 2018 2018

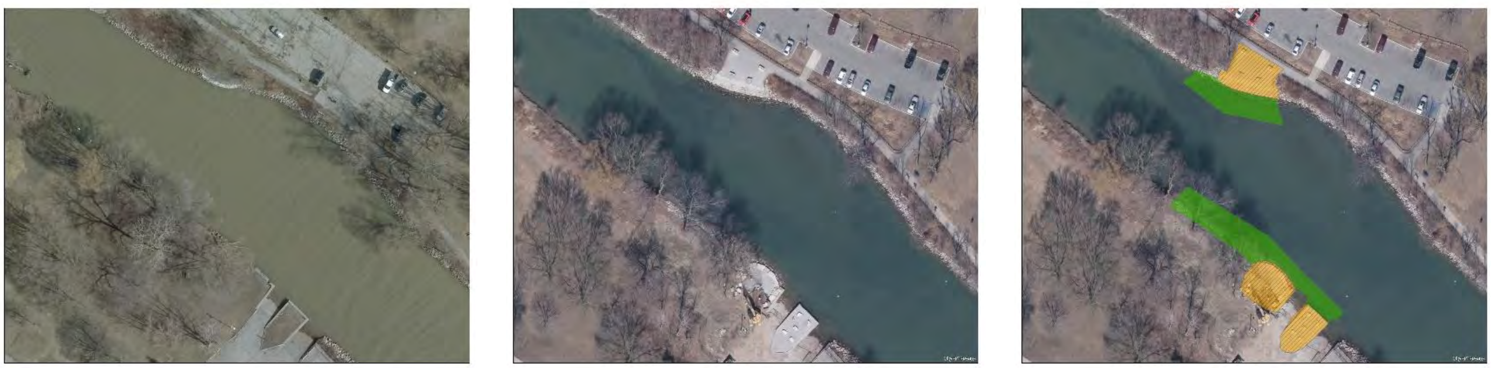


Figure 25: Before and After, shoreline restoration projects at Etobicoke Creek. Project polygons are shown on the right. (Photos: First Base Imagery 2009; City of Toronto 2018)

Figure 26: Shoreline restoration work underway at Marie Curtis Park's Etobicoke Creek. *(TRCA 2017)*

Minimal changes in fish communities were expected at this site due to limited alteration of the aquatic area. Restoration occurred at this site first in 2012 then began again in 2017 then continued until 2018. This site has a large amount of pre-restoration data (1989-2011) with strong inter-annual variation in piscivore and native CPUE. Forage fish CPUE appeared to be very low until approximately 2000 after which CPUE appeared to vary among years. Native species CPUE was lower post-2012 not reaching the peaks observed in many of the years pre-restoration. The adjusted IBI was variable across the entire time period although was almost zero in 2019. Further monitoring at this site is important to determine if native CPUE and the adjusted IBI return to pre-restoration levels in future years. Coolwater species had the highest CPUE consisting of primarily Emerald Shiner while warmwater species CPUE was lower and consisted of primarily Common Carp. The CPUE of fall spawning species appeared to have declined at this site and was strongly affected by declines in Brown Trout. Brown Trout were stocked by the MNR at their highest levels ever in the late 1980s and early 1990s and this may be contributing to these trends (MNRF 2019). Other fall migratory species using this site include Chinook Salmon, Coho Salmon and Rainbow Trout.

Species communities were similar pre- and post-restoration. There were significant declines in Spottail Shiner CPUE at this site ($r=-0.677$, $p<0.0001$) although again, these declines may have begun long before restoration. Several other species had significant declines between 1989 and 2019 including Common Carp ($r=-0.391$, $p=0.040$), White Perch ($r=-0.609$, $p<0.01$) and Goldfish ($r=-0.521$, $p<0.01$). Green Sunfish were only found in 2016 and 2017 and in low numbers although produced a significant increasing trend ($r=0.378$, $p=0.047$). The Lakeview Water Connection Project (now the Jim Tovey Lakeview Conservation Area) is located approximately 200 m west of the Etobicoke Creek River mouth at Marie Curtis Park and a large amount of lakefilling began in 2016. Future changes in fish communities at Marie Curtis Park could be related to this nearby construction and should be considered in future analyses.

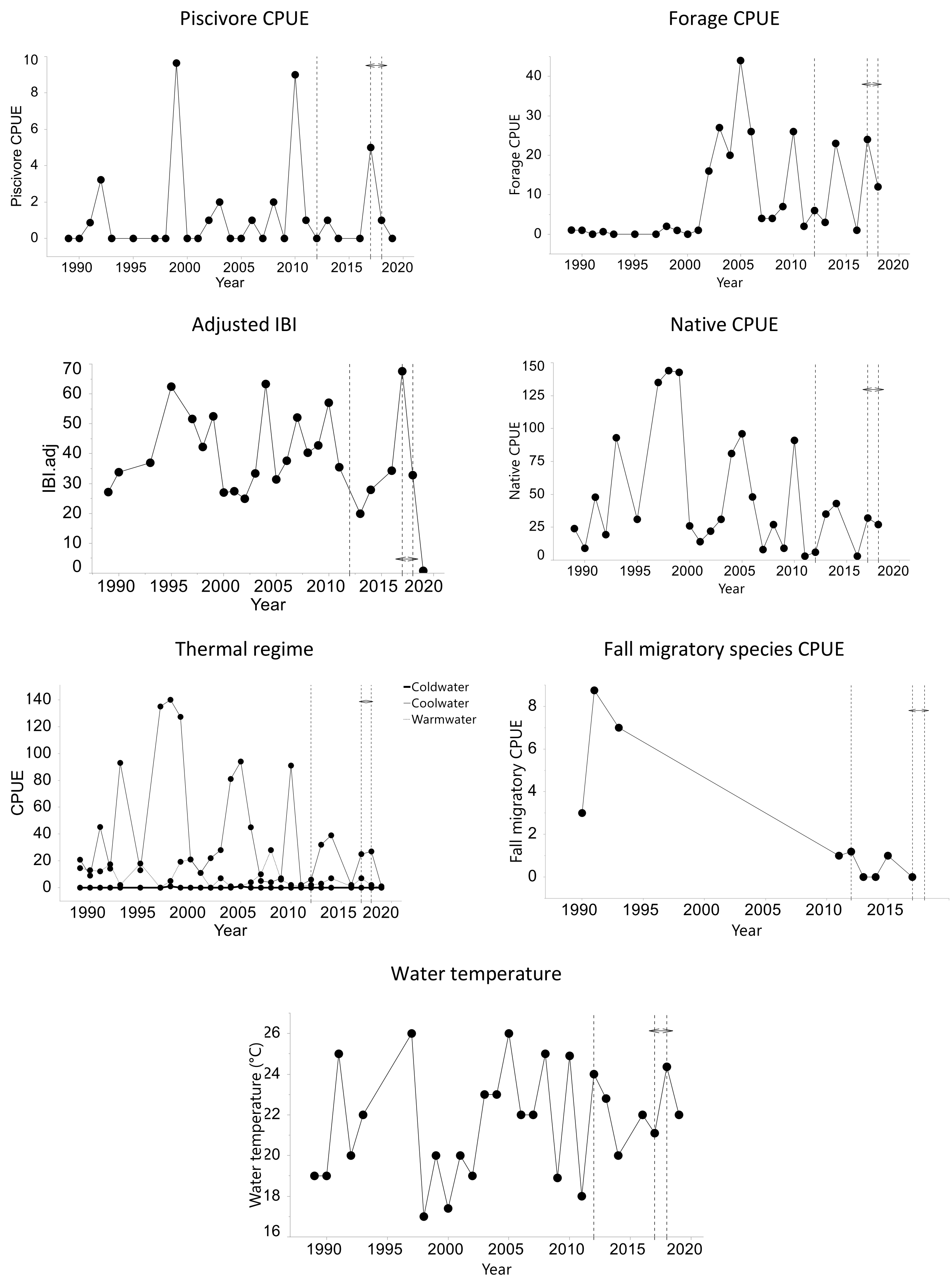
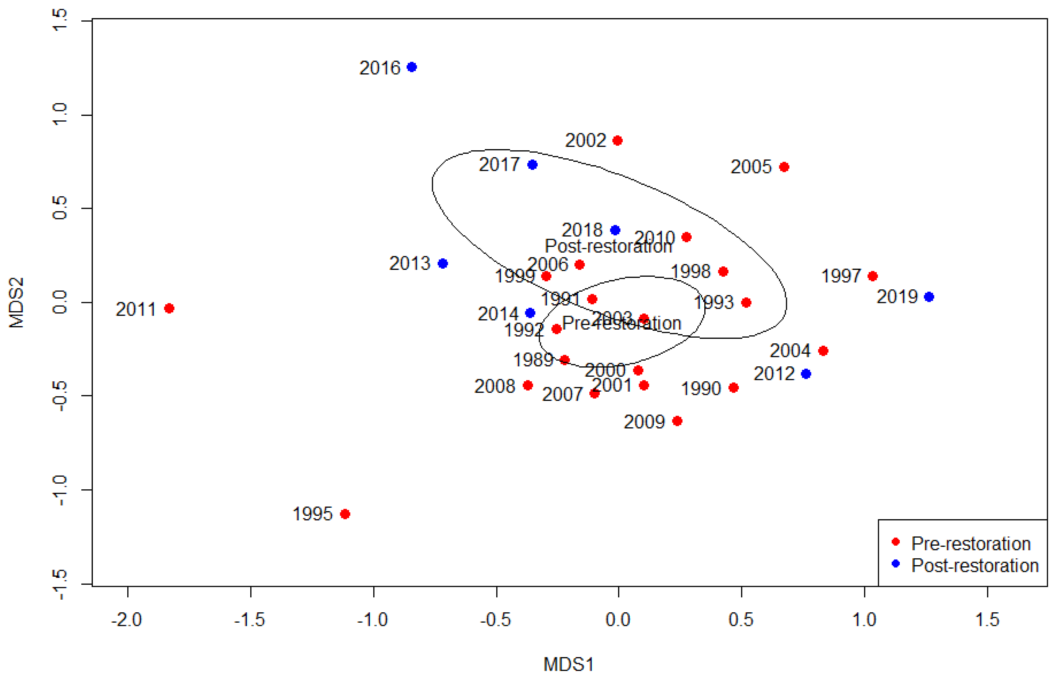


Figure 27: Etobicoke Creek TWAHRS Assessment Metrics



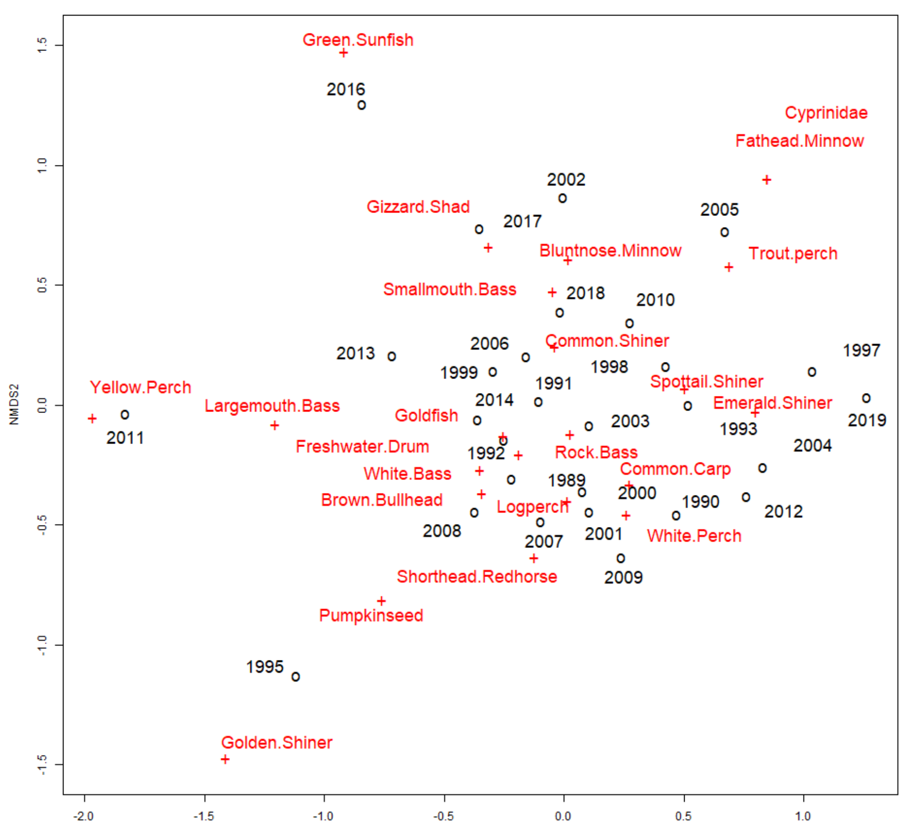


Figure 28: Etobicoke Creek Fish Community Ordination (Stress = 0.18)

A total of 215 m^2 of aquatic stone placed in 2012, and 430 m^2 in 2018, contribute to the local habitat supply at the mouth of Etobicoke Creek. The two projects occupy an additional 500 m^2 of area supporting the creation of recreation nodes. This site exhibits considerable diversity in fish species, especially when compared to the reference site. Although there are few apparent directional trends in CPUE metrics, the diversity and catches were maintained over time through restoration works, although variable. The IBI ranges from poor to excellent, and although it is lowest post-restoration, this is most likely due to the impact of historic water levels on electrofishing catches. Notably, Green Sunfish (*Lepomis cyanellus*), a regionally rare monitoring find, have increased significantly at this site. The site continues to be used by fall migratory species despite reductions in lake-wide salmonid stocking. The site is primarily used by warm and coolwater species, contributing to suitable habitat for these guilds that are targeted through TWAHRS and RAP restoration measures.

3.5 Sheltered Embayment Projects

3.5.1 Reference Site – Toronto Islands Sunfish Cut

Toronto Islands Sunfish Cut was chosen as a reference site for the sheltered embayment habitat type. The Toronto Islands represent an area of regionally depleted, relatively natural embayment conditions. Fish community trends can be analyzed here, to help inform if trends observed at restoration sites are ubiquitous across restored and unrestored embayments. The site features a blend of naturalized beach, forested riparian areas, and includes a small section of pre-1950 vertical dockwall. No notable landscape alteration occurred at this site over the timeframe examined here.

2018

Figure 29: Reference site Toronto Islands Sunfish Cut. (Photo credit: City of Toronto 2018)

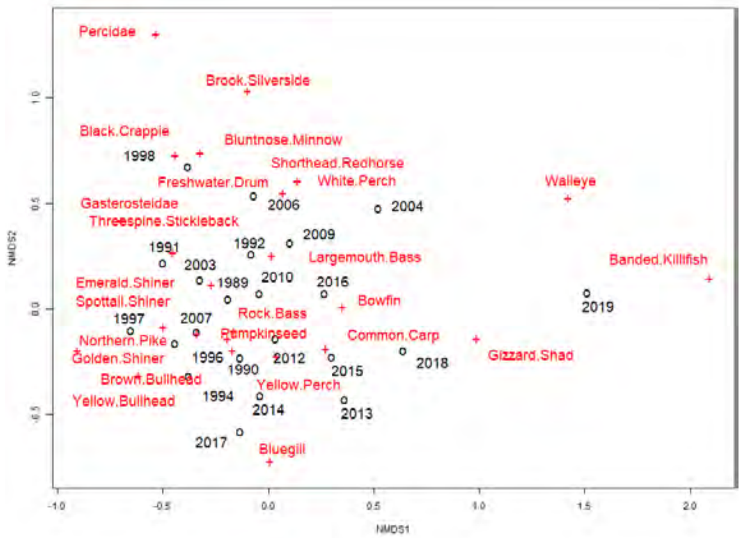


Figure 30: Toronto Islands Sunfish Cut Community ordination (Stress = 0.22).

This site had 22 years of July night electrofishing data (collected between 1989 and 2019) for temporal comparisons. Species with the highest CPUE over all years included Pumpkinseed (436), Emerald Shiner (316), Yellow Perch (273), Spottail Shiner (187) and Rock Bass (113). Pumpkinseed, Rock Bass and Yellow Perch were caught almost every year. Emerald Shiner were caught with the highest CPUE between 2006 and 2009 although were not caught pre-1996 or post-2014. Spottail Shiner CPUE decreased significantly between 1989 and 2019 ($r=-0.779$, $p<0.0001$). Spottail Shiner were caught almost every year between 1989 and 2007, although have not been caught post-2007. Pumpkinseed and Rock Bass CPUE also decreased between 1989 and 2019 at this site ($r=-0.742$, $p<0.0001$ and $r=-0.508$, $p=0.016$, respectively). Several other species had a moderate CPUE including Brown Bullhead (65), Bluntnose Minnow (54), Largemouth Bass (44), Northern Pike (26) and Common Carp (26). These species were caught in low numbers in almost every year except for Bluntnose Minnow that was only occasionally caught (6 of 22 years) but in higher numbers. Northern Pike CPUE decreased significantly between 1989 and 2019 ($r=-0.682$, $p<0.001$).

3.5.2 Mimico Waterfront Linear Park

This project was led by Waterfront Toronto, with construction and restoration expertise provided by TRCA. Mimico Waterfront Linear Park consists of four separate parks (shown below): 1) Norris Crescent Parkette, 2) Mimico Waterfront Park, 3) Amos Waites Park and 4) Humber Bay Promenade Park. The site's design features several TWAHRS-recommended techniques, and nearby areas also received TWAHRS restoration actions in compensation. This area consists of two separate electrofishing runs that are immediately adjacent to each other: Humber Bay West Superior Ave (running south/west of Humber Bay Promenade Park) and Humber Bay West Marina Del Ray (next to Amos Waites Park and north/east). These sites have had different restoration techniques but are presented in sequence due to their proximity.

2005 2018 2018

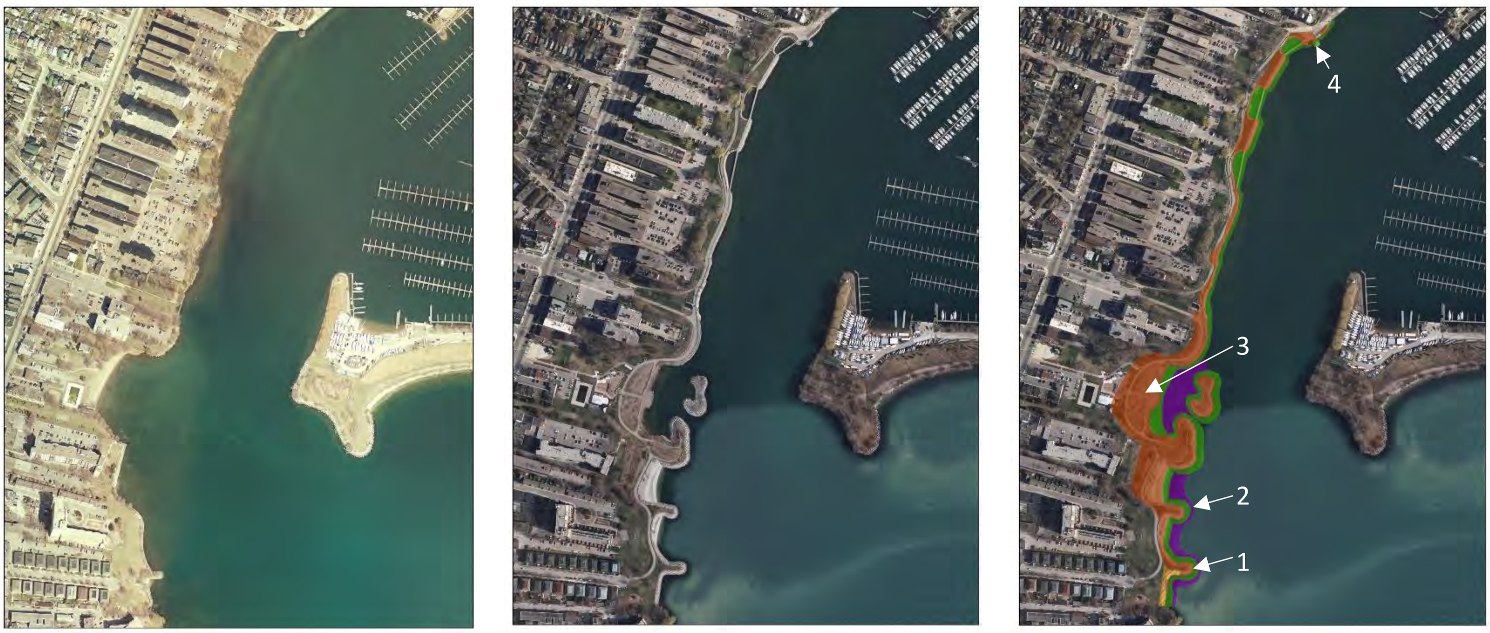


Figure 31: Before and after Mimico Waterfront Linear Park Restoration Project. Project polygons are shown on the far right. (Photos: First Base Imagery 2005; City of Toronto 2018).

3.5.2.1 Humber Bay West Superior Ave

These works serve both to protect critical infrastructure, and create and enhance the public realm, while connecting waterfront resource users to a restored environment. In addition to shoreline armouring (using armourstone), this site received the sheltering effects of a constructed island and promontory headland. The area anterior was surcharged with silty-sand material to raise the grade, planted with emergent vegetation, and inoculated with woody material; however, the plantings were unsuccessful. Public realm works in the backshore included a trail, boardwalk, and a restored sand dune environment. Construction of this Phase I of Mimico Waterfront Linear Park occurred from 2006 to 2008. This site is just west of the Humber Bay West Marina Del Ray transect, where restoration occurred between 2011 and 2012.

2005 2018

Figure 32: Humber Bay West Superior Avenue before (left) and after (right). *(Photos: First Base Imagery 2005; City of Toronto 2018).*

With only one year of pre-restoration data, interpreting changes in fish communities at this site is not recommended. Although the pre-restoration data are presented, only post-restoration fish communities are described here and communities may or may not be attributed to the restoration itself.

Piscivore CPUE was variable post-restoration ranging from no piscivores in multiple years to seven in 2012. Piscivores using this site included 14 Smallmouth Bass, 3 Largemouth Bass and 1 Northern Pike between 2000 and 2017. Smallmouth Bass using this site were exclusively juvenile fish in 2012, 2013 and 2016. In 2017, all Smallmouth Bass were juveniles except for one 40 cm long adult. The presence of numerous juvenile Smallmouth Bass at this site suggests that it provides important nursery habitat for this species.

Forage fish CPUE was also variable ranging from 2 fish in 2008 to 39 in 2013. Forage fish species primarily consisted of Emerald Shiner although Rock Bass and Yellow Perch were also abundant. Emerald Shiner were the most abundant forage fish species between 2010 and 2013 although occurred infrequently between 2014 and 2017. Between one and four Rock Bass were consistently caught each year and Rock Bass CPUE may have increased between 2000 and 2017 although results were only approaching significance (r=0.610, p=0.061). Yellow Perch were first caught in 2011 and reached 17 individuals in 2013. Other forage fish species included species often only caught in one year and in very low numbers: Bluntnose Minnow, Brook Stickleback (*Culaea inconstans*), Common Shiner, Creek Chub, Pumpkinseed, Spottail Shiner and White Perch. Similar to forage fish, native CPUE was variable but peaked in 2012. The only non-native species at this site (other that Brown Trout and Chinook Salmon) included Common Carp and Goldfish found in low numbers prior to 2014 and Common Carp CPUE may have decreased between 2000 and 2017 (r=-0.624, p=0.054).

The fish community consisted of primarily coolwater species with a low CPUE of both warmwater and coldwater species. Coolwater species included primarily Rock Bass, Yellow Perch and Emerald Shiner. Smallmouth Bass was a unique coolwater species found at this site compared to other embayments. Warmwater species included primarily Brown Bullhead and Common Carp. While caught in only low abundance, the CPUE of coldwater species was higher at this site compared to other embayments and could be due to the more open coast nature of the site and lower water temperatures. Coldwater species caught included mostly Brown Trout but also one Chinook Salmon and one Rainbow Trout. The adjusted IBI ranged from 22 in 2008 to 56 in 2012. The IBI was generally higher post-restoration although again, the pre-restoration data were limited.

Fish community composition was not compared pre- and post-restoration but the most recent years post-restoration (2015-2017) suggest a fish community consisting of predominantly Rock Bass, Smallmouth Bass and Common Shiner. Several other species only occurred in 2015-2017 including Bluntnose Minnow, Creek Chub, Pumpkinseed, Rainbow Trout and White Perch. October data suggest that this site is not used heavily by staging fall spawners with only one Brown Trout caught in 2015.

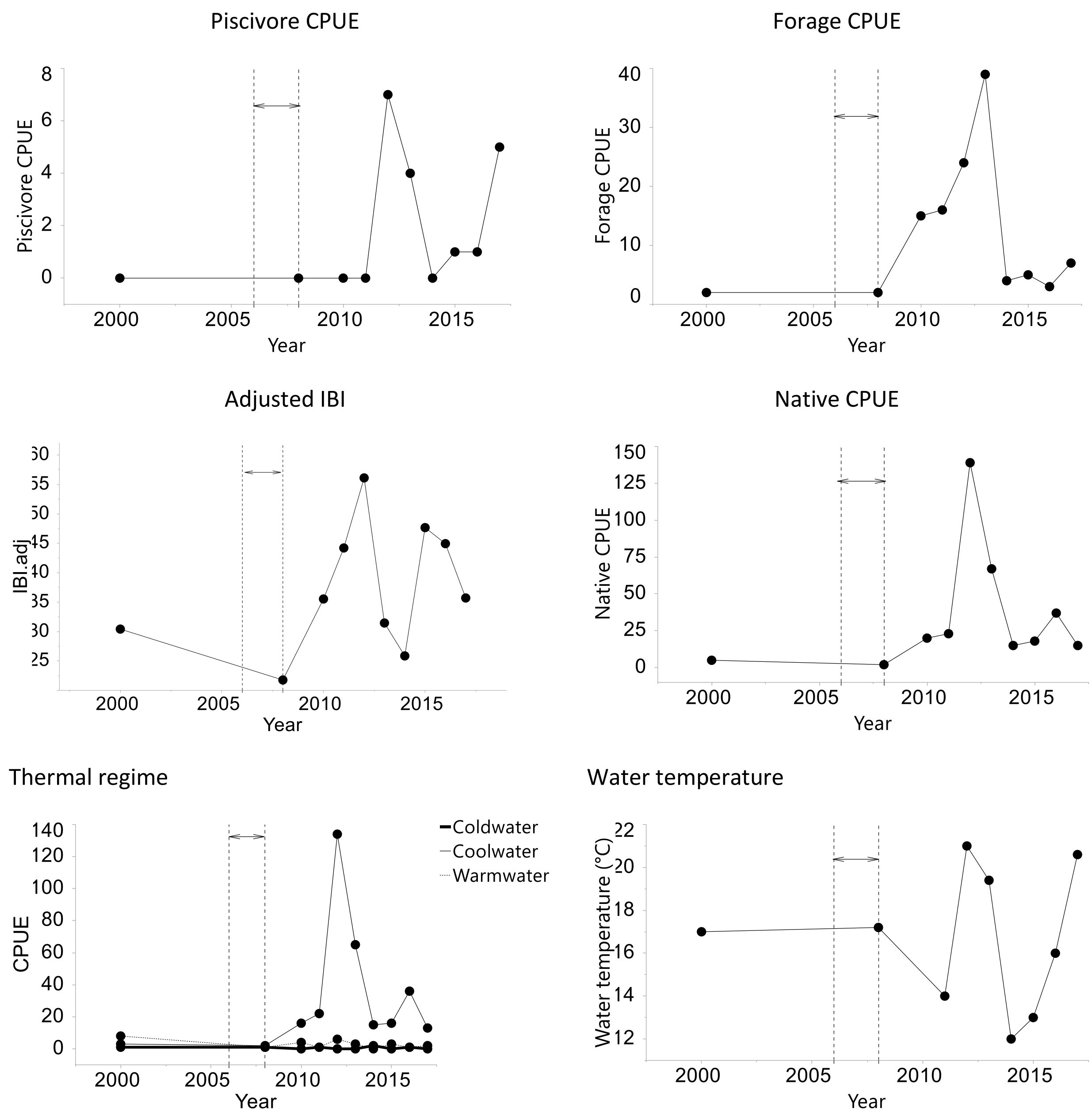


Figure 33: Humber Bay West Superior Ave TWAHRS metrics.

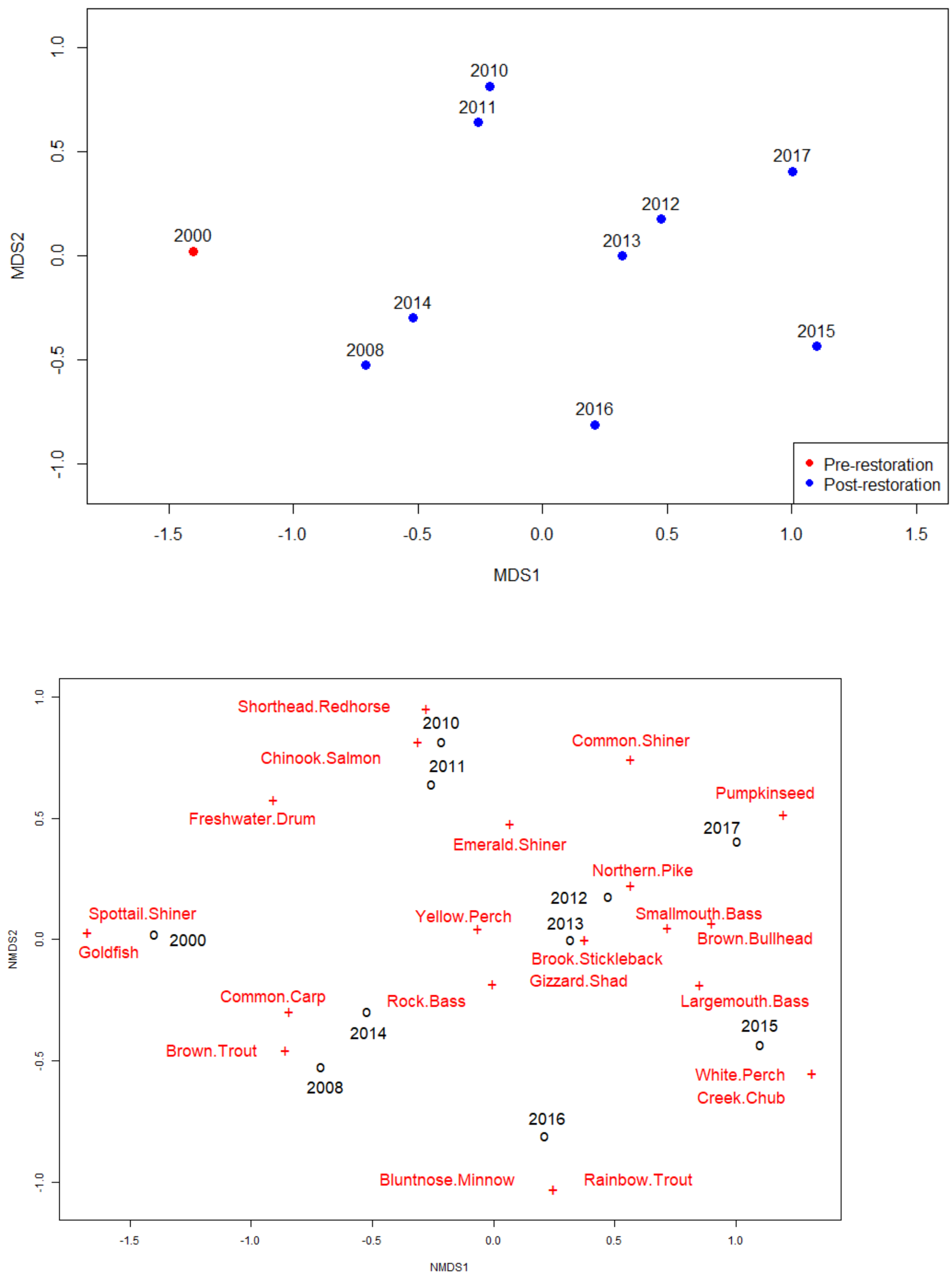


Figure 34: Humber Bay West Superior Ave fish community ordination (Stress = 0.16).

3.5.2.2 Humber Bay West Marina Del Ray

Phase II of Mimico Waterfront Linear Park featured a boardwalk atop surcharged shorelines, with three backwater hemi-marshes, which were lined with small roundstone cobbles and finished with emergent vegetation plantings which were unfortunately entirely unsuccessful. A lighthouse promontory was also surcharged with medium aggregate stone. Construction took place from 2011 to 2012. This site is just east of the Humber Bay West Superior Ave transect where restoration occurred between 2006 and 2008.

2005 2018

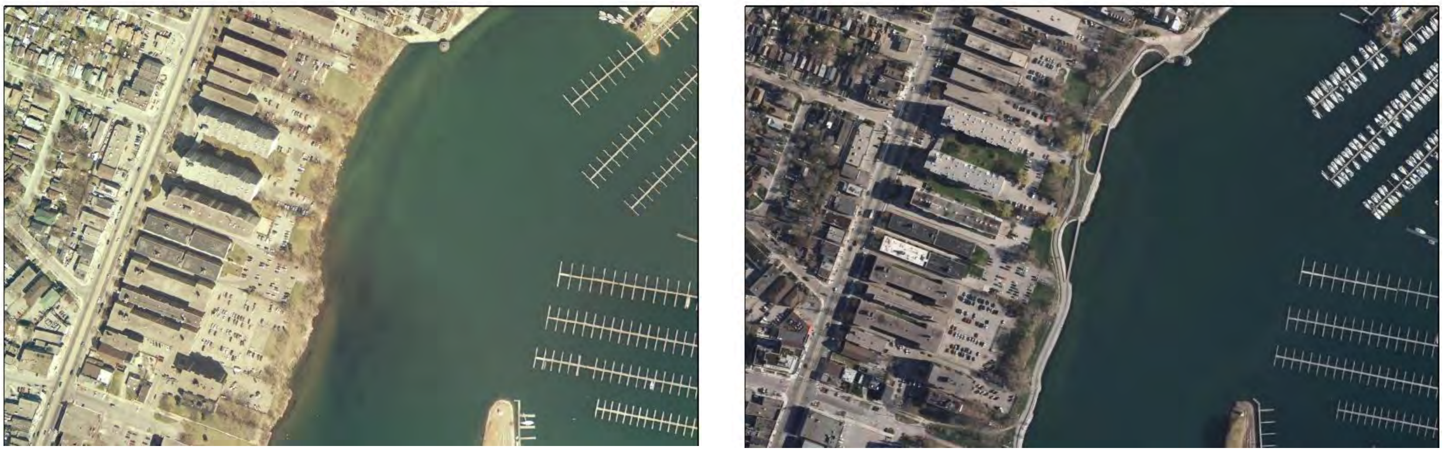


Figure 35: Humber Bay West Marina Del Ray before (left) and after (right). *(Photos: First Base Imagery 2005; City of Toronto 2018)*

This site had sufficient pre- and post-restoration data for temporal comparisons. Piscivore CPUE was variable at this site peaking in 2003 with a catch of four Northern Pike. All piscivore species as defined for the purpose of this report were caught at this site including Northern Pike (10 individuals), Largemouth Bass (7 individuals), Walleye, Smallmouth Bass and Bowfin (1 individual each). The Walleye, Bowfin and most of the Northern Pike at this site in July were adults; however, all of the Largemouth Bass were juveniles.

Forage CPUE was low between 1989 and 2005 but increased almost 10-fold between 2006 and 2013. Increases in forage and native CPUE between approximately 2000 to 2010 have also occurred at other sites and could be representative of factors unrelated to restoration such as Round Goby invasion and new food sources (Steinhart et al. 2004) or cyclical patterns in schooling forage species such as Emerald Shiner (Scott and Crossman 1998). These are speculative and have not been confirmed empirically. Increases in 2006-2008 could also be related to the nearby restoration work at Humber Bay West Superior Ave. Emerald Shiner was the most abundant forage fish at this site followed by Yellow Perch. Other abundant forage fish species included Pumpkinseed, Rock Bass and Spottail Shiner. Spottail Shiner were predominantly found between 1991 and 2007, while Rock Bass only started becoming more abundant in 2009. Rock Bass CPUE increased significantly between 1989 and 2019 ($r=0.474$, $p=0.014$). Emerald Shiner were most abundant between 2006 and 2013 and higher catches of this species in these years also occurred at other sites.

Native CPUE primarily consisted of Emerald Shiner and Yellow Perch, although Rock Bass and Brown Bullhead were also found in high abundance at this site. The very high CPUE in 2012 was caused by high catches of both Emerald Shiner and Yellow Perch. Pre- and post-restoration fish communities did not separate completely in the ordination although some differences for specific species were apparent. For example, White Bass, Shorthead Redhorse (*Moxostoma macrolepidotum*), White Perch and Trout-perch were either found only prior to 1993 or in higher abundance prior to 1993. These species also had declining CPUEs between 1989 and 2019 likely due to their occurrence only in earlier years (all $p<0.08$). Several other species may have had declining CPUEs including Common Carp, Gizzard Shad and Goldfish although the results were only approaching significance (all $p<0.090$). High CPUE of multiple species occurred in 2012 and 2013 including Emerald Shiner, Yellow Perch, Brown Bullhead and Largemouth Bass. The most recent fish community was characterized by a high CPUE of Rock Bass compared to previous years.

The adjusted IBI appeared to be lower post-restoration although low IBI values also occurred infrequently prior to restoration in 1995 and 2006. These lower values post-restoration were due to zero values for two of the IBI metrics: native Cyprinid richness and piscivore percent biomass.

The fish community consisted of primarily coolwater species although both warmwater and coldwater species were also present in variable abundance. Coolwater species with the highest CPUEs included Emerald Shiner, Yellow Perch and Rock Bass. Warmwater species included primarily Brown Bullhead and Common Carp. Freshwater Drum and Pumpkinseed were also abundant warmwater species but to a lesser extent. Similar to Humber Bay West Superior Ave, the CPUE of coldwater species was low compared to the other thermal guilds but high compared to other embayments. Coldwater species caught included Brown Trout, Chinook Salmon and Trout-perch.

The occurrence of fall migratory species at this site was generally low and consisted of primarily Brown Trout. Brown Trout may have occurred in higher numbers due to stocking efforts in the early 1990s. One Chinook Salmon was also caught in 1993 and one Rainbow Trout in 2002.

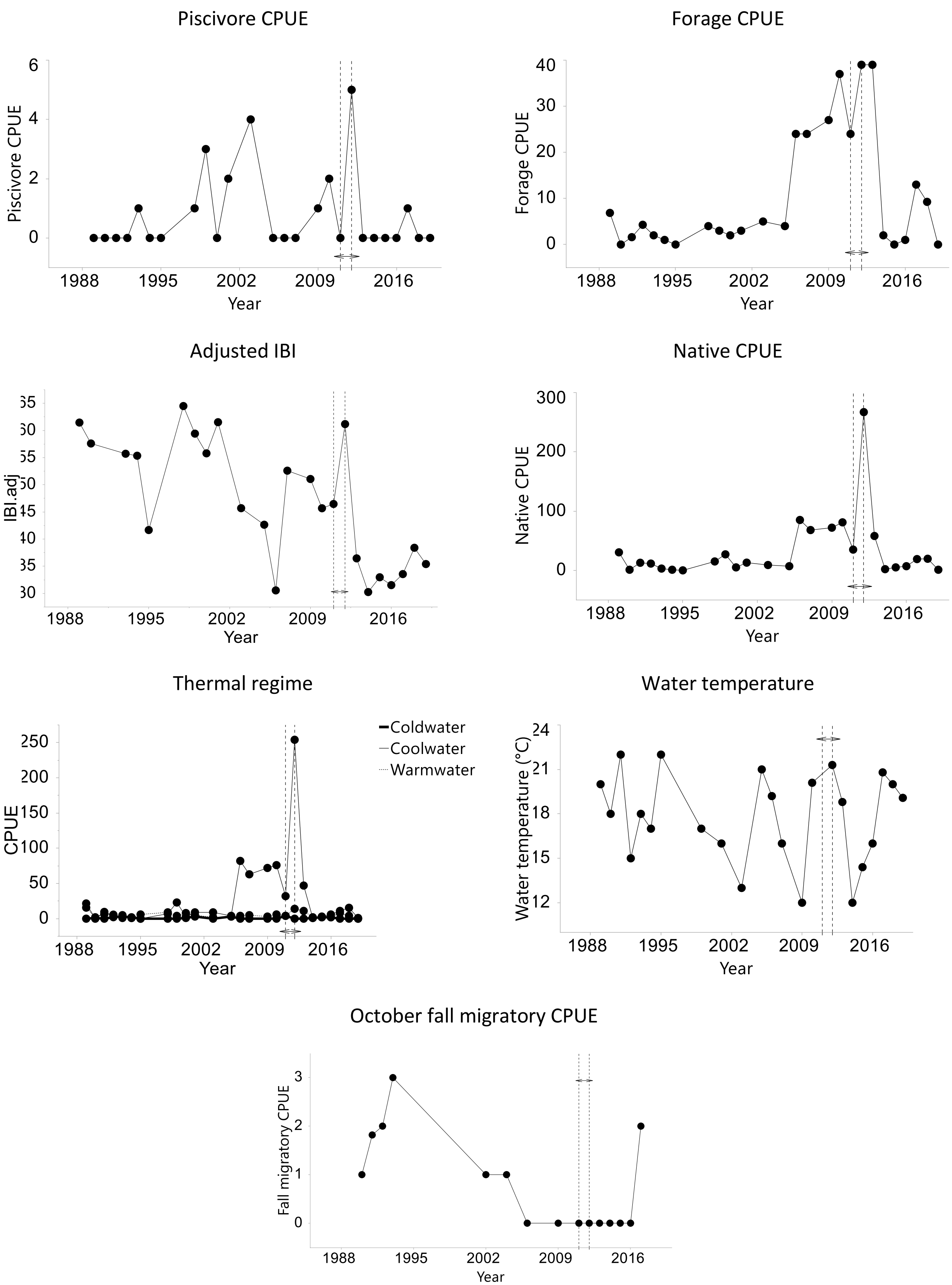


Figure 36: Humber Bay West Marina Del Ray TWAHRS metrics.

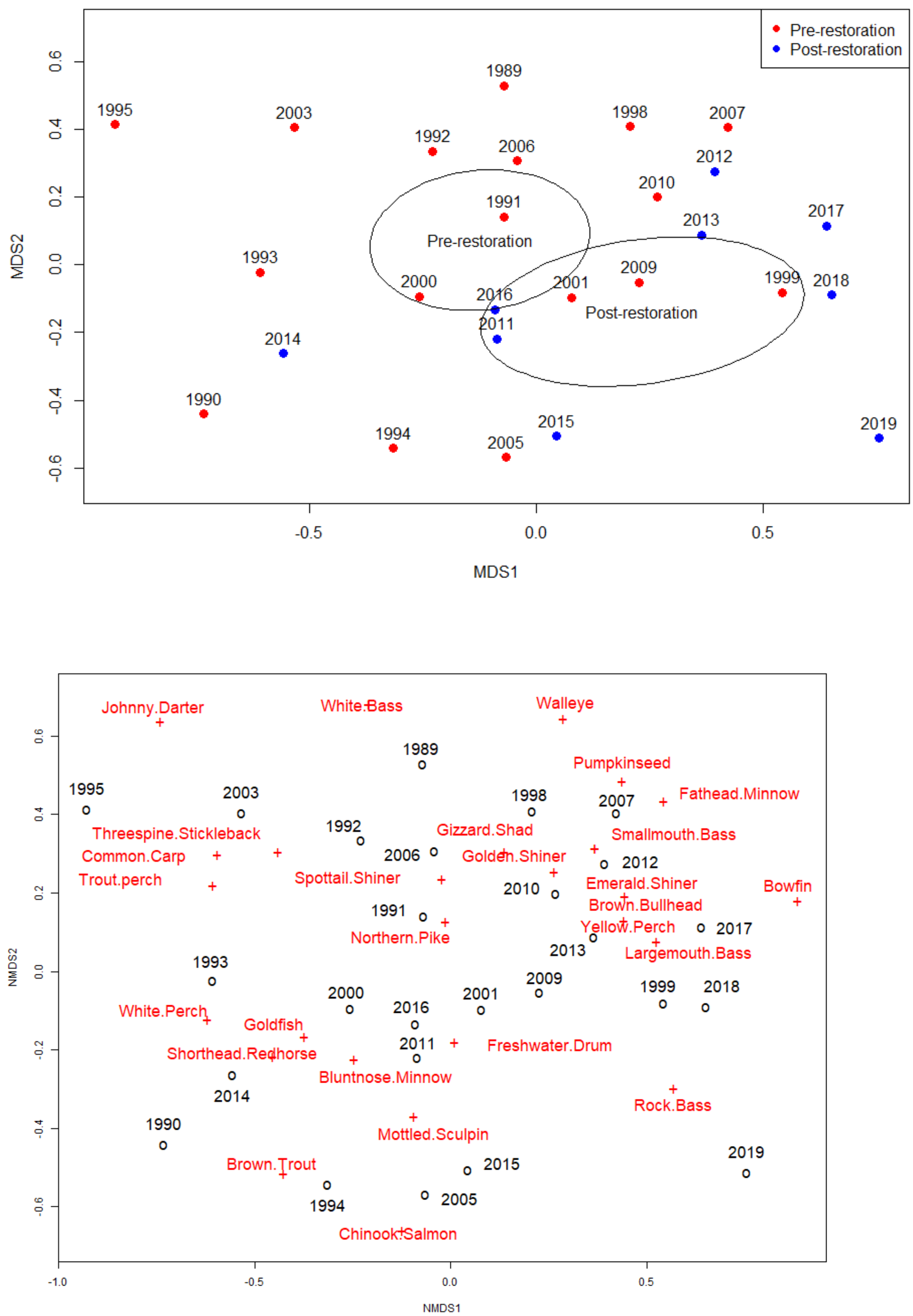


Figure 37: Humber Bay West Marina Del Ray fish community ordination (Stress = 0.21).

3.5.3 Toronto Islands Donut Island

The Toronto Islands formed on and around an active sand beach bar system that developed over the past few thousand years. A series of beach bars extended progressively westward from what is now Ashbridges Bay to partially enclose the Toronto Harbour. Waterways, parks and native uplands connect Toronto Island's natural areas to each other. The few remaining coastal marshes within the Toronto Islands are remnants of what was once part of the largest coastal wetland complex in the western portion of Lake Ontario, which included Ashbridges Bay. Coastal wetlands are now considered rare in the western end of Lake Ontario.

The objective of this project was to create approximately 1.5 ha of wetland around the Toronto Islands to assist the RAP objective of 75 ha of wetland creation. The wetland creation project was undertaken over a three-year period from 2011-2013, creating three discrete fish habitat enhancements occurring in three phases. This was a rare type of habitat restoration project where existing terrestrial habitat was converted into aquatic habitat.

The goal of this habitat creation work in the Toronto Islands was to create fish and wildlife habitat by creating functional vegetated shorelines consisting of coastal marsh, shrub thickets, mudflats, cobble beaches, sand dunes as well as wet meadow. Non-traditional shoreline treatments were employed which utilize log tangles and bioengineering to protect the shoreline and provide habitat for aquatic species and semi-aquatic terrestrial species. Critical habitat features were installed to improve aquatic habitat. Woody debris, boulders and other large substrates were strategically placed near and below the average water level to enhance habitat for fish and other aquatic species. Strategic placement of some material above water also benefits semi-aquatic and terrestrial species that use wetland habitat.

This project was in accordance with the interim target 'Support the implementation of priority projects' as identified in the TWAHRS outlined by the Toronto RAP for the Toronto waterfront. This project implements the TWAHRS/RAP delisting targets for coastal wetlands and estuaries and compensates for the historic loss of the approximately 500 ha wetland complex at Ashbridges Bay.

2009 2017 2017

Figure 38: Toronto Islands created wetland project before (left) and after (centre). Project polygons are shown at right. (Photos: First Base Solutions 2009; City of Toronto 2017)

This site had sufficient pre- and post-restoration data for temporal comparisons (18 years pre- and 6 years post-restoration). Piscivore CPUE was high at this site peaking with a CPUE of 242 in 2005. The high CPUE consisted of 1 adult Bowfin (62 cm), 1 adult Largemouth Bass and 240 juvenile Largemouth Bass. Northern Pike also frequently used this habitat with 28 individuals caught over the entire time period (1992 to 2019) consisting of 12 juveniles. Northern Pike CPUE decreased significantly at this site between 1992 and 2019 and only 1 individual was caught post-restoration ($r=-0.426$, $p=0.038$). Northern Pike were primarily caught prior to 2013 with only one juvenile Northern Pike caught since 2013. Bowfin were also caught throughout the time period including 13 adults and 2 juveniles.

Forage CPUE was moderate and appeared to be increasing steadily since the 1990s although has been lower since about 2013. Forage fish primarily consisted of Pumpkinseed and Yellow Perch. Yellow Perch CPUE increased significantly between 1992 and 2019 ($r=0.527$, $p<0.01$). Rock Bass and Spottail Shiner were also important forage fish although Spottail Shiner has not been caught since 2006. Native CPUE primarily consisted of the species already mentioned but also consisted of higher numbers of Bluegill, Bluntnose Minnow, Brown Bullhead, Emerald Shiner and Gizzard Shad. The adjusted IBI appeared to be similar pre- and post-restoration showing a high degree of variability among years.

The fish community consisted of primarily warmwater species including Largemouth Bass, Pumpkinseed and Brown Bullhead. There were also many coolwater species with Yellow Perch and Spottail Shiner having the highest CPUE. There were no coldwater fish at this site. Fish communities were similar between pre- and post-restoration time periods. This similarity could be due to large increases in CPUE occurring during the middle time period between approximately 2000 and 2010.

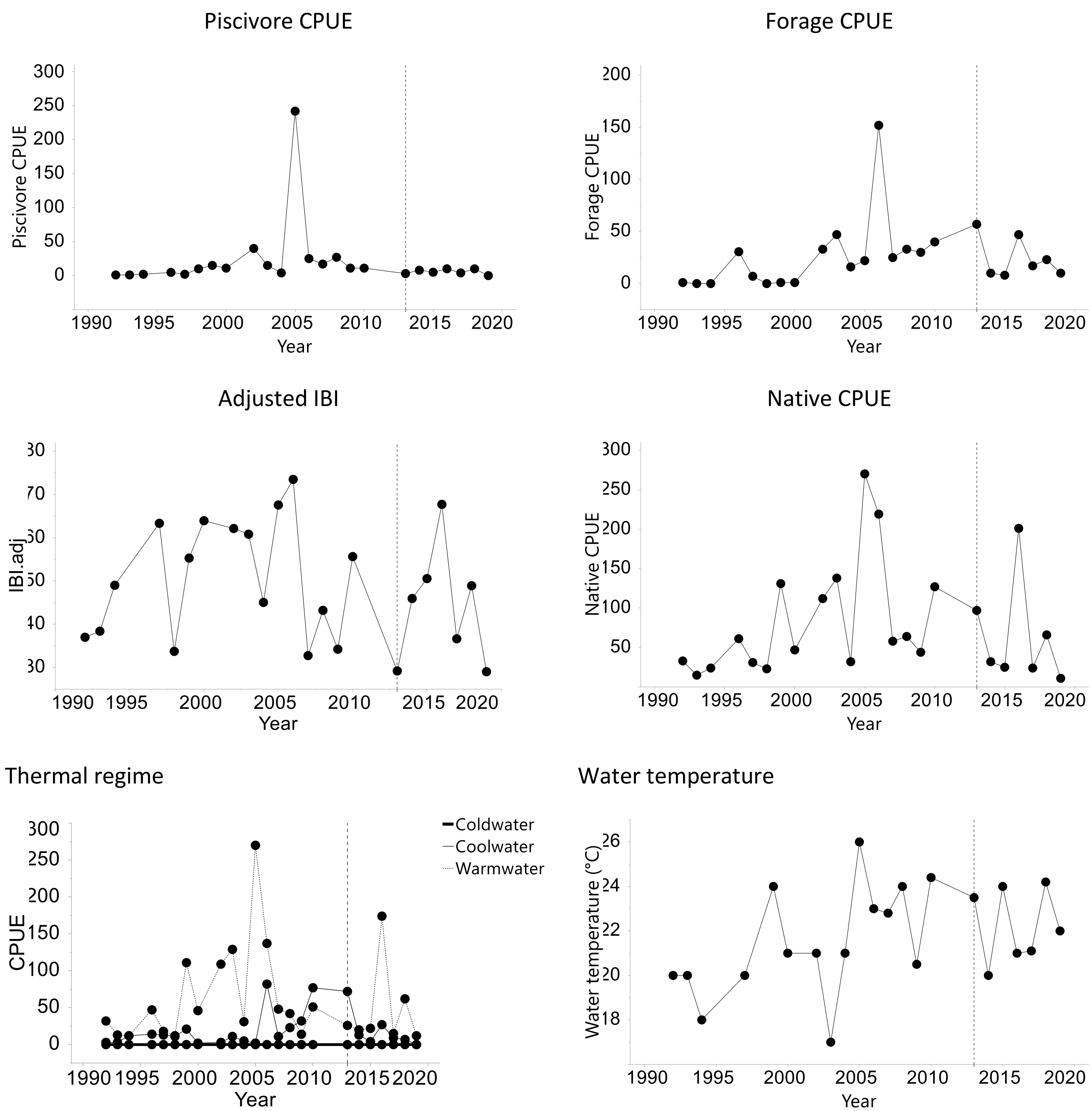


Figure 39: Donut Island TWAHRS metrics.

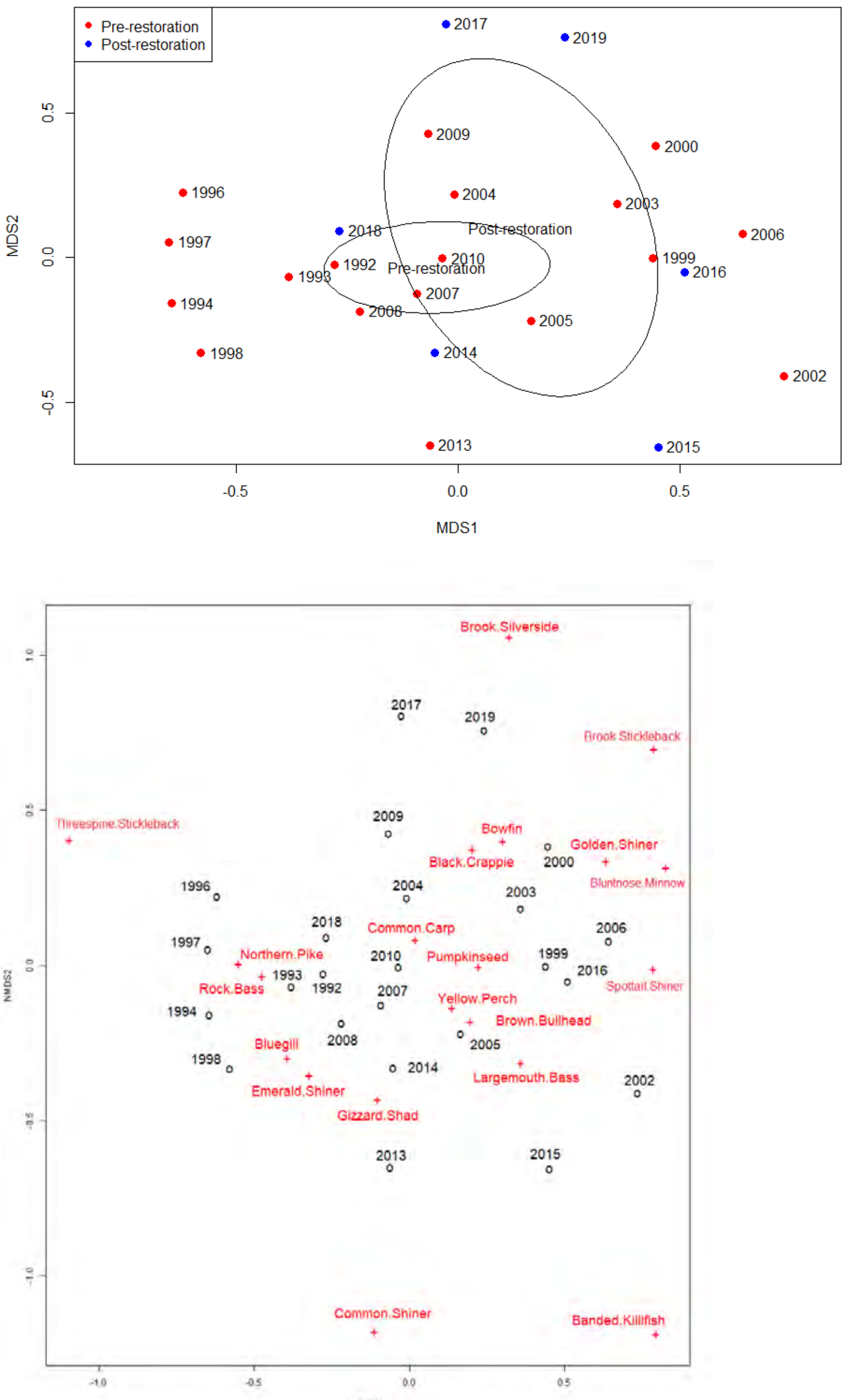


Figure 40: Donut Island fish community ordination (Stress = 0.23).

3.5.4 Hearn Generating Station Recreation Node

This site was selected to receive a recreation node, which was installed by TRCA over a relatively short period in the winter of 2015. The node received a surcharged shoreline with smaller roundstone aggregate, as well as anchored logs protruding from the armourstone horizontally, underwater.

Figure 41: Hearn recreation node project before (left) and after (centre). Project polygons are shown, right. *(Photos: First Base Solutions 2009; City of Toronto 2018)*

Figure 42: Newly opened recreation node with angler, March 25, 2015. *(TRCA 2015)*

This site had sufficient pre- (2004-2014) and post-restoration (2015-2019) data for temporal comparisons although future monitoring may contribute more information on inter-annual variation post-restoration. Piscivore CPUE was low at this site with only seven Largemouth Bass, four Northern Pike and one Smallmouth Bass caught over the entire time period (2004-2019). Forage CPUE was variable consisting of primarily Rock Bass, Yellow Perch, Gizzard Shad, Emerald Shiner and Pumpkinseed (in descending order of CPUE). Rock Bass and Yellow Perch occurred in moderate numbers over the entire time period while Pumpkinseed occurred in low numbers. Emerald Shiner and Gizzard Shad occurred infrequently over the years but when they occurred, they had moderate numbers. Native species CPUE was moderate and peaked with a CPUE of 64 in 2012 consisting of primarily Yellow Perch. Other native species included the species mentioned above along with several other infrequently occurring species: Black Crappie (*Pomoxis nigromaculatus*), Bluntnose Minnow, Brown Bullhead, Freshwater Drum, Spottail Shiner and Threespine Stickleback. The fish community consisted of primarily coolwater species including Yellow Perch, Rock Bass, Gizzard Shad and Emerald Shiner. There were also many warmwater species with Pumpkinseed, Common Carp, Freshwater Drum and Largemouth Bass having the highest CPUE. There were no coldwater fish at this site. Fish communities were similar between pre- and post-restoration time periods. The adjusted IBI appeared to be similar pre- and post-restoration showing a high degree of variability throughout the entire time period.

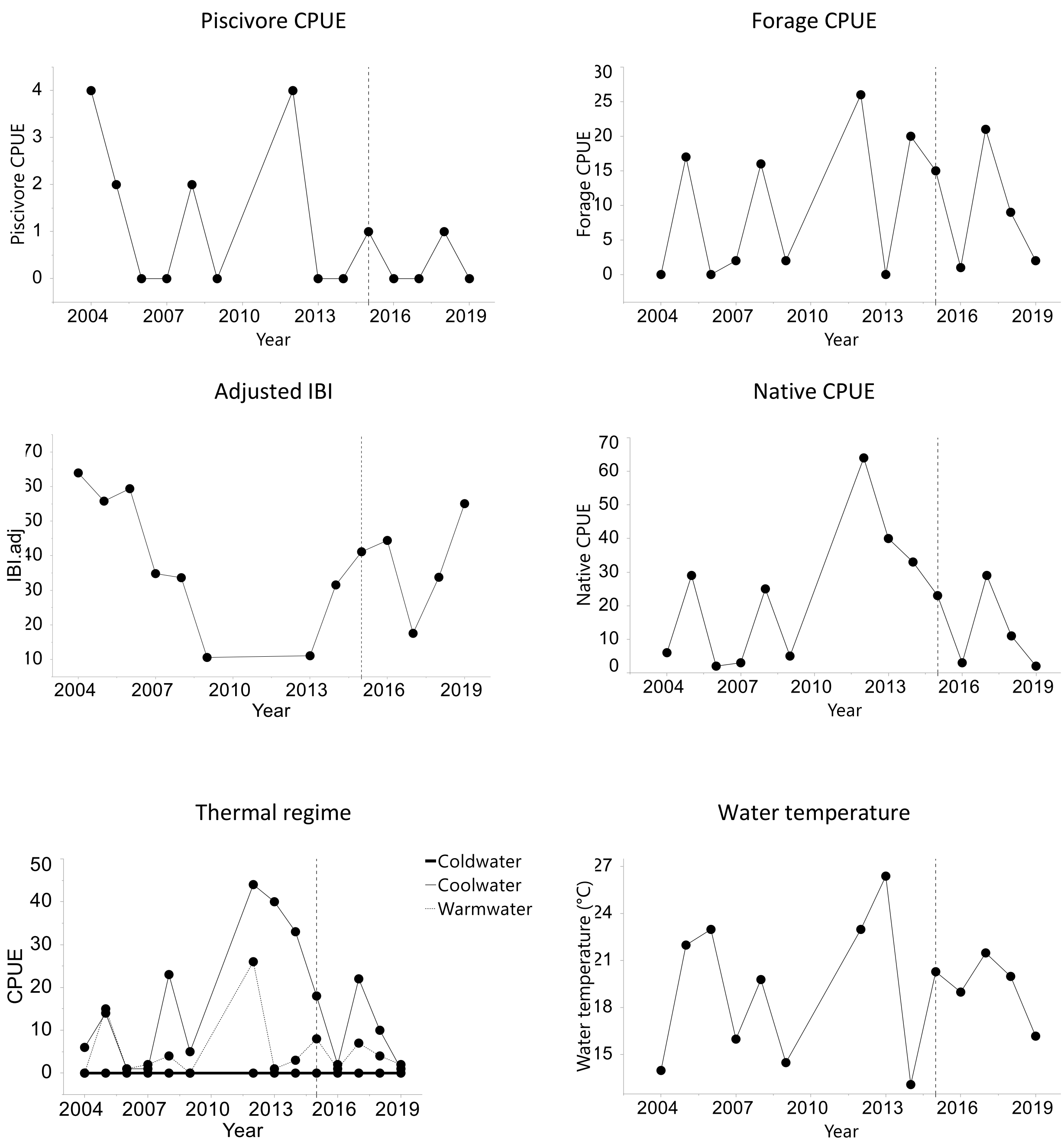


Figure 43: Hearn recreation node TWAHRS metrics.

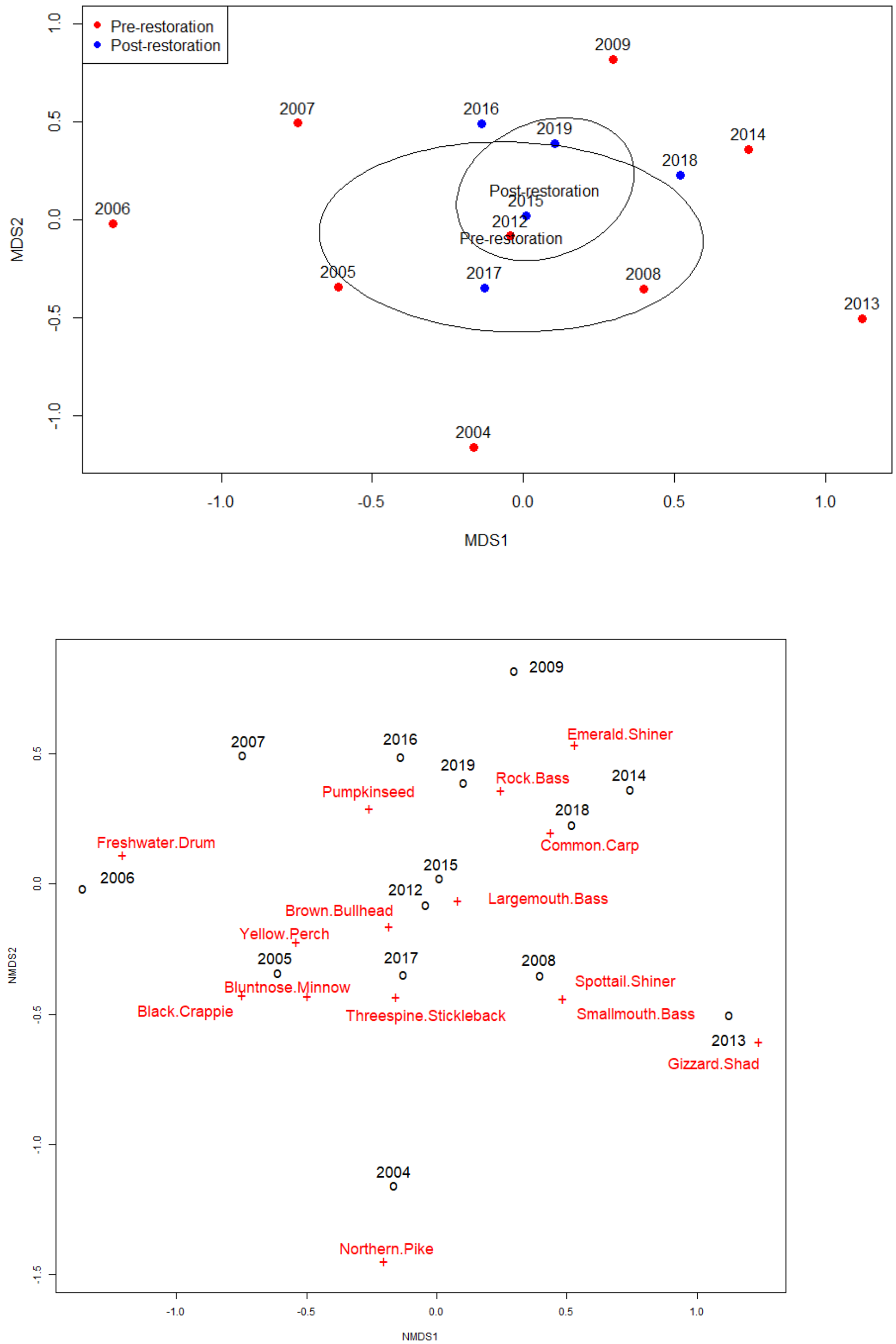


Figure 44: Hearn recreation node fish community ordination (Stress = 0.19).

3.5.5 Inner Harbour Habitat Restoration

We examined fish community composition at four boat slips in Toronto Harbour. A created wetland, the Spadina Slip wetland, is located west of Spadina Slip and fish passage is possible at higher water levels both into the Spadina Slip and to the south of the wetland. A reference slip was also assessed (York Quay).

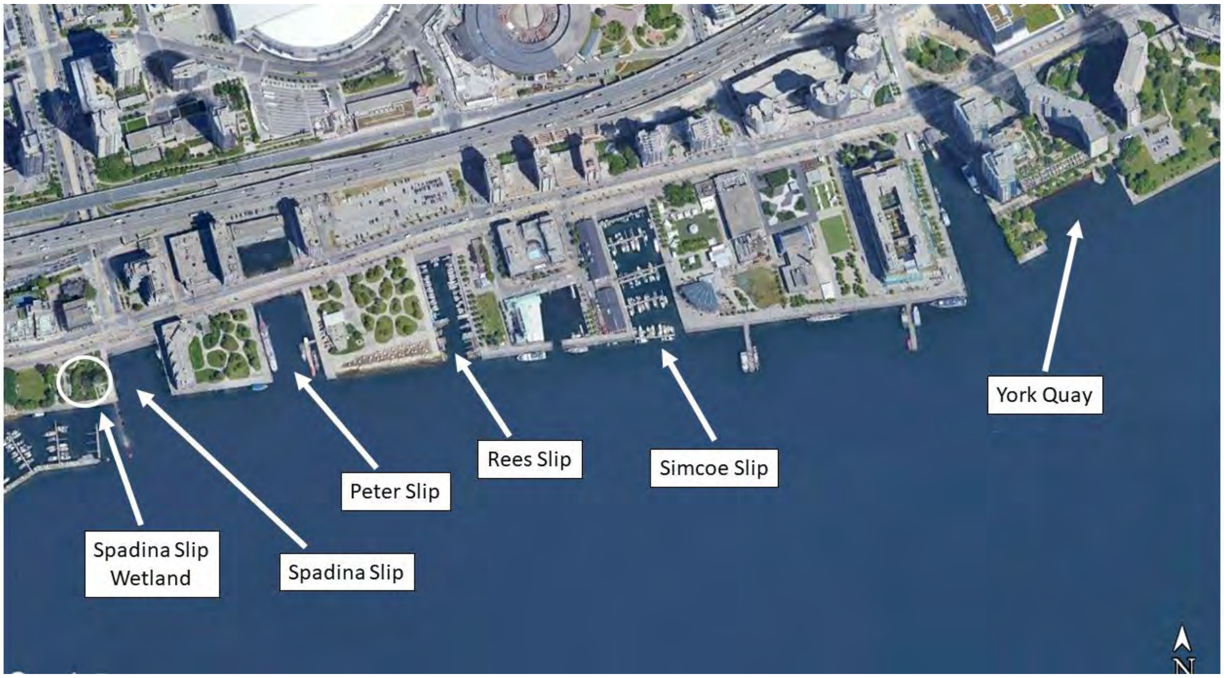


Figure 45: Four slips of Toronto Harbour assessed for changes in fish community.

3.5.5.1 Toronto Harbour York Quay

Although material was placed beneath the boardwalk of York Quay in 1996, this slip was chosen to represent background or reference fish community conditions within the slips as it had the longest record of electrofishing data available.

2017

Figure 46: Reference site York Quay. *(Photo: City of Toronto 2018)*

Common Carp had the highest CPUE over all years (1999-2018) at this site (38), followed by Northern Pike (29) and Emerald Shiner (17). The CPUE of Common Carp may be declining although results were only approaching significance (r=-0.495, p=0.085). Of the 16 Northern Pike caught over all years, 14 were adults (>45.7 cm) and 2 were juveniles (<45.7 cm). Other species occurred in multiple years but had a lower CPUE including Freshwater Drum, Gizzard Shad, Largemouth Bass, Spottail Shiner, Threespine Stickleback and Yellow Perch. Species only caught in one year included Central Stoneroller, Chinook Salmon, Common Shiner, and Mottled Sculpin. Mottled Sculpin, Spottail Shiner only occurred pre-2005. Spottail Shiner and Threespine Stickleback CPUE decreased significantly between 1989 and 2018 (r=-0.629, p=0.021 and r=-0.732, p<0.01, respectively).

3.5.5.2 Toronto Harbour Spadina Slip

In 2007, this slip received TWAHRS inner harbour quay treatments. Waterfront Toronto led the installation of public realm wavedecks, which where lit from below for the public. The shoreline around the seawalls and under the constructed wavedeck was surcharged with small roundstone aggregate. The stone treatment was sloped beneath the wave deck to mimic the natural shoreline and soften the effects of the hardened dock wall. Plenty of woody material and anchored logs were installed amidst the stone placement. A large area was deposited with sandy material and left open, to encourage submergent aquatic plant growth. This restoration action occurred over a relatively short period in the spring of 2007.

2005 2018

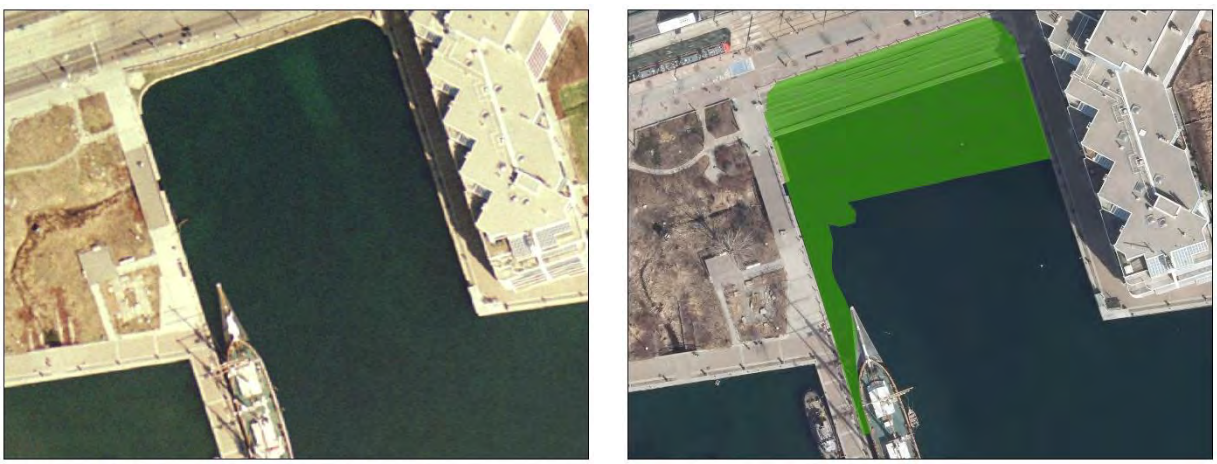


Figure 47: Spadina Slip Wavedeck Project before (left) and after (right), shown with project polygons. (Photos: First Base Solutions 2005; City of Toronto 2018)

In addition to the data presented here (2012, 2014, 2016, 2018 and 2019), this site was also surveyed in July 2007-2010, but the only species caught included species removed from the analysis (72 Alewife, 1 Rainbow Smelt and 1 White Sucker). This lack of pre-restoration data makes pre- and post-restoration comparisons impossible. Piscivores caught at this site included one juvenile Largemouth Bass and one large Northern Pike in 2012 (77 cm) and three large Northern Pike caught in 2014 (62, 70 and 92 cm). Although Alewife were excluded from the analysis, Northern Pike may have been using the abundant Alewife schools (105 individuals) as a food source in 2014. Forage fish species consisted of primarily Yellow Perch (10 individuals in 2012 and 2014), although Brown Bullhead, Common Shiner, Emerald Shiner, Gizzard Shad, Pumpkinseed, Rock Bass and Threespine Stickleback were caught to a much lesser extent (less than two individuals over all years). These species also generally represent the composition of native species. The fish community consisted of primarily coolwater species such as Yellow Perch and Northern Pike although there was also a small warmwater and coldwater community. The only fall migratory species using this site was one Chinook Salmon in July of 2016. A fish community ordination was not completed at this slip, or subsequent slips, due to limited catch and there were no significant changes in species-specific CPUE.

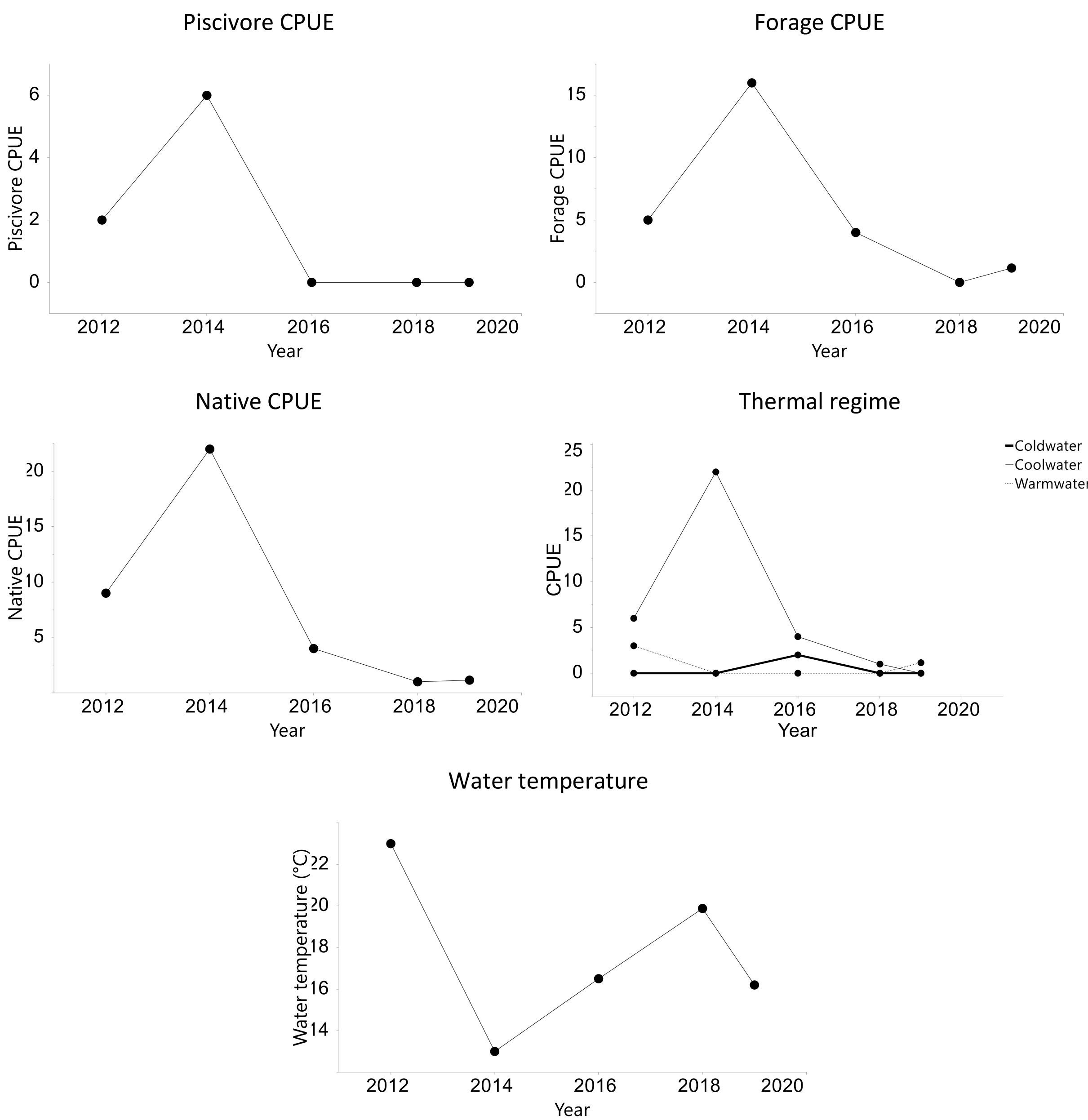


Figure 48: Spadina Slip TWAHRS Assessment Metrics

3.5.5.3 Toronto Harbour Peter Slip

Restoration work was undertaken here in 2007 as part of compensation for the City of Toronto's H_TO park. Surcharging was undertaken against the vertical seawalls of Peter Slip to ameliorate underwater conditions. The project polygons are an imagining of work undertaken, as work is completely submerged, and no design drawings were available.

2018

Figure 49: Peter Slip submerged aquatic habitat polygon. (Photo: City of Toronto 2018)

Due to the lack of data on restoration dates, assessing the effectiveness of restoration at this site was not possible. Piscivores using this site included two juvenile Largemouth Bass (one caught in each of 2011 and 2013), one juvenile Smallmouth Bass (2013) and three large adult Northern Pike (77, 81 and 90 cm). Two of the pike were caught in 2009 and one in 2011 and due to these detections early in the time period, these resulted in declines that were approaching significance (r=-0.639, p=0.064). Again, pike may be foraging on Alewife due to a higher Alewife catch in 2009, although catches were not as high in 2011 and were higher in other years when pike were not caught. Forage fish CPUE included four Emerald Shiners in 2010, one Emerald Shiner, one Yellow Perch and one Gizzard Shad in 2013, four Threespine Stickleback in 2014, one Gizzard Shad in 2016 and four Threespine Stickleback again in 2018. Threespine Stickleback was the most abundant species at this site with 24 caught in October 2015 including 20 juveniles. Stickleback may be dispersing from the Spadina Quay Outer Breakwall, another site nearby that tends to have very high catches of this species. The only non-native species using this site was Common Carp including four adults caught in 2009 and one adult in 2016. The fish community consisted of primarily coolwater species such as Emerald Shiner and Threespine Stickleback although there was also a small warmwater community. No fall migratory species were caught at this site during July or October night-fishing runs; however, CPUE appeared to be higher during October surveys compared to July surveys.

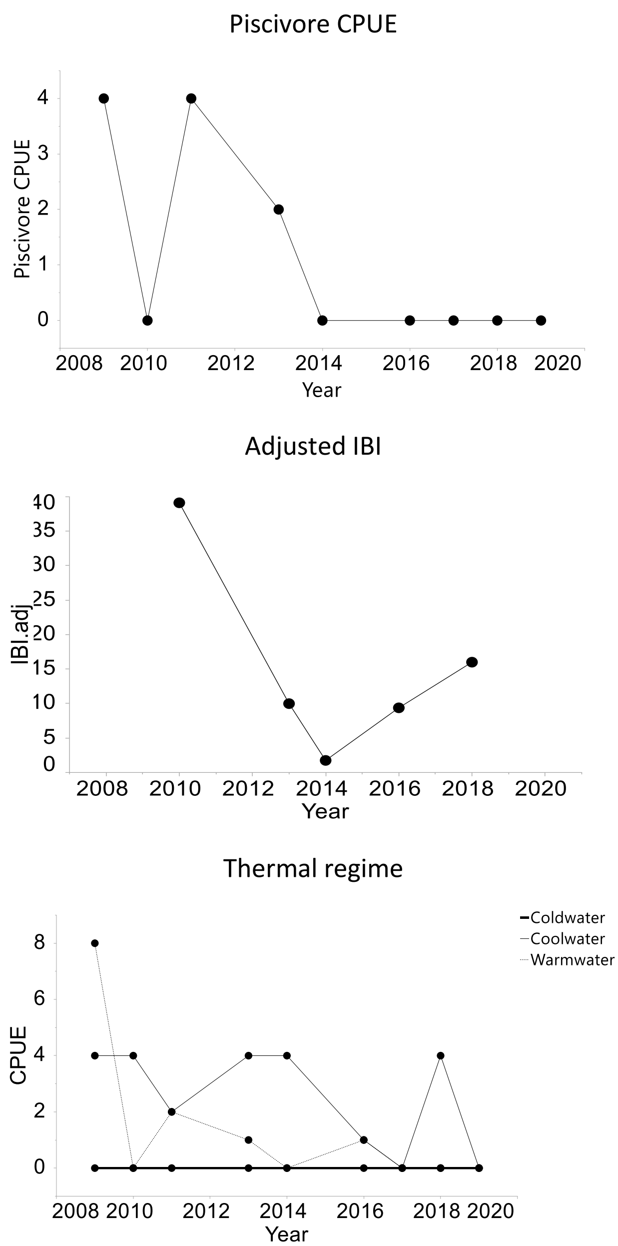


Figure 50: Peter Slip TWAHRS Assessment Metrics

3.5.5.4 Toronto Harbour Rees Slip

Another wavedeck, implemented in 2009, played off the successes incurred at nearby Spadina Slip. The inner harbour quay treatments at Rees slip included a series of underwater log cribs, as well as shoreline surcharging. The proponent once again was Waterfront Toronto.

2005 2018

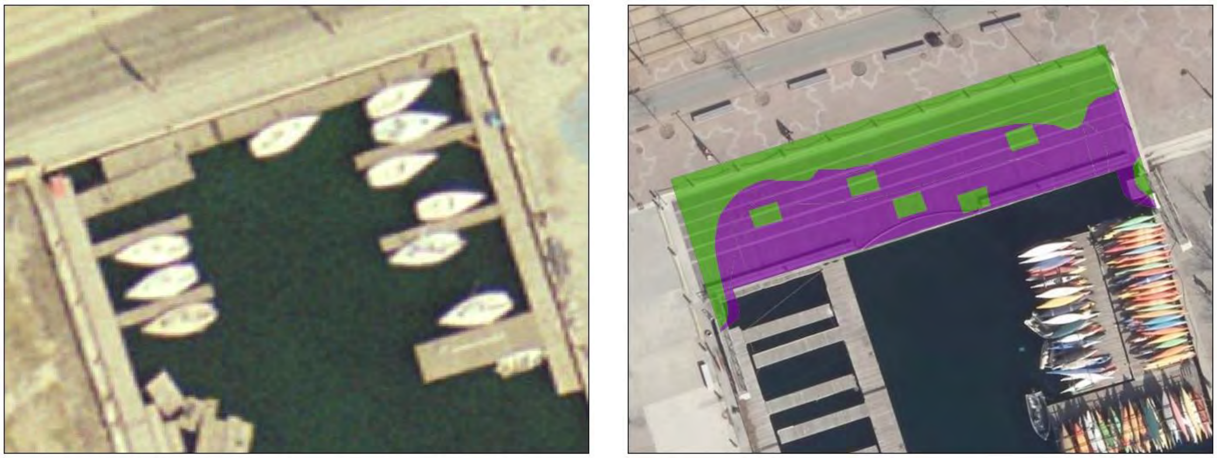


Figure 51: Rees Slip Wavedeck Project before (left) and after (right), shown with project polygons. (Photos: First Base Solutions 2005; City of Toronto 2018)

This site only had one year of pre-restoration data making it difficult to evaluate the effectiveness of the restoration. Northern Pike were the only piscivore using this site. One large adult was caught in 2008 (88 cm), two large adults in 2009 (82 and 90 cm) and one juvenile in 2013. Northern Pike CPUE declined significantly at this site between 2008 and 2018 (r=-0.697, p=0.37). Northern Pike may have also been using the abundant Alewife schools as a food source in 2008 (62 individuals) and 2009 (35 individuals) at this site. Forage fish CPUE (excludes Alewife) was generally low at this site although it was higher in 2014 when 16 adult Brook Stickleback (*Culaea inconstans*) and 6 adult Threespine Stickleback were caught. These are coolwater species than spawn in shallow water from late April to July (depending on water temperature) and their occurrence could be related to the nearby potential source population and lower water temperatures in the slip during the 2014 run. Threespine Stickleback construct nests using small twigs and other plant debris (Scott and Crossman 1998) and restoration may be providing needed nesting substrate. Few other native species used this site including one Blacknose Dace (*Rhinichthys atratulus*) in 2018, one Emerald Shiner in 2013 and one Pumpkinseed in 2008. The fish community consisted of almost exclusively two coolwater species: Brook Stickleback and Threespine Stickleback. The only fall migratory species using this site was one Chinook Salmon in July of 2009.

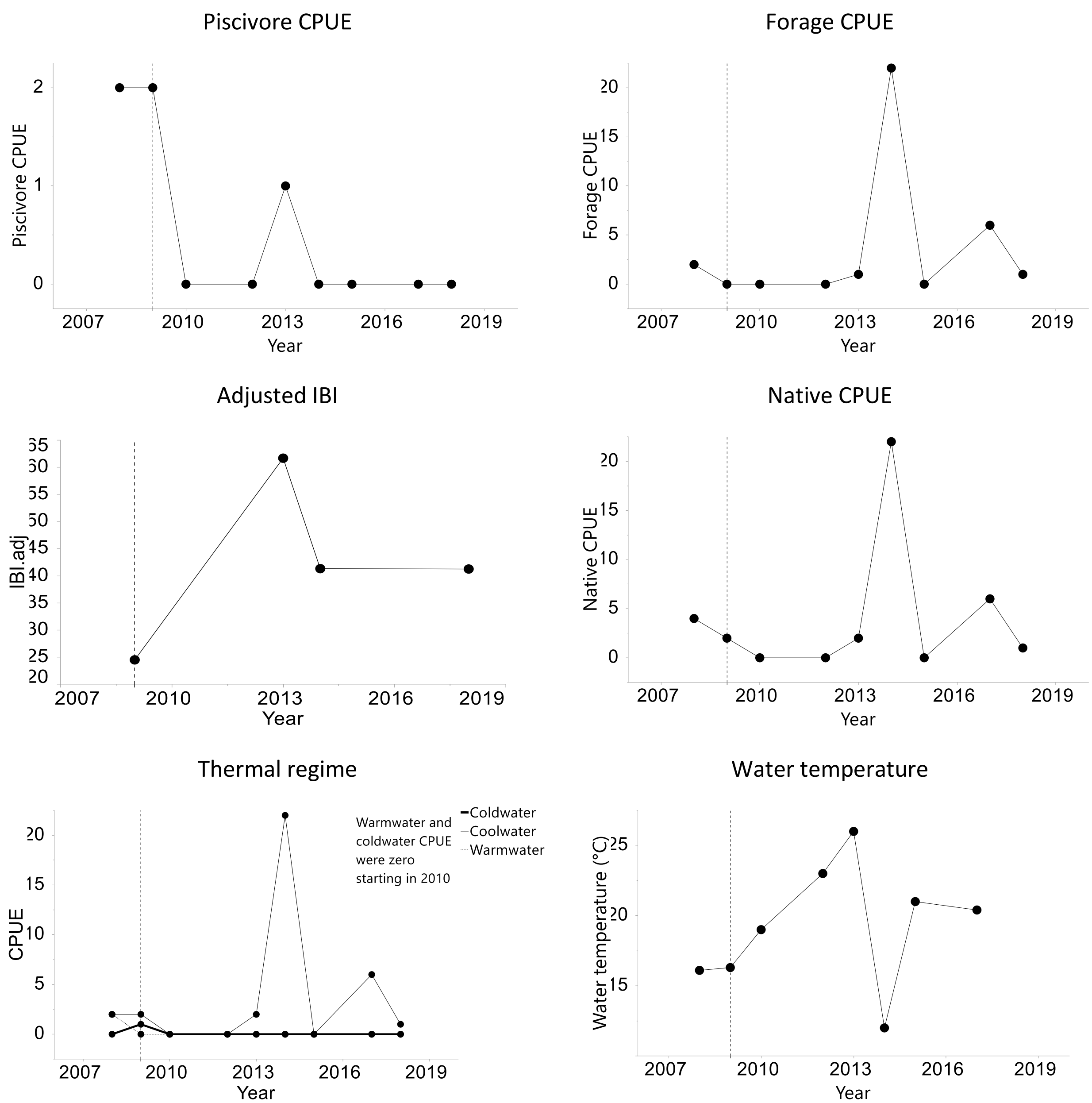


Figure 52: Rees Slip TWAHRS Assessment Metrics

3.5.5.5 Toronto Harbour Simcoe Slip

Like Rees slip, in 2009 Simcoe Slip received inner harbour quay treatments involving shoreline surcharging, shoreline shoals, and log cribs. One notable difference is the filling of the north portion of the slip to accommodate greater pedestrian use around the slip. Waterfront Toronto led the implementation of these TWAHRS-derived habitat concepts, creating greater continuity in available habitat for fish across the stark inner harbour landscape.

2005 2018

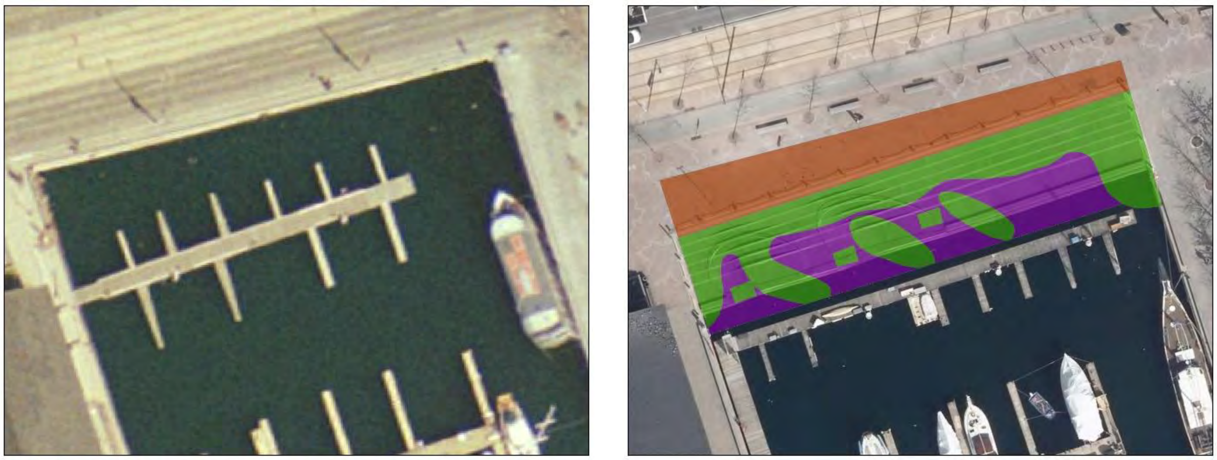


Figure 53: Simcoe Slip Wavedeck Project before (left) and after (right), shown with project polygons. (Photos: First Base Solutions 2005; City of Toronto 2018)

Simcoe Slip was surveyed in July 2008, 2010, 2012 and 2019 and due to the limited pre-restoration data, comparisons pre- and post-restoration were difficult. Only one Emerald Shiner was caught during these surveys (excluding species showing lake-wide trends) and as such, no temporal correlations were conducted at this site and results are described qualitatively. We also describe October catch data from 2007-2009 and 2011. This site was primarily used by Alewife (267 individuals) and Emerald Shiner (1155 individuals including 1062 caught in 2009). Other species caught included one Brook Silverside (*Labidesthes sicculus*) in October 2008 and one Common Carp in May 2010. No piscivores or fall migratory species were caught at this site. The limited catch and potential absence of piscivores at this site could be due to its distance from the Spadina Slip wetland or another source habitat. Higher catches of Alewife and Emerald Shiner suggest that these slips provide habitat for large numbers of these species.

3.5.6 Tommy Thompson Park (Leslie Street Spit)

When the St. Lawrence Seaway opened in 1959, the Toronto Harbour Commission (now PortsToronto) anticipated that shipping traffic would increase in the Port of Toronto and worried that there would not be enough space to accommodate the influx. As such, a new lakefilling project was initiated to construct the Leslie Street Spit (also known then as the Eastern Headland) at the end of Leslie Street, an extension of the previously filled Ashbridges Marsh. This land base was zoned to provide port related infrastructure such as warehouses and was designed to provide shelter for the Outer Harbour.

A three phased design was followed in the creation of the land base. The Baselands and the Neck were created between 1959 and 1972 from earth, brick and large rubble from construction and demolition sites around the city. Almost two million truckloads of materials (over nine and a half million cubic metres) were used to build this land. The second phase of construction, the creation of the Peninsulas and Embayments, was initiated in 1973 when the Outer Harbour was dredged to maintain a shipping channel. This two-year project consisted of the deposition of over seven million cubic metres of silty sand material on the leeward side of the headland.

Due to concerns over open water disposal of polluted dredged material, the Toronto Port Authority designed a plan to create Confined Disposal Facilities (CDFs, also referred to as Cells) at the Spit. This third phase of construction began in 1979 and consisted of the creation of an Endikement on the lake ward side of the headland to house three CDFs for storage of dredged sediments from the Keating Channel and Inner Harbour. Over one and a half million truckloads of earth, brick and large rubble (over 10 million cubic metres) had been used to build the Endikement by 1991. The first CDF was filled to capacity in 1985 covering an area of 8.2 hectares, and the second in 1997 covering an area of 9.3 hectares. The third CDF is significantly larger than the others at 32.1 hectares and is not expected to be filled to capacity for several decades.

3.5.7 Embayments of Tommy Thompson Park

Four embayment habitats of TTP received substantial habitat restorations and enhancements since the mid-1990s in keeping with the TTP Master Plan and incorporating the best restoration practices of TWAHRS. Several TWAHRS techniques such as wetland shoreline profile and complex shoreline profile improvements were used to raise the grade and depth of embayment shorelines, to raise water temperatures creating thermal refugia, construct sheltering islands and berms, and to enhance aquatic vegetation growth. Other ubiquitous techniques included enhancing the nearshore diversity through introducing shoreline shoals and boulder clusters, and by installing woody material such as anchored logs, log piles or log tangles, as well as log cribs. Cribs were not described explicitly as a technique by the TWAHRS document, but their inclusion was encouraged in the compendium drawings and their widespread use in embayment and wetland habitats evolved from TRCA's restoration expertise. As with other sites, aquatic and riparian plantings were a cornerstone technique for finalizing the restoration plan at embayment sites. This section explores the resultant changes in fish communities, as well as summaries of the restoration habitat implemented.

3.5.7.1 Tommy Thompson Park - Embayment A

Embayment A of TTP received multiple rounds of restoration. Until 1999, its shores were primarily sand with limited shoreline variety. From 1999-2000, a first round of restoration was applied to the rear shores of Embayment A. This restoration work was conducted opportunistically, as were many of the projects undertaken before the inception of TWAHRS. The work changed the depth of the shoreline and created shallow backwater channels behind sand-filled habitat islands. A protective outer edge surcharged with TWAHRS prototype techniques, such as boulder armouring and anchored logs, protected inlet channels. Native aquatic species were planted on and among the constructed islands and channels. The purpose of this restoration was to create warm water channels at a depth and substrate conducive to submergent and emergent vegetation growth.

Shortly after this initial project, in 2003 the eastern side of Embayment A received a 450 m^2 wetland habitat creation project as compensation for City of Toronto's Eastern Beaches project. A modest wetland was built along the eastern shore of Embayment A. The wetland featured protected inlet channels, protection of the outer edge using rock and woody debris, and native aquatic plantings. This piece was later tied-in to larger restoration work along the backshore of Embayment A.

In 2009, implementation of the TTP Master Plan resulted in more extensive restoration of the backshore area of Embayment A. The project saw the creation of additional backwater channels to provide spawning and nursery habitat and also thermal refuge for warm and coolwater fish to help mitigate the cold water surges from Lake Ontario. The channels were created through surcharging the existing shoreline with sand material to create three shallow island landforms with crested berms. Large boulders and willow fascines were placed along the berms to provide protection against erosion. Features including root wads, logs and rocky shoals were added to improve near shore aquatic and terrestrial habitats and the shallow islands were planted with native trees, shrubs, wet meadow wildflowers and aquatic herbaceous plants. Deep water enhancements were also added, including fish cribs, log tangles and rock shoals.

In 2010, an estimated 9,600 aquatic plants were introduced to finalize the habitat dressing of Embayment A, totaling an area of approximately 200 m^2 planted to a density of 80-100%. A further 4,740 m^2 of riparian area on the islands and along the shore was planted. Emergent plantings included great bur-reed (*Sparganium eurycarpum*), cattail (*Typha* spp.), hard-stemmed bulrush (*Schoenoplectus acutus* var. *acutus*), soft-stemmed bulrush (*Schoenoplectus tabernaemontani*), sedges (*Carex sp.*), black-fruited bulrush (*Scirpus atrovirens*) and seeds of northern wild rice (*Zinzania palustris* var. *palustris*). Submergent areas were planted with fragrant water lily (*Nymphaea odorata*). Riparian plantings included spotted Joe-Pye weed (*Euphatorium maculatum* var. *maculatum*), swamp milkweed (*Asclepias incarnata* ssp. *incarnata*), blue vervain (*Verbena hastata*), willow species (*Salix sp*.), and red osier dogwood (*Cornus sericea*). Finally, in 2014 a tern raft was added to the centre of Embayment A to supplement tern nesting conditions.

Figure 54: Habitat details immediately post-restoration in Embayment A. These details are typical of the restoration style at Tommy Thompson Park. Fencing can be seen encircling emergent vegetation plots (to protect from waterfowl herbivory), while anchored logs and boulders armour the leeward edges of the newly constructed habitat islands. *(City of Toronto 2012)*

Figure 55: Log crib left on ice of Embayment A, March 2010. *(TRCA 2010)*

Figure 56: Woody material and boulders armour the created islands, giving way to the vegetated backwater channels of Embayment A. *(TRCA 2013)*

Figure 57: Embayment A projects before (left) and after (centre). Project polygons are shown on the right.
(Photos: Triathlon Mapping 1999; City of Toronto 2016)

This site has 12 years of pre-restoration data (1989-2008) and 9 years of post-restoration data making comparisons possible. Piscivore CPUE was low at this site with only two adult Northern Pike caught in 1990, one adult Northern Pike caught in 1993 and three juvenile Largemouth Bass caught in 2012. The limited occurrence of Northern Pike only in the earliest years resulted in a decline in CPUE that was approaching significance (r=-0.405, p=0.068). Forage CPUE was also generally low except for in 2006 and 2008. This site appears to be more heavily used by piscivores in October. Both adult and juvenile Largemouth Bass and Northern Pike used this site frequently in October. Several suspected young-of-year Northern Pike (<24.5 cm) were caught in 1993 (3), 1998 (1), 2004 (3), 2005 (3) and 2015 (12).

We found multiple forage fish species (<150 mm) at this site with the most abundant species being Pumpkinseed, Rock Bass, Yellow Perch and Bluntnose Minnow. Even though they were some of the most abundant species, Pumpkinseed and Rock Bass CPUE decreased significantly between 1989 and 2018 (r=-0.691, p<0.001 and r=-0.450, p=0.041, respectively). Native species CPUE was generally low at this site except for in 1991 when 140 Pumpkinseed and 21 Rock Bass were caught. The only non-native species using this site was Common Carp occurring both pre- and post-restoration. The adjusted IBI was relatively similar across the time period except for in 2016 and 2018 when it was lower than any previous years. The fish community consisted of almost all coolwater species (e.g. Gizzard Shad, Yellow Perch, Rock Bass) and warmwater species (e.g. Pumpkinseed, Common Carp) although many of these species had declining trends.

Fish community composition was statistically similar pre- and post-restoration (overlapping 95% CI's) although some species were characteristic of pre- and post-restoration time periods. Pre-restoration communities appeared to be more species rich compared to post-restoration. Pre-restoration communities can be distinguished by the presence/higher CPUE of Bluntnose Minnow, Brown Bullhead, Fathead Minnow, Freshwater Drum, Johnny Darter, Lake Whitefish, Brook Stickleback, Northern Pike, Pumpkinseed, Rock Bass, and Spottail Shiner. Both Brown Bullhead and Spottail Shiner CPUE decreased significantly between 1989 and 2018 (r=-0.472, p=0.031 and r=-0.667, p<0.001, respectively). Post-restoration communities can be distinguished by a higher CPUE of Gizzard Shad, Yellow Perch and Common Carp.

Future assessments of this site would benefit from additional annual electrofishing surveys conducted during the month of July and at night.

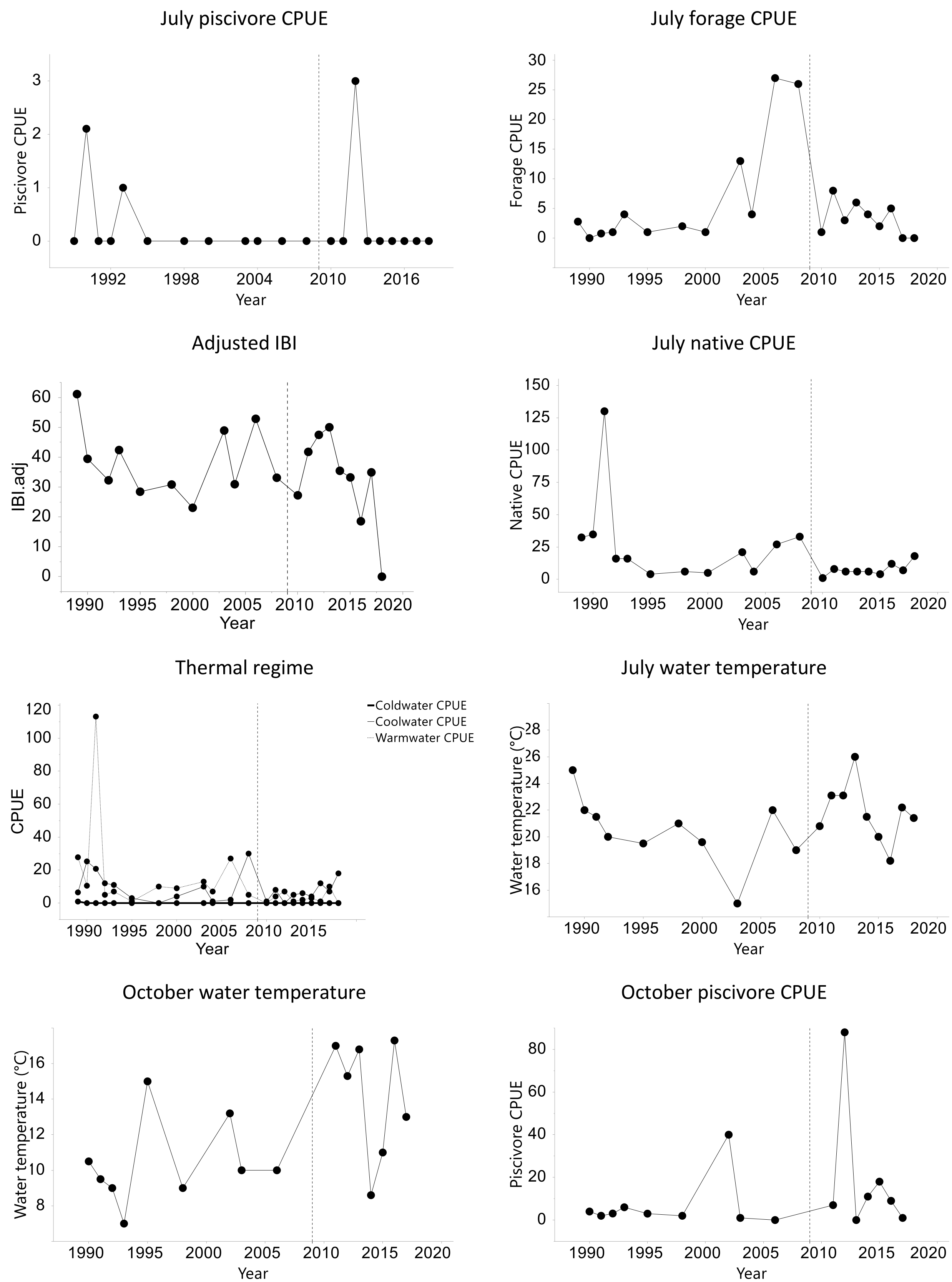
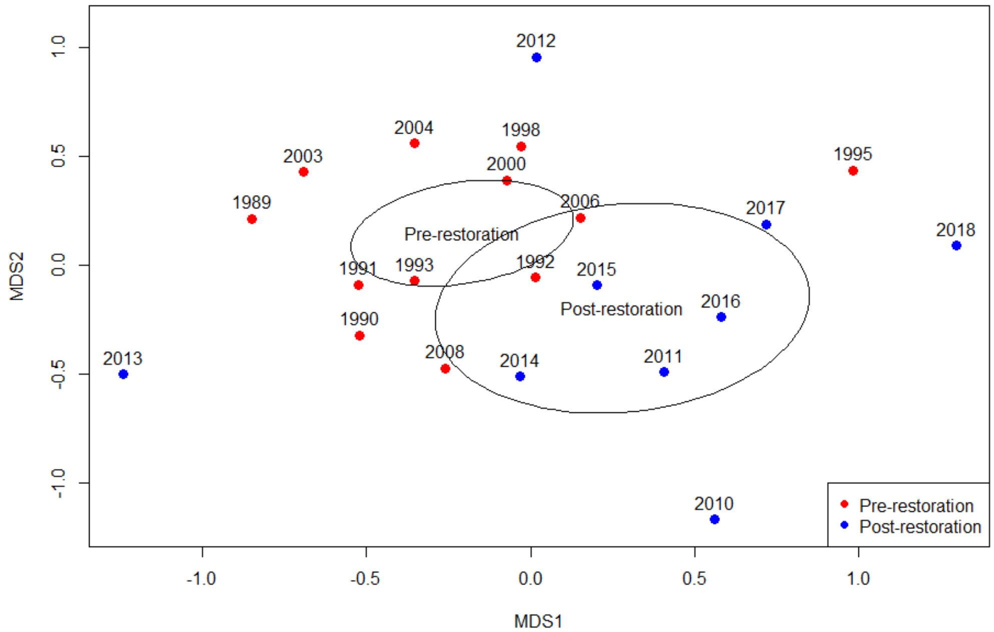


Figure 58: Embayment A TWAHRS Assessment Metrics



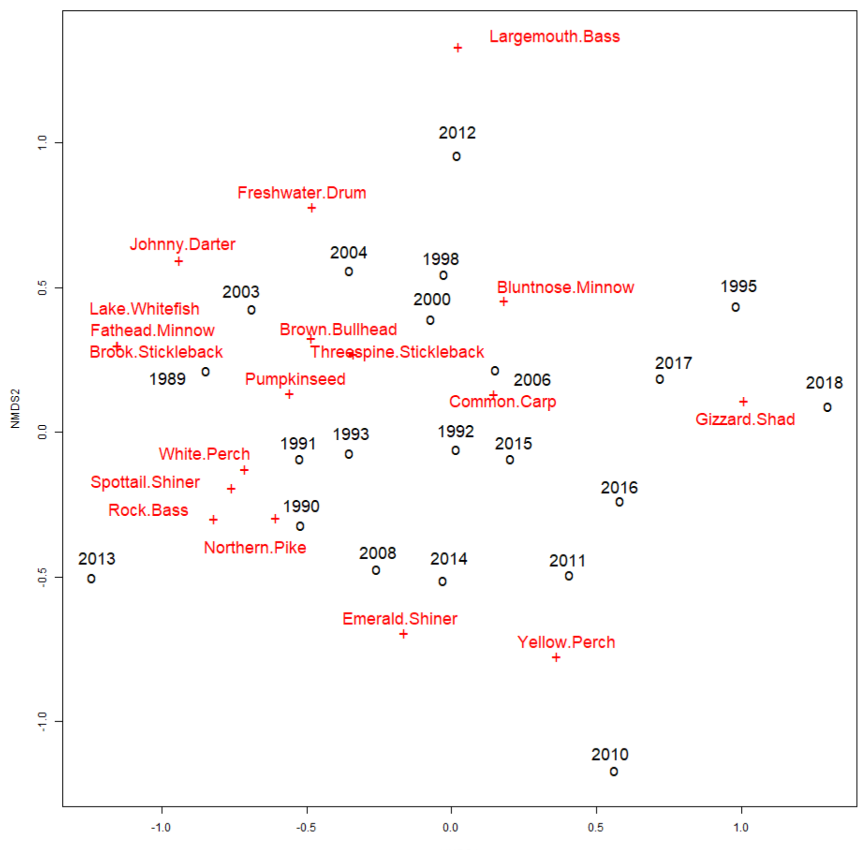


Figure 59: Embayment A Community Ordination (Stress = 0.206)

Table 5: Embayment A Habitat Summaries

Restored Area	TWAHRS Techniques Used	Area Planted (m^2)	Total Area Restored (m^2)	Increase in Shoreline Length (m)
Embayment A	Aquatic Vegetation, Wetland Berms, Wetland Shoreline Profile, Complex Shoreline Profile Improvements, Shoreline Vegetation Zones, Anchored Logs, Shoreline Shoal, Log Tangles, Reptile Habitat	4,740	14,410 - aquatic 4,575 - terrestrial	566 (93% increase)

The habitat restoration at Embayment A accomplished many of the intended restoration goals, yet this site may be influenced by several outside factors that limit the expected fish community outcomes. Piscivores were seen to be using the site, particularly in the fall data, and included adult and juvenile Northern Pike and Largemouth Bass. July piscivores were few, but the highest catch occurred post-restoration. Thermal goals were accomplished as shown by the site's use by cool and warmwater guild species, such as Gizzard Shad and Pumpkinseed. Post-restoration communities reflected one comprised of Gizzard Shad, Yellow Perch and Common Carp. This site may benefit from the inclusion of carp exclusion barriers, to limit access of large carp to the backwater spawning channels.

3.5.7.2 Tommy Thompson Park - Embayment B

Like Embayment A, Embayment B received two rounds of restoration. As an embayment connected to Toronto's Outer Harbour, this area received wave and wake action, as well as cold water upwellings. The habitat restoration goals of Embayment B were as follows:

- Create a shallow backwater area more protected from upwellings, suitable for cool and warmwater fish
- Create spawning channels for Northern Pike
- Enhance the embayment's aquatic and riparian vegetation
- Create multi-seasonal habitat for reptiles and amphibians, including spawning pools and hibernacula

Embayment B received the first round of restoration in 1995-1997, when pike spawning channels and amphibian pools unconnected to the lake were dug out. An artificial barrier was created across the back end of the bay, to provide protection from wind and wave action as well as thermal protection. TRCA also enhanced the barrier beach formation by armouring the small created island with boulders. A detailed account of the pre-TWAHRS restoration action can be found in TTP Habitat Creation and Enhancement Projects, 1995-2000 (TRCA 2000).

From 2010-2011, during implementation of Phase I of the TTP Master Plan, many of these initial concepts were embellished by implementing TWAHRS techniques. Further structural habitat such as shoreline shoals, anchored logs, log tangles, and log cribs were placed in the shallow landward edge of the embayment. The exposed shoreline was further protected by boulder stones. The result was a well-defined semi-isolated backwater bay within Embayment B, which is the location of the long-term electrofishing transect. In 2018, an additional pike spawning channel was excavated in the south west corner of the back bay, contributing to the aquatic restored areas summary.

Figure 60: Embayment B restoration project before (left) and after (centre). Project polygons are shown far right. *(Photos: First Base Solutions 2009; City of Toronto 2016)*

This site had limited post-restoration data (2016 and 2019) with 2016 data collected in August and during the day and 2019 collected in July and at night. Although the 2016 data were included here, caution should be used when interpreting the 2016 data compared to other years. Piscivore CPUE was generally low at this site although variable among years. Piscivores included one adult Northern Pike in 1993 and exclusively juvenile Largemouth Bass caught in other years. Forage fish CPUE was generally low at this site although similar to other sites, CPUE increased in the early 2000s followed by a decline. Forage fish species included primarily Pumpkinseed, Bluntnose Minnow, Emerald Shiner, Rock Bass and Yellow Perch. Yellow Perch CPUE increased significantly between 1993 and 2019 ($r=0.561$, $p=0.015$). Native species CPUE was generally high at this site peaking with the single August day-fishing survey in 2016 when a large number of native fish were caught primarily consisting of juvenile Gizzard Shad (461 individuals). Adjusted IBI values were quite variable pre-restoration although were low in the two years of data post-restoration. Common Carp occurred frequently and in high numbers at this site with a CPUE of 22 in 2016. The fish community consisted of only coolwater and warmwater species. Coolwater species with the highest CPUE included Emerald Shiner, Yellow Perch, Gizzard Shad and Rock Bass. Warmwater species with the highest CPUE included Pumpkinseed, Common Carp, Bluegill, and two Spotfin Shiner. October data were limited at this site with only four surveys conducted pre-restoration.

Fish community change was difficult to assess at this site with only two years of post-restoration data although some variability in community composition was apparent through ordination. Pre-restoration had a higher CPUE of many species including Spottail Shiner, Emerald Shiner, Bluntnose Minnow, Brown Bullhead, Common Shiner, Fathead Minnow, Freshwater Drum, Johnny Darter and Threespine Stickleback. Spottail Shiner CPUE may be decreasing at this site although the results were only approaching significance ($r=-0.450$, $p=0.061$). Several species occurred only once and only pre-restoration including Mottled Sculpin, Northern Pike and Longnose Gar (*Lepisosteus osseus*). Fish communities post-restoration had a higher CPUE of Gizzard Shad and Bluegill. Future assessments of this site would benefit from additional annual electrofishing surveys conducted during the month of July and at night.

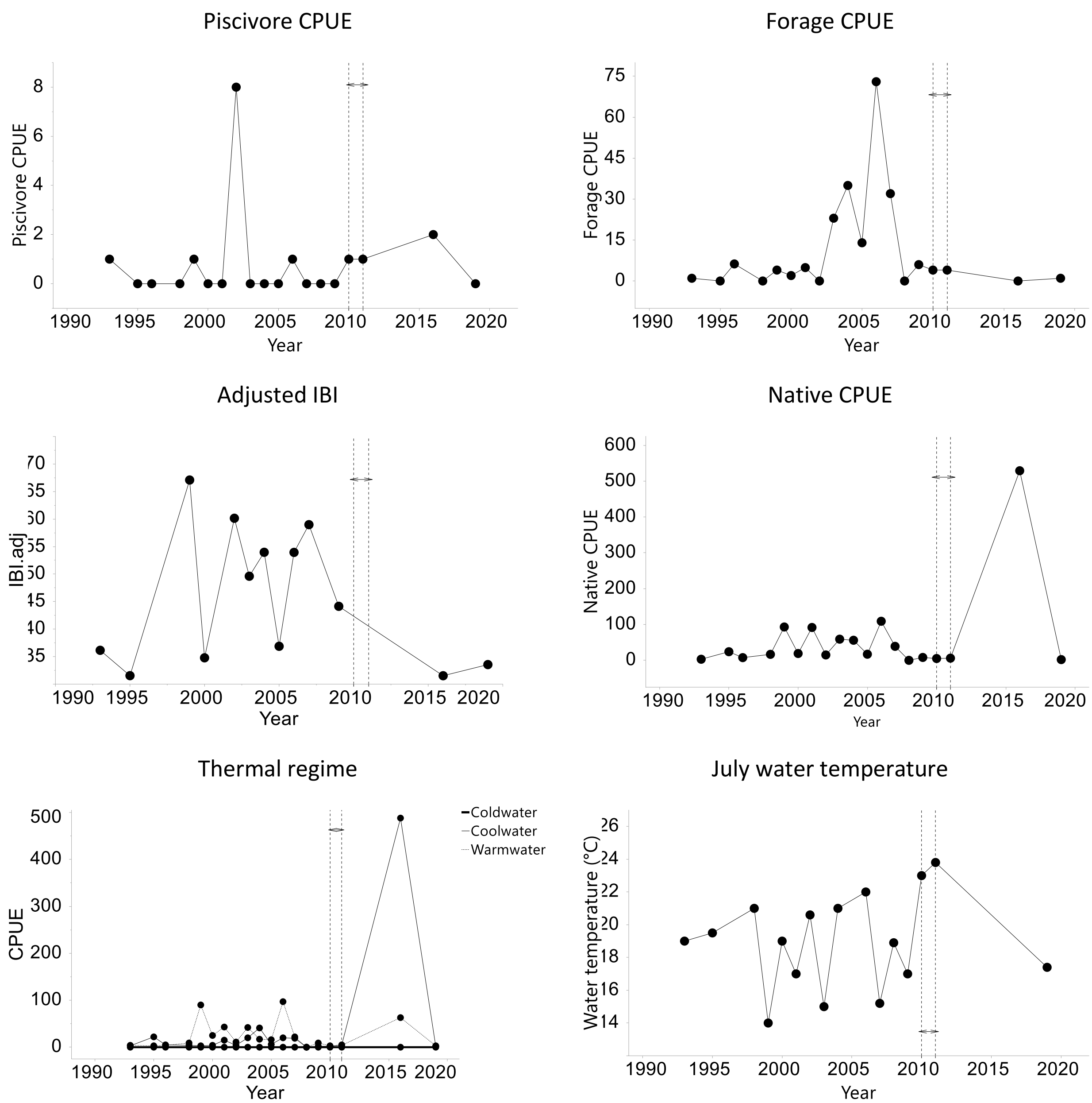


Figure 61: Embayment B TWAHRS Assessment Metrics

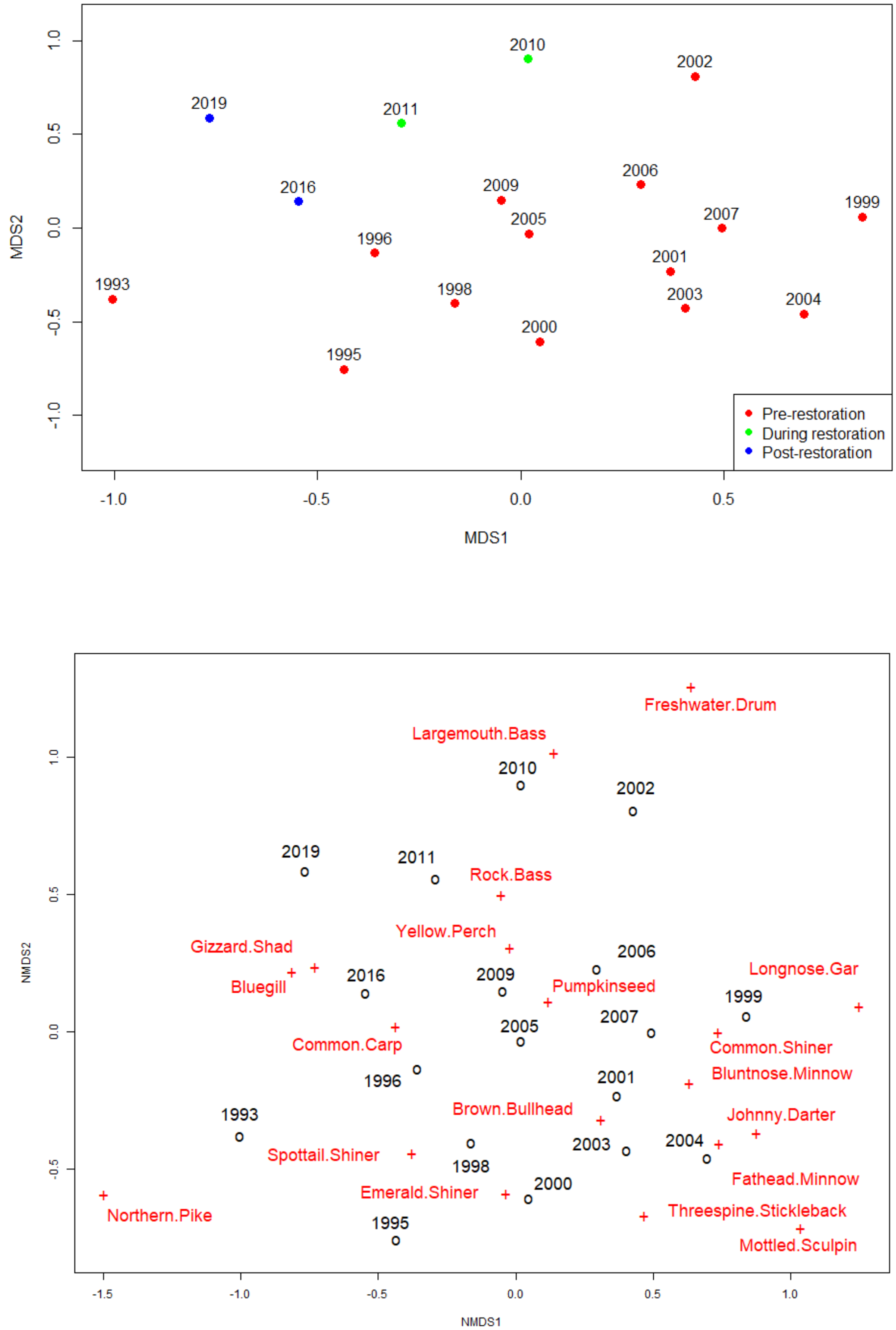


Figure 62: Embayment B Community Ordination (Stress = 0.16)

Table 6: Embayment B Restoration Summaries

Restored Area	TWAHRS Techniques Used	Area Planted (m^2)	Total Area Restored (m^2)	Increase in Shoreline Length (m)
Embayment B	Aquatic Vegetation, Wetland Berms, Wetland Shoreline Profile, Complex Shoreline Profile Improvements, Shoreline Vegetation Zones, Anchored Logs, Shoreline Shoal, Log Tangles, Reptile Habitat	170	1,010 – aquatic 1,265 - terrestrial	732 (150% increase)

The goals of habitat restoration at Embayment B were to create more suitable habitat for cool and warmwater species, providing refuge from cold water upwellings. Through examining the fish community change, it appears the community shifted from fish found only in pre-restoration years such as small bodied Cyprinids, to Gizzard Shad, Bluegill and Yellow Perch in the post-restoration. Given that carp exclusion methods included more passive techniques such as low water boulder wall, we see the area used heavily by Common Carp in both the pre- and post-restoration data. Consequently, the aquatic vegetation community is not as evident in the back bay area of Embayment B as in other, more excluded areas of TTP, such as behind the exclusion barrier of Embayment C. Adult and juvenile Northern Pike are not seen to use this site in July; the efficacy of the spawning channels are evaluated through other monitoring means, such as video evidence.

3.5.7.3 Tommy Thompson Park - Embayment C

The landform of Embayment C was roughly completed in 1974, and terrestrial and riparian vegetation was allowed to populate naturally. The pre-restoration shoreline was characterized by silt and sand substrate, was relatively homogeneous in formation and backed by a successional forest of shrubbery and young trees. It remained unrestored until 1996-1997, when pike spawning channels as well as sand ‘footpads’ were added to increase nearshore habitat variability. TRCA targeted Embayment C from 2008 to 2014 for restoration using multiple sheltered embayment restoration techniques as prescribed by TWAHRS.

Figure 63: Restored areas and associated electrofishing transects (blue lines) in Embayment C, Tommy Thompson Park. (Google 2017)

3.5.7.3.1 Embayment C South Shore

The South shore received complex shoreline profile improvements. These works began in late winter of 2010 and were completed in the spring of 2011. Wetland berms (primarily a coastal wetland technique) were used to create sheltered backwater areas which were then filled to a wetted depth of approximately 0.2-0.5 metres under typical water levels. A fringe of anchored logs was installed on the outer berms to provide underwater structural habitat, as well as to provide out of water shoreline cover. A carp exclusion barrier made of steel bars with gaps approximately 9 cm wide was installed at the inlet to the northern backwater area of the south shore (but not the southern area). Gates were installed to prevent adult Common Carp from accessing the area for spawning and foraging, thus allowing submerged and emergent aquatic plantings to flourish. Reptile habitat was supplemented, and the lowland riparian woods technique was used for plantings to establish in the near-shore zone.

The restoration goals of this habitat work included creating a shallow warm backwater area with sections of it inaccessible to Common Carp. The area behind the berm was expected to become highly vegetated with emergent and riparian vegetation, given the shift in depth and addition of substrate conducive to flora growth. As a consequence, small-bodied fish such as Cyprinids and juvenile fish, as well as juvenile and adult piscivores, were expected to enter and exit the backwater area, occupying the area adjacent of the berm, among the anchored logs and boulders.

Figure 64: Live stakes, nearshore boulder shoal and anchored log fringe of the created wetland berm in Embayment C, South Shore. (TRCA 2011)

Figure 65: Inside the wetland berm of Embayment C South Shore, September 2012 - one year post-restoration. (TRCA 2012)

2009 2017 2017

Figure 66: Embayment C South Shore Project before (left) and after (centre). Project polygons are shown at right. (Photos: First Base Solutions 2009; City of Toronto 2017)

This electrofishing transect was monitored between 2001 and 2019. Common carp CPUE decreased to one individual caught post-restoration. Although inside the gated berm was not assessed through electrofishing, these results are supplemented anecdotally by the following photographs, which demonstrate the effectiveness of the carp exclusion barrier in protecting natural and planted aquatic vegetation.

Figure 67: Comparison of vegetation recruitment without carp exclusion barrier (Left) and with barrier (Right). (TRCA 2012)

Piscivore CPUE was generally high and appeared to have increased post-restoration peaking in 2012, 2013 and 2016. Piscivores included primarily Largemouth Bass and Northern Pike comprising 66 and 28% of the catch. The majority of Largemouth Bass were juvenile fish (91%) while only 35% of Northern Pike were juveniles. Two adult Walleye were caught in 2019 and one adult Bowfin was caught in 2013 and in 2016. Yellow Perch and Pumpkinseed were the most abundant forage fish at this site followed by Gizzard Shad, Emerald Shiner, Rock Bass and Bluntnose Minnow. Gizzard Shad and Rock Bass increased in CPUE between 2001 and 2019 ($r=0.723$, $p<0.01$ and $r=0.450$, $p=0.081$, respectively).

Native species CPUE appeared to be higher post-restoration although was variable from year-to-year. Similar to the forage fish species composition, CPUE of Yellow Perch, Pumpkinseed, Gizzard Shad and Emerald Shiner was the highest. Other abundant native species included Largemouth Bass, Brown Bullhead, Rock Bass, Bluntnose Minnow and Northern Pike. Bluntnose Minnow CPUE decreased significantly between 2001 and 2019 ($r=-0.523$, $p=0.038$). Several other native species were caught less frequently (see ordination figure below). Common Carp occurred in low numbers at this site with between one and three individuals caught almost every year. Only one Common Carp has been caught since 2015. Adjusted IBI values follow a similar pattern as the other variables appearing to increase slightly immediately post-restoration then decreasing post-2015/2016.

The fish community consisted of similar catches of coolwater and warmwater species in some years but in most years the CPUE of coolwater species was higher. Coolwater species primarily consisted of Yellow Perch although Emerald Shiner, Gizzard Shad, Northern Pike and Rock Bass were also fairly abundant. Pumpkinseed had the highest CPUE of the warmwater species although Bluntnose Minnow, Brown Bullhead and Largemouth Bass were also relatively numerous.

Fish communities have changed significantly at this site between the first and second post-restoration time periods. Species associated with the restoration time period after 2010 included Largemouth Bass, Pumpkinseed, Rock Bass, Gizzard Shad, Walleye, Banded Killifish (*Fundulus diaphanus*) and Bowfin.

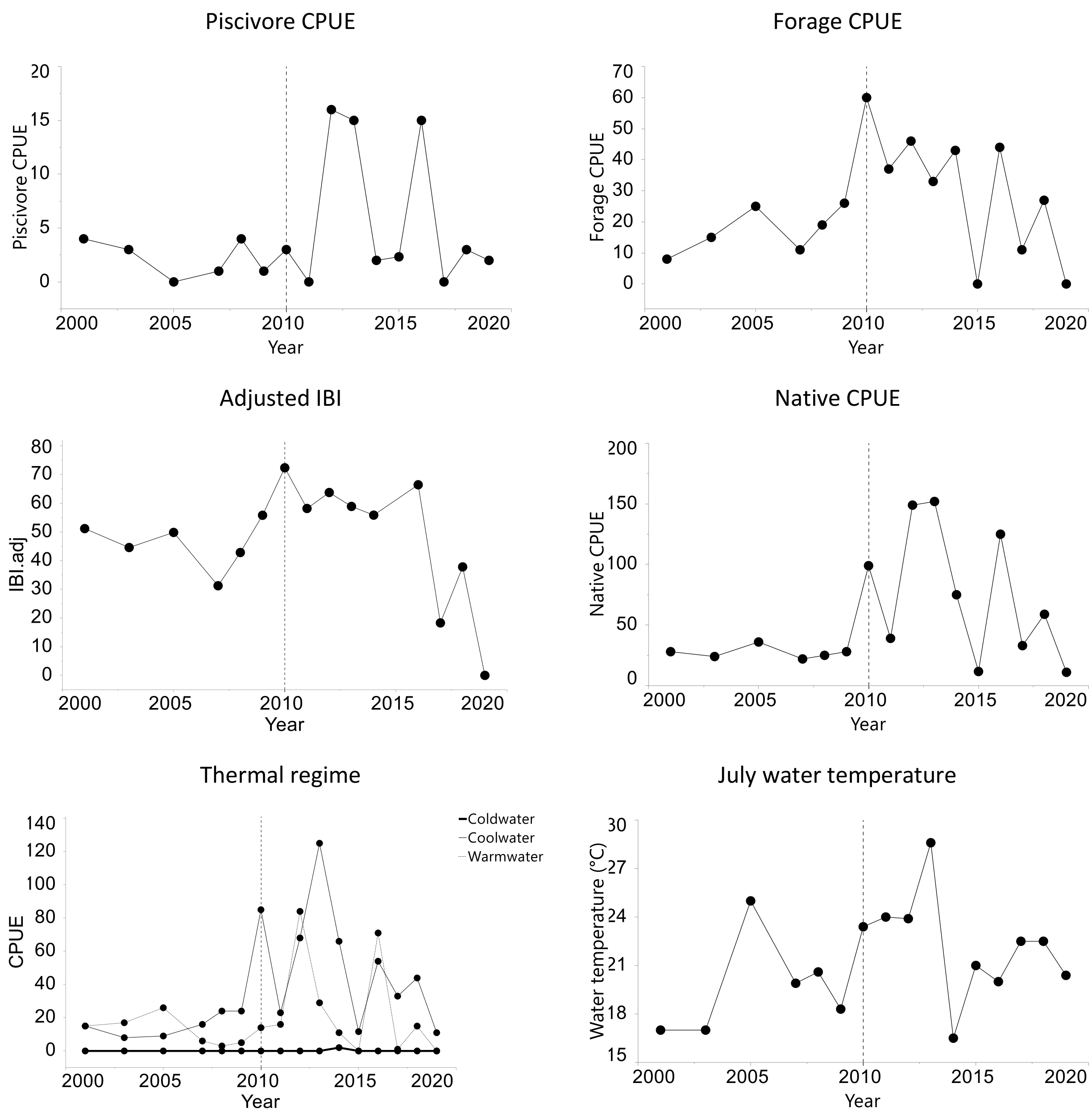


Figure 68: Embayment C South Shore TWAHRS assessment metrics

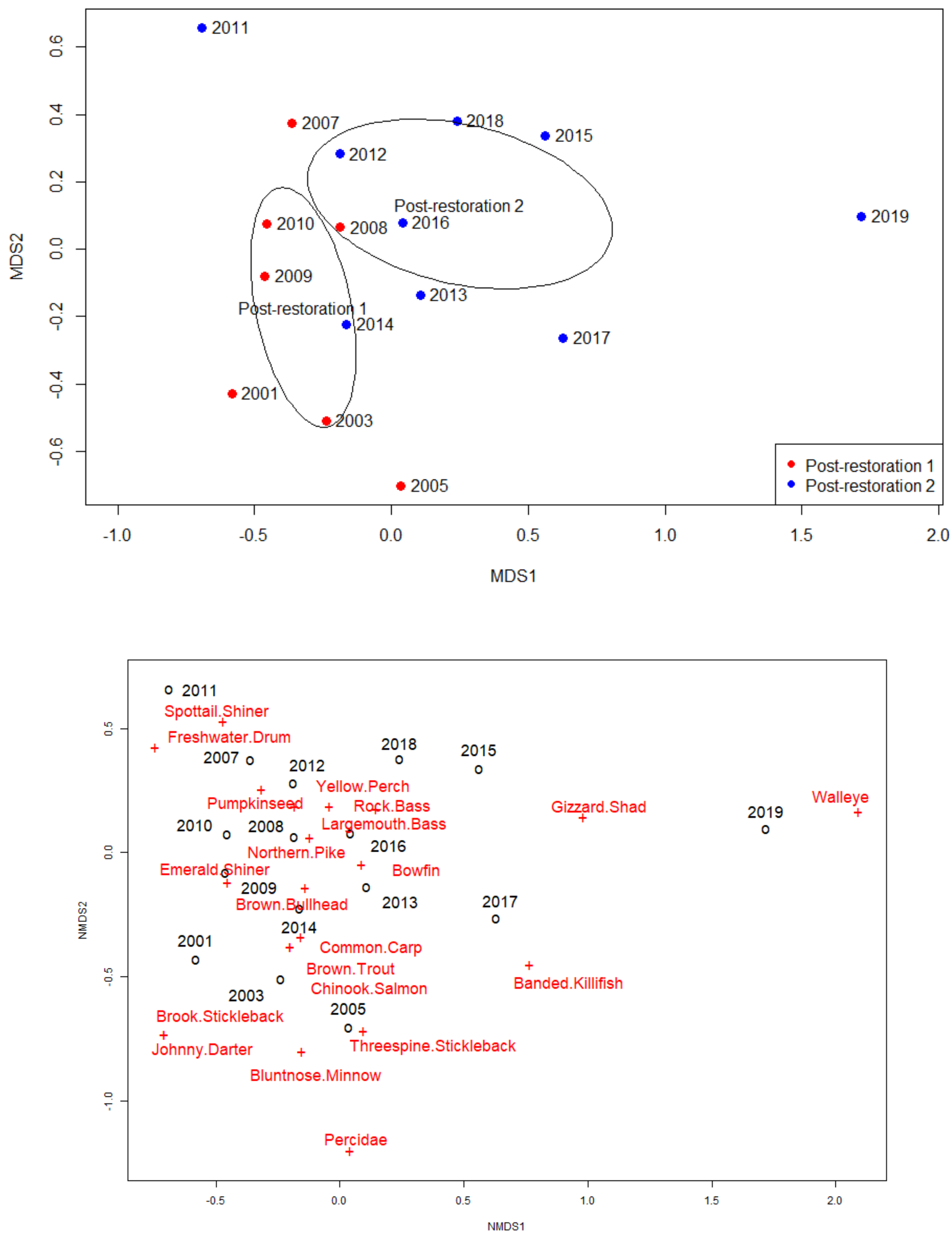


Figure 69: Embayment C South Shore Community Ordinations (Stress=0.21)

A total of 11,135 m^2 of habitat was created and modified at Embayment C South Shore. The shoreline has become more sinuous and increased from 357 to 1,073 m in length, a 200% increase. The fish community response to Embayment C South Shore habitat restoration work appears to have met several of the TWAHRS targets and goals. Piscivore CPUE increased, indicating that this restoration project provides suitable habitat for use of both juvenile and adult Largemouth Bass and Northern Pike, as well as adult Bowfin and Walleye. The project also created suitable habitat for forage fish such as Yellow Perch and Pumpkinseed, which dominate catches, but also for Gizzard Shad and Rock Bass, whose CPUEs increased significantly post-restoration. Banded Killifish and Bowfin, both vegetation-loving species, were found only in the post-restoration data.

3.5.7.3.2 Embayment C North East Shore

On the North East shore of Embayment C, multiple underwater log piles and log tangles populate the nearshore, providing structural habitat and contributing to shoreline heterogeneity. These structural elements were placed on ice over winter in early 2010 and sequentially sank to the bottom over spring as the ice melted (see figure below). The TWAHRS restoration targets of log piles and log tangles are used to increase essential habitats for coolwater species, to improve forage for aquatic species, and to add structural elements to improve near-shore habitats. The targets of shoreline shoals are to improve forage for aquatic and terrestrial species, and to add structural elements to improve near-shore habitats. The overall restoration goals of this project were to diversify the deep underwater habitat and provide structural elements for fish and aquatic insects.

Figure 70: Log Piles, Log Tangles, and Boulder Clusters left on ice and melting through ice of Embayment C North East Shore. *(TRCA 2010)*

2009 2011 2011

Figure 71: Embayment C North East Shore restoration before (left) and after (centre). Project polygons are shown on the right. (Photos: First Base Solutions 2009; 2011)

Piscivore CPUE was moderate at this site and variable among years. Piscivore CPUE peaked in 2000 with a catch of 10 Largemouth Bass and 2 Northern Pike. Largemouth Bass and Northern Pike remained the dominant piscivores post-restoration although three juvenile and three adult Bowfin were caught in 2018. Seventy-seven percent of Largemouth Bass caught at this site were juveniles while only 17% of Northern Pike caught at this site were juveniles. Forage CPUE was generally high at this site and appeared to be higher post-restoration although CPUE remained variable among years. Pumpkinseed, Yellow Perch and Spottail Shiner had the highest CPUE. Pumpkinseed CPUE was generally high throughout the entire time period although decreased significantly post-2014 ($r=-0.626$, $p<0.01$). Spottail Shiner also decreased significantly between 1989 and 2019 and has not been caught since 2012 ($r=-0.723$, $p<0.0001$). Yellow Perch CPUE may have increased between 1989 and 2019 although the results were only approaching significance ($r=0.349$, $p=0.095$). These trends have also been occurring at other sites in this assessment. Rock Bass and Bluntnose Minnow were also an important component of the forage CPUE although decreased between 1989 and 2019 ($r=-0.375$, $p=0.071$ and $r=-0.443$, $p=0.030$, respectively).

Native species CPUE was high at this site although variable among years. Similar to the forage fish composition, Pumpkinseed, Yellow Perch and Spottail Shiner made up the majority of the native CPUE at this site with other species including (in descending order of overall CPUE): Rock Bass, Bluntnose Minnow, Brown Bullhead, Northern Pike, Gizzard Shad, Emerald Shiner and Largemouth Bass (along with several other species to a lesser extent). The very high native CPUE in 1989 was due to high CPUE of Spottail Shiner (148) and the high CPUE in 1999 was due to a high CPUE of Pumpkinseed (165). Common Carp was the only non-native species caught at this site and its CPUE has remained relatively constant. The adjusted IBI ranged between about 30 and 80 for most of the time period but was very low in 2019 (5.2). The low value was primarily due to low values for many of the IBI metrics including the number of native species, native Cyprinids and piscivore biomass.

Fish communities were not significantly different pre- and post-restoration although the CPUE of several species were associated with specific time periods. White Perch were captured each year but only prior to 1993 and this resulted in significant declines at this site ($r=-0.649$, $p<0.001$). Black Crappie, Bluegill, Fathead Minnow, Johnny Darter, Threespine Stickleback, Trout-perch and White Bass were only caught pre-restoration and in low numbers. Banded Killifish and Bowfin were the only two species that were only caught post-restoration. The fish community consisted of almost exclusively coolwater and warmwater species with coolwater species having a higher CPUE overall than warmwater species. Coolwater species primarily consisted of Yellow Perch although Emerald Shiner, Gizzard Shad, Northern

Pike, Rock Bass and Spottail Shiner were also fairly abundant. Pumpkinseed had the highest CPUE of the warmwater species although Bluntnose Minnow, Brown Bullhead, Largemouth Bass and Common Carp were also relatively numerous.

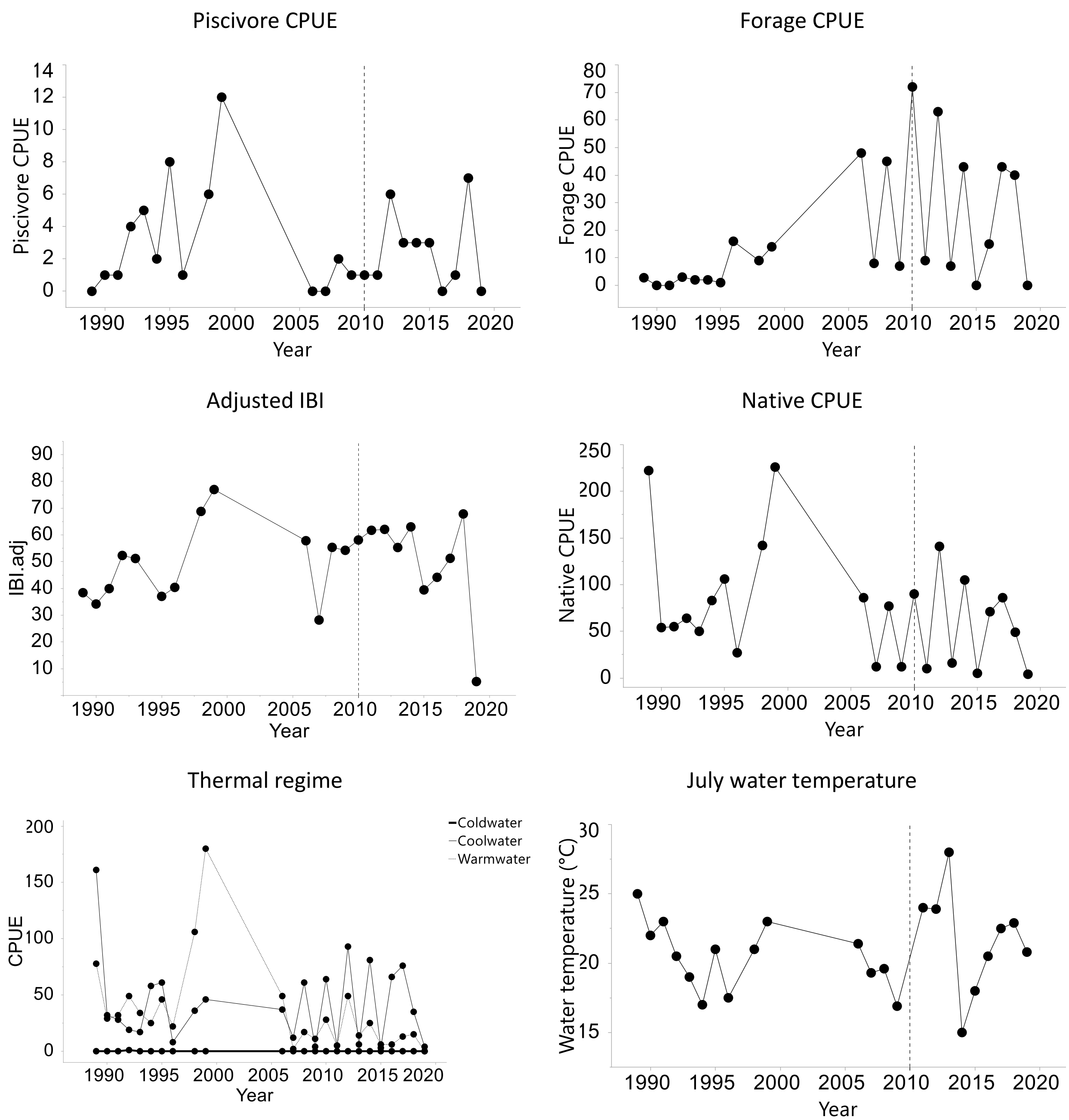


Figure 72: Embayment C North East Shore TWAHRS Assessment Metrics

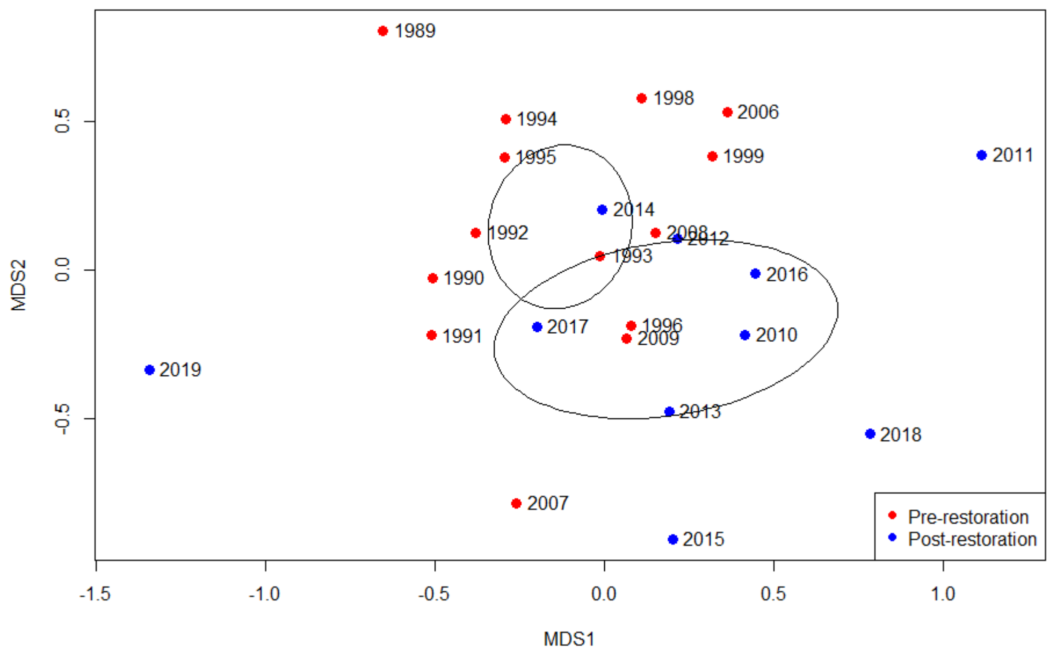


Figure 73: Embayment C North East Shore Community Ordinations (Stress=0.21)

A total of 740 m^2 of habitat structures along 334 m of shoreline were implemented at Embayment C North East Shore. The forage base is utilizing this area post-restoration, while species such as Yellow Perch increased post-restoration, still others declined (Rock Bass and Bluntnose Minnow). We observe Spottail Shiner declining between pre- and post-restoration at several other sites; however, the observed decline in Pumpkinseed may be heavily influenced by the abnormally large pre-restoration catch in 1999. Overall, this woody and rocky habitat appears to be benefitting juvenile Largemouth Bass, with adult Largemouth Bass and Northern Pike using this site post-restoration. Although many of these individual trends are unclear between the pre- and post-restoration time periods, the average IBI score post-restoration was higher than the average IBI score pre-restoration when using a more limited time range for a pooled assessment of embayment habitat IBI scores. Results of the pooled assessment of embayment project can be found immediately prior to the discussion section. Warm and coolwater guilds use this site both before and after restoration. Banded Killifish and Bowfin, both vegetation-loving species, were found only in the post-restoration data similar to Embayment C South Shore.

3.5.7.3.3 North West and South East Footpads

Between December 1996 and January 1998, sand "footpads" were created in the south west shoreline of Embayment C. These protrusions were armoured at their tips with large boulders, and round-stone shoals were established underwater at their periphery. They were graded to create a diversity in riparian vegetation communities and were seeded and planted with typical riparian vegetation. Electrofishing transects were set up at this time to monitor the fish community response. These footpads create the basis for TWAHRS habitat enhancements from 2008 to 2011. In January to April of 2008, this area received further habitat work. Anchored logs, log tangles, log piles, boulder clusters and shoals were left on ice to melt in the spring, populating the inner bay with underwater structural habitat. Finally, this area received a third round of restoration from November 2010 to January 2011, when complex shoreline improvements were also applied to the western edge of the passage into Cell 3. The shallow passage behind the south east footpad also received a stump field, constructed of numerous log tangles both underwater and protruding from typical water levels. The TWAHRS targets of this round of restoration were to increase essential habitats for coolwater species, improve forage for aquatic species, and add structural elements to improve near shore habitats.

3.5.7.3.3.1 Embayment C North West Footpad

2005 2017 2017

Figure 74: Embayment C North West Footpad restoration before (left) and after (centre). Project polygons are shown to the right. (Photos: First Base Solutions 2005; City of Toronto 2017)

This transect was shorter (approximately 200m) than the North East and South Shore electrofishing transects. The shorter distance sampled could have affected the number of species caught at this site compared to the North East and South Shores, even when controlling for sampling effort using CPUE.

Piscivore CPUE was low compared to the North East and South Shores and consisted of Largemouth Bass and Northern Pike although Northern Pike were only caught in 1997. The Largemouth Bass were all juveniles while the single Northern Pike was an adult. Forage fish CPUE was also moderate at this site compared to the North East and South Shores. Forage fish species included primarily (in descending order): Rock Bass, Bluntnose Minnow, Pumpkinseed, Spottail Shiner, Gizzard Shad, Yellow Perch and Emerald Shiner. Rock Bass, Gizzard Shad and Yellow Perch were caught throughout the time period while Bluntnose Minnow, Pumpkinseed and Spottail Shiner were not caught post-2001 although occurred almost every year prior. Bluntnose Minnow and Pumpkinseed CPUE decreased significantly between 1997 and 2019 ($r=-0.621$, $p=0.024$ and $r=-0.819$, $p<0.001$, respectively). The high CPUE in 1997 was due to high catches of Bluntnose Minnow, Rock Bass, Pumpkinseed and Spottail Shiner.

Native species CPUE consisted of the piscivores and forage fish already mentioned along with smaller numbers of Brown Bullhead, Freshwater Drum, Johnny Darter, Mottled Sculpin and Threespine Stickleback. Between two and four Common Carp were caught in 2001, 2009, 2010, 2011, 2015 and 2018. Adjusted IBI scores appear to be declining although pre-restoration data did not exist for comparison due to variation in sampling effort. These changes appear to be due to declines in two of the IBI metrics: Centrarchid richness and piscivore biomass. IBI values for this site were assessed using only runs that were 500 seconds or close to 500 seconds (e.g. 508). This makes these individual site assessments not comparable to other individual site assessments reporting IBI values.

The fish community consisted of primarily coolwater species with Rock Bass making up the largest portion of coolwater species CPUE. Fish communities appear to have changed between the first and second restoration time periods. Species primarily associated with the first post-restoration time period prior to 2008 included Bluntnose Minnow, Johnny Darter, Mottled Sculpin, Northern Pike, Pumpkinseed, Spottail Shiner and Threespine Stickleback. Gizzard Shad and Common Carp were more associated with years post-2008 compared to pre-2008.

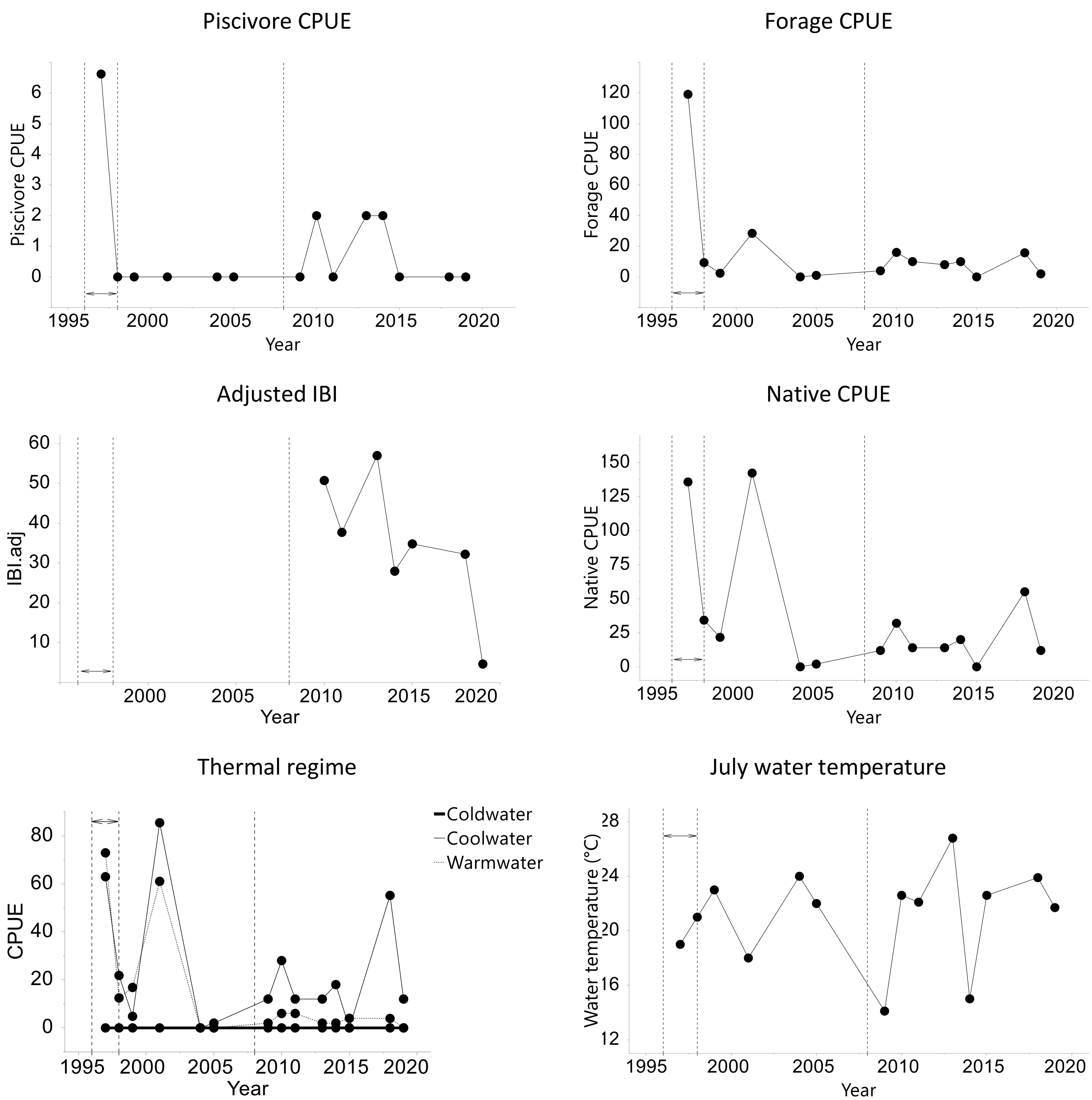


Figure 75: Embayment C North West Footpad TWAHRS assessment metrics

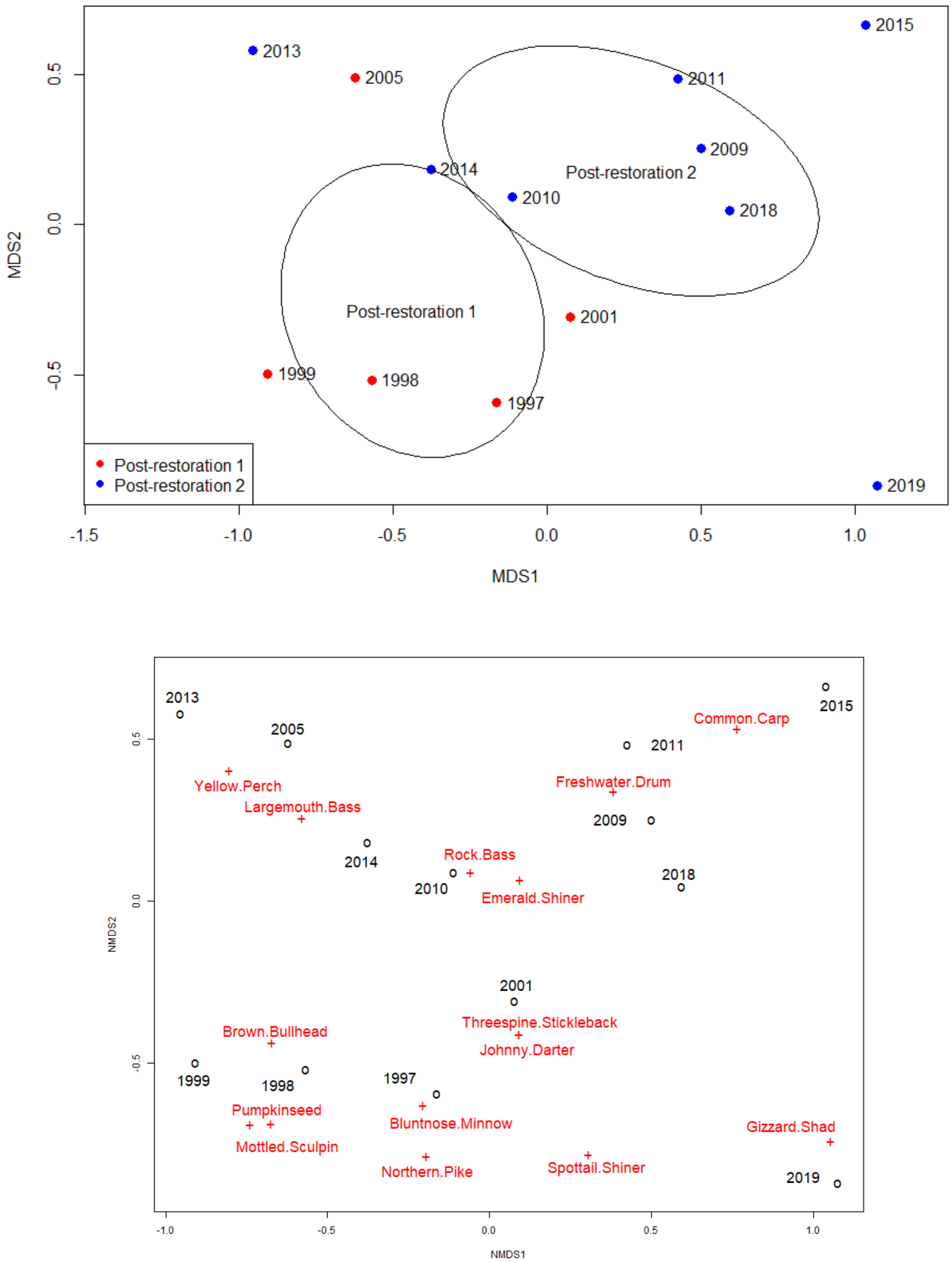


Figure 76: Embayment C North West Footpad Community Ordination (Stress=0.11)

Although the shift in community was significant, the resultant fish community post-restoration is different in some ways than expected. For example, Common Carp and Freshwater Drum are strongly associated with post-restoration years, while Pumpkinseed and Yellow Perch were caught more frequently pre-restoration. Nevertheless, species like Rock Bass appear to be using the rocky substrate placed around the sand footpads, and coolwater Emerald Shiner continue to use this site consistently post-restoration. This site is used primarily by coolwater fish, accomplishing thermal guild restoration objectives.

3.5.7.3.3.2 Embayment C South East Footpad

2005 | 2017 | 2017

Figure 77: Embayment C South East Footpad project before (left) and after (centre). Project polygons are shown to the right. (Photos: First Base Solutions 2005; City of Toronto 2017)

This transect was also shorter (approximately 200 m) than the North East and South Shore electrofishing transects. The shorter distance sampled could have affected the number of species caught at this site compared to the North East and South Shore even when controlling for sampling effort using CPUE. Piscivore CPUE was variable among years and consisted of Largemouth Bass, Northern Pike, Bowfin and Walleye. The Largemouth Bass caught included four juveniles and one adult while the Northern Pike caught consisted of one juvenile and five adults. One adult Walleye was caught in 2014 and one adult Bowfin was caught in 2004 and 2018. Forage fish CPUE was low-moderate at this site compared to the North East and South Shores. Forage fish species included primarily (in descending order): Rock Bass, Emerald Shiner, Pumpkinseed, Bluntnose Minnow, Gizzard Shad and Spottail Shiner. Rock Bass, Gizzard Shad and Pumpkinseed were caught generally throughout the time period. Gizzard Shad CPUE may have increased while Pumpkinseed CPUE may have decreased although the results were only approaching significance (r=0.479, p=0.071 and r=-0.452, p=0.091, respectively). Spottail Shiner were caught infrequently post-2003 although occurred almost every year prior and may have declined at this site (r=-0.449, p=0.093). Bluntnose Minnow were only caught in 1997 and 2003. The high CPUE in 1997 and 2003 was due to high catches of Bluntnose Minnow and Emerald Shiner. This site can be distinguished from other sites at TTP by its very low numbers of Yellow Perch.

Native species CPUE consisted of the piscivores and forage fish already mentioned along with smaller numbers of Brown Bullhead, Johnny Darter and Threespine Stickleback. Between one and eight Common Carp were caught in 1997, 2001, 2003, 2009, 2010, 2011 and 2013.

The fish community consisted of both coolwater and warmwater species with coolwater species having a higher CPUE overall than warmwater species. Coolwater species primarily consisted of Rock Bass although Emerald Shiner and Gizzard Shad were also fairly abundant. Pumpkinseed had the highest CPUE of the warmwater species although Bluntnose Minnow and Common Carp were also relatively numerous.

Fish communities appear to have changed between the first and second restoration time periods although the 95% confidence intervals still overlapped slightly. Species primarily associated with the first post-restoration time period prior to 2008 included Bluntnose Minnow, Brown Bullhead, Emerald

Shiner, Johnny Darter, Spottail Shiner and Threespine Stickleback. Gizzard Shad, Largemouth Bass and Yellow Perch were more associated with years post-2008 compared to pre-2008.

The adjusted IBI was assessed using only 500 second runs or those that were close to 500 seconds (e.g. 504). This makes these individual site assessments not comparable to other individual site assessments reporting IBI values. Adjusted IBI values were only available post-restoration due to only including 500 second runs. The IBI was quite variable during this time ranging from 11 in 2014 to 48 in 2013.

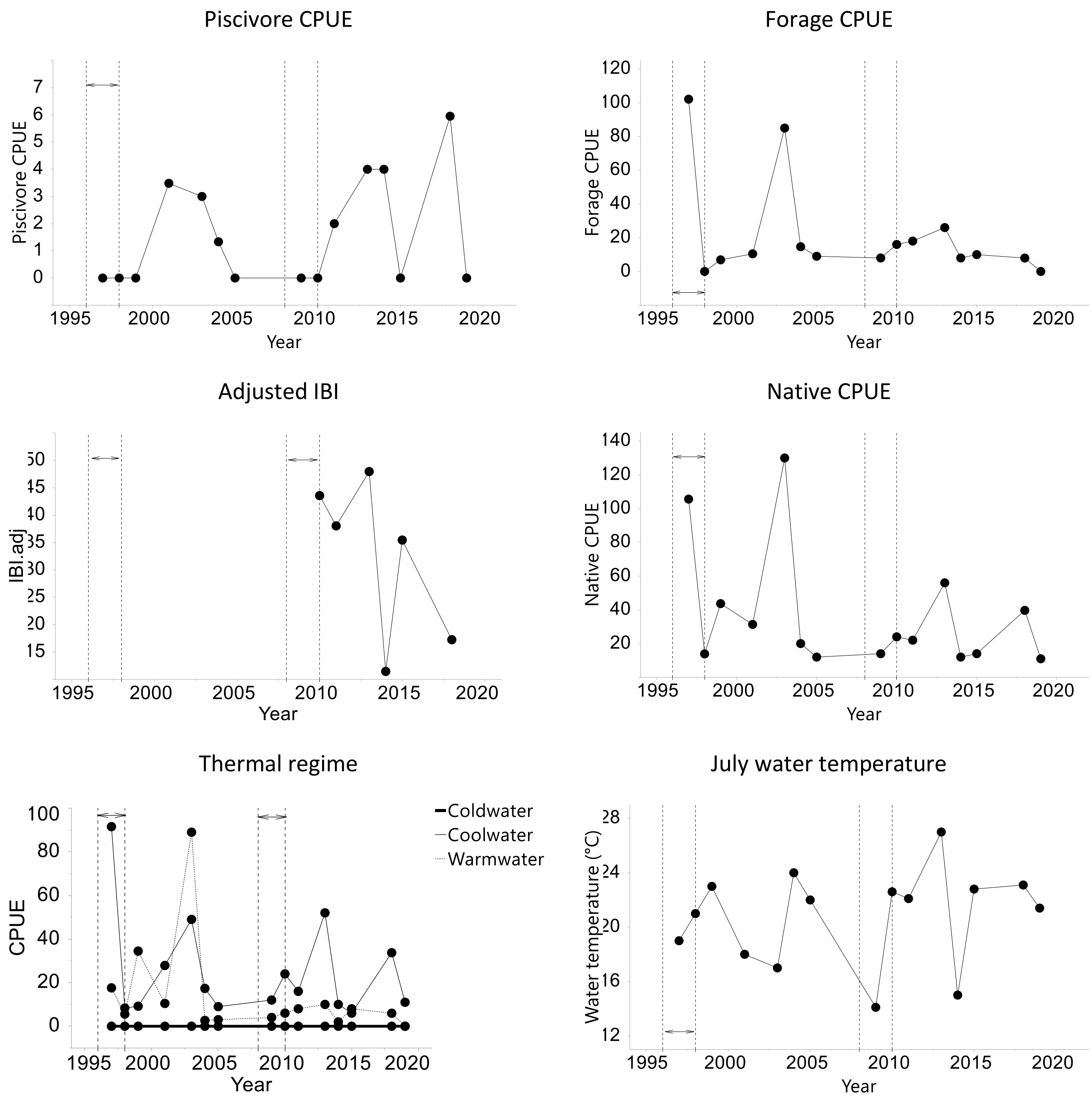


Figure 78: Embayment C South East Footpad TWAHRS Assessment metrics

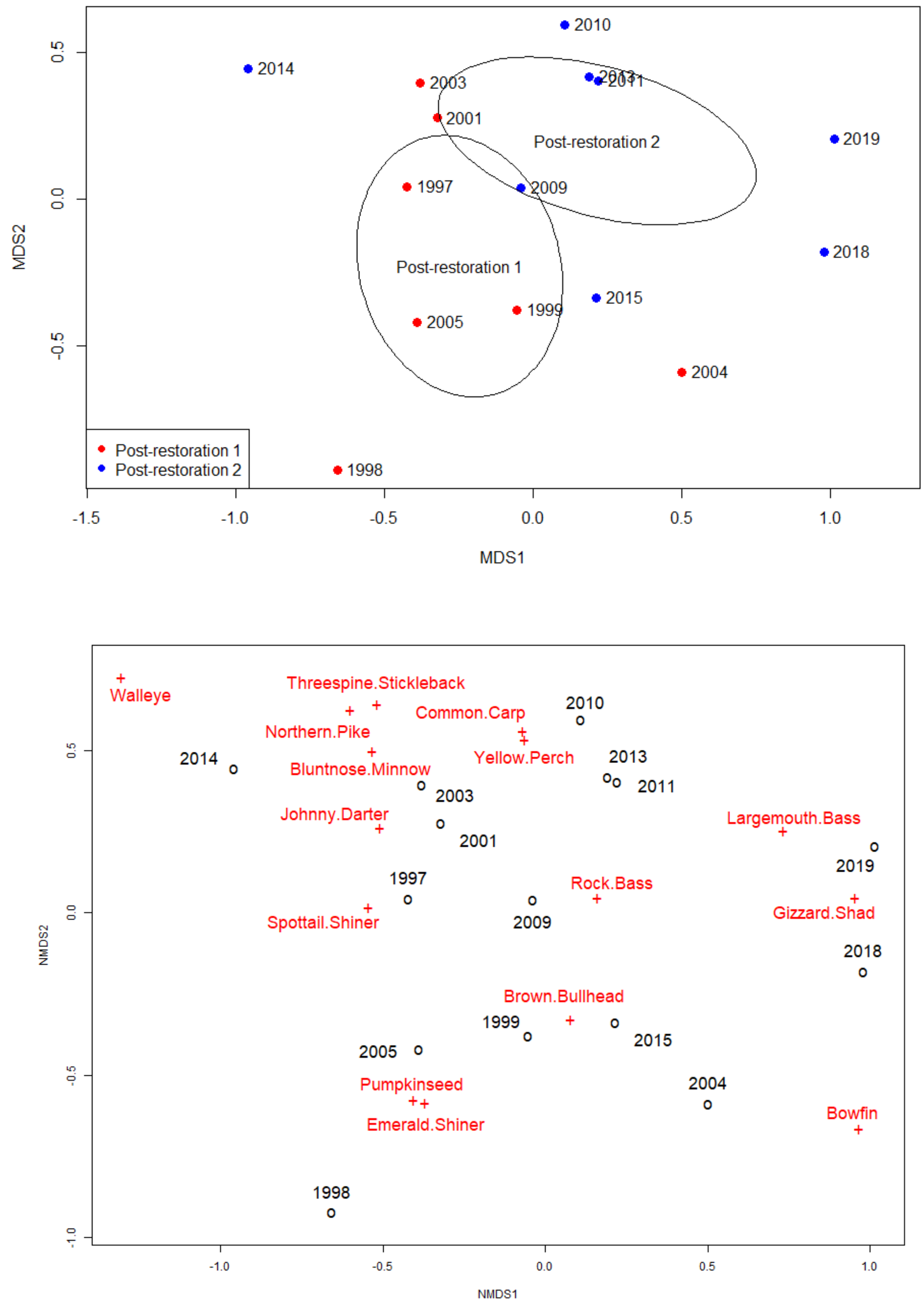


Figure 79: Embayment C South East Footpad Community Ordination (Stress = 0.17)

The fish community appeared to shift (although not significantly) from Bluntnose Minnow, Johnny Darter and Spottail Shiner, to Yellow Perch, Largemouth Bass, Walleye and Bowfin. Common Carp were ubiquitous among pre- and post-restoration sampling. Although forage CPUEs did not reach the peaks of pre-restoration, the post-restoration forage CPUEs appear to be able to support piscivorous fish use of this site. The log fringe, as well as a beaver lodge, on the western side of the entrance to Cell 3 provide suitable woody material for species such as Largemouth Bass, which were captured only in post-restoration samples. The habitat restoration of this site achieved some of the anticipated goals such as use of the site by cool and warmwater species and creating underwater structural diversity by implementing 995 m^2 of structural material along the North West and South East Footpad extent such as submerged timber and rocky shoals.

Embayment C Summary

Table 7: Summaries for restored areas of Tommy Thompson Park Embayment C.

Restored Area	TWAHRS Techniques Used	Area Planted (m^2)	Total Area Restored (m^2)	Increase in Shoreline Length (m)
North East Shore	Shoreline Shoal, Log Piles, Log Tangles	-	740	0 (334 m shoreline modified)
South Shore	Wetland Berms, Shoreline Shoal, Anchored Logs, Log Piles, Log Tangles, Aquatic Vegetation, Lowland Riparian Woods, Reptile Habitat, *Carp Exclusion Barrier*	7,520	9,105 – aquatic 2,030 - terrestrial	716 (200% increase)
Western Footpad Basin (North West and South East Footpads combined)	Shoreline Shoal, Anchored Logs, Log Piles, Log Tangles, Aquatic Vegetation	-	3,200	106 (11% increase)
Embayment C (Total)	Wetland Berms, Shoreline Shoal, Anchored Logs, Log Piles, Log Tangles, Aquatic Vegetation, Lowland Riparian Woods, Reptile Habitat, *Carp Exclusion Barrier*	7,520	15,075	822 (62% increase)

Embayment C received multiple restoration techniques informed by TWAHRS. Both sides of the embayment received submerged rock shoals, log piles and log tangles between 2008 and 2010. Further restoration along the south shore entailed anchored logs, shoreline shoals, and a carp exclusion barrier with plenty of aquatic and riparian plantings. In total, 2,654 m^2 of woody material and 1,330 m^2 of shoals and boulder clusters were deposited. A further 345 m of anchored logs was placed on the south shore. Approximately 7,520 m^2 of vegetation was planted in water, and 250 m^2 of emergent vegetation grew naturally as a result of the constructed wetland berm.

The fish community significantly changed at two of the four electrofishing transects; South Shore and South East Footpad. At the additional two sites, North East Shore and North West Footpad, the fish community changed, but not significantly, as per the 95% confidence ellipses in the community ordination. Banded Killifish and Bowfin were only detected post-restoration at North East Shore and South Shore, indicating their utilization of the structural habitat. Largemouth Bass were associated with the South Shore post-restoration time stanza, although their CPUE did not increase significantly. At the footpad sites, Spottail Shiner and Bluntnose Minnow were found primarily pre-restoration. Gizzard Shad, Common Carp, Largemouth Bass and Yellow Perch are most associated with the post-restoration community.

3.5.8 Tommy Thompson Park – West Shore (Outer Harbour Marina)

Between 2016 and 2018, the interior shoreline of TTP was restored. From 2016 to 2017, the area nearest to Outer Harbour Marina was completed, followed in 2017 to 2018 by the area nearest to Embayment D. Along the shoreline, restoration work consisted of removal of construction-grade rubble and rebar, re-grading the shoreline to more appropriate in-water slopes, anchoring logs, installing log tangles and shoreline shoals, and installing viewing nodes. The shoreline was extensively planted with bank stabilizing native trees and shrubs such as willow and dogwood. Due to the recent completion of this restoration project, the fish community could not be assessed as there is limited post-restoration data. The two electrofishing transects along this shoreline will continue to be monitored to assess restoration efficacy.

Figure 80: Tommy Thompson Park West Shore restoration project before (left) and after (centre). Project polygons are shown to the right. (Photos: City of Toronto 2016; 2018)

Table 8: Tommy Thompson Park West Shore Habitat Restoration Summary

Restored Area	TWAHRS Techniques Used	Area Planted (m^2)	Total Area Restored (m^2)	Length of Shoreline Restored (m)
TTP West Shore	Complex Shoreline Profile Improvements, Shoreline Shoals, Anchored Logs, Log Tangles, Reptile Habitat, Lowland Riparian Woods	3,740	5,420	1,000

3.6 Coastal Wetland Projects

3.6.1 Coastal Wetlands of Tommy Thompson Park

Three discrete areas of TTP were converted from open, sheltered embayment habitat types to coastal wetlands. While one is considered to be a restored wetland, two were strictly created from CDFs that were initially slated to be filled to terrestrial grade. The mechanism for these conversions included implementing several TWAHRS techniques such as complex shoreline profile improvements, where substrates were used to fill the embayments to reduce depth and raise the grade. Other common techniques include installing wetland berms to create quiescent backwater areas uninfluenced by coastal wave processes, and all three areas received carp exclusion barriers. These barriers also function as water control structures, when the water levels need to be managed. Water levels were managed in Cell 1 and Cell 2 during high lake level events in 2017 and 2019 while water levels over-topped the berm to Embayment D. The three wetlands were planted extensively with aquatic and riparian vegetation, and the resultant shallow depths and sheltered water resulted in further recruitment of submergent and emergent macrophytes. This section explores the resultant changes in fish communities, as well as summaries of the restoration habitat implemented.

3.6.1.1 Tommy Thompson Park - Cells 1 and 2

We examined changes in fish communities at two coastal wetland sites all within TTP: Cell 1 and Cell 2. These wetlands have had considerable restoration including the creation of berms, shoreline vegetation plantings, log tangles and installation of carp exclusion gates. We also examined Common Carp CPUE at these sites in relation to the carp gate installation dates.

Both cells received several habitat restoration treatments from the TWAHRS compendium of techniques. Bio-engineered wetland berms were used to isolate each cell. An outcome of the TWAHRS document was the introduction of carp exclusion gates to Toronto wetland restoration projects. Excluding large Common Carp from coastal wetlands has the benefit of preventing carp from spawning, resulting in a theoretical decline in carp population. The barrier also protects planted and natural growth of aquatic vegetation from foraging carp. Furthermore, water quality benefits are also observed through the reduction in turbidity from carp foraging and spawning, allowing aquatic vegetation better chances of establishing. The bar spacing varies but is approximately 9 cm on average, passing native fish including adult Northern Pike. Carp exclusion gates are critical features for TRCA’s constructed wetlands, where time and money are spent on seeding and planting wetland vegetation.

Restoration started with Cell 1 when a berm was installed in 2003/2004 and the cell was isolated from Lake Ontario. It remained isolated from the lake until 2011 when a carp gate was installed and allowed fish passage. In 2015, Cell 2 was isolated from the lake when a berm was constructed. This also restricted fish passage between the lake and Cell 1 since fish must travel through Cell 2 to get to the Cell 1 carp gate. Fish passage was also restricted between Cell 1 and Cell 2 starting in 2015 due to ongoing restoration work in Cell 2. In 2018 the carp exclusion gate was installed between Cell 2 and the lake and remains closed to this day to allow wetland vegetation to establish due to unpredictable water levels. It is anticipated that both the gates to Cell 1 and Cell 2 will be opened in the spring of 2021, pending water levels.

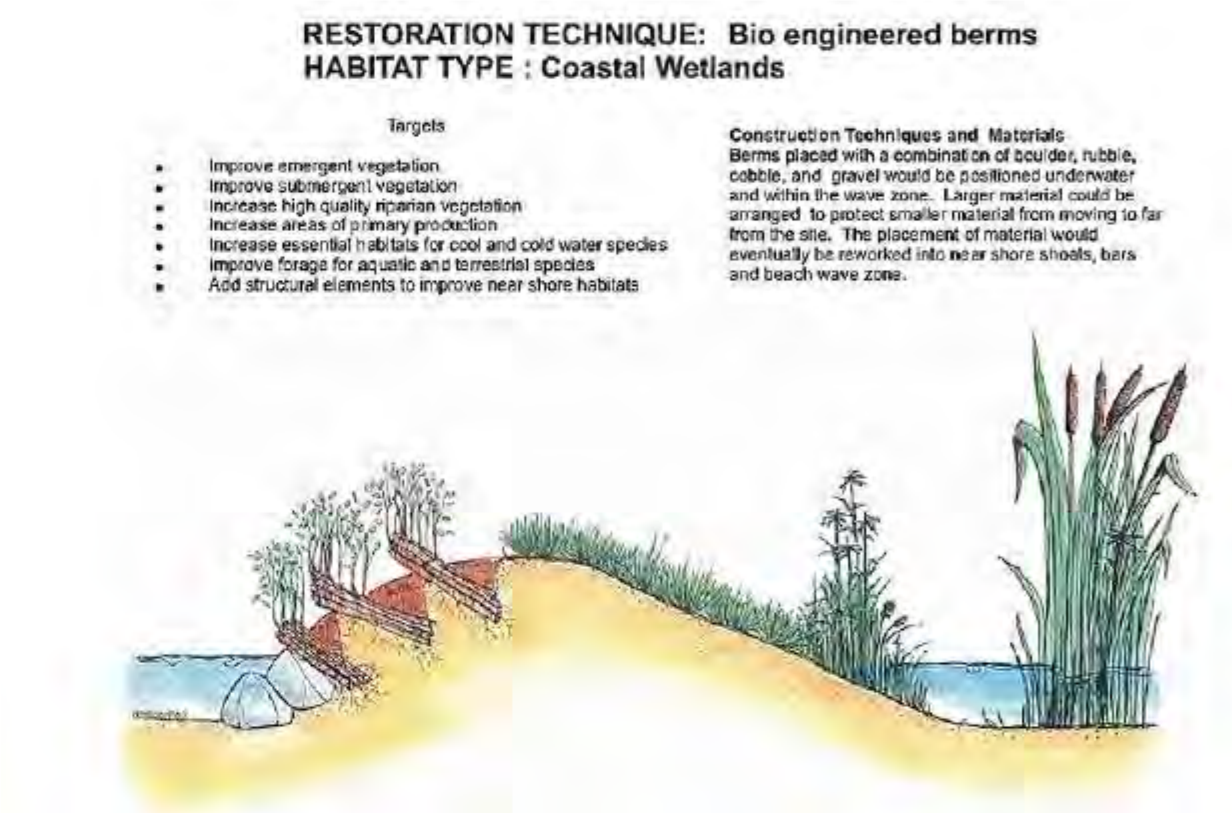


Figure 81: Habitat technique concept from the TWAHRS compendium of techniques. (TRCA 2003)

Table 9: Habitat Restoration Summary for Cells 1 and 2 of Tommy Thompson Park

Restored Area	TWAHRS Techniques Used	Area Planted	Total Area Restored (m^2)	Increase in Shoreline Length (m)
Cell 1	Wetland Berms, *Carp Exclusion Barriers*, Aquatic Vegetation, Complex Shoreline Profile Improvements, Shoreline Vegetation Zones, Shoreline Shoals, Anchored Logs, Log Piles, Log Tangles, *Log Cribs*	4,940	50,950 - aquatic 63,870 - terrestrial	242 (19% increase)
Cell 2	Wetland Berms, *Carp Exclusion Barriers*, Aquatic Vegetation, Complex Shoreline Profile Improvements, Shoreline Vegetation Zones, Shoreline Shoals, Anchored Logs, Log Piles, Log Tangles, *Log Cribs*	6,675	67,350 - aquatic 69,570 - terrestrial	1,450 (117% increase)

3.6.1.1.1 Tommy Thompson Park Cell 1

Cell 1 was used as a CDF from 1979-1985. Upon reaching its capacity to receive fill in 1985, it was not capped, but with the cessation of annual dredgate dumping, aquatic vegetation began to grow. Cell 1 remained in this state until 2003, when funding received initiated the restoration plan outlined in the TTP Master Plan. The cell was capped during the winter of 2003 and 2004, and an exclusion berm was erected. The cell remained isolated from the lake until 2011 when the carp exclusion barrier and water control structure was installed into the wetland berm and was opened. This allowed for the passage of native fish, while excluding adult-sized carp from entering to feed and reproduce in the newly finished wetland. The cell remained open to the lake until 2015 when it was closed as restoration on Cell 2 began.

Cell 1 began almost as a complete blank slate, devoid of any natural attributes save the clean graded cap of soil. This provided ample opportunity to apply a suite of TWAHRS techniques to create a new wetland connected to Lake Ontario. Cell 1 received many additional TWAHRS restoration actions, including grading for shoreline vegetation growth, aquatic and riparian planting, log tangles including log cribs, log piles and anchored logs, and plenty of in-water and upland reptile habitat.

The first CDF to be converted into aquatic habitat was Triangle Pond (not accessible to fish) from 1999-2000. Lessons learned from this process were applied on a larger-scale to Cell 1. Still more lessons were learned in the construction of the Cell 1 wetland, which were further applied to the construction of Cell 2. Examples include the substrate choice of Cell 1, which is comprised primarily of clay, which has the consequence of low-clarity water due to the suspension of fine particles.

Overall restoration goals of Cell 1 included providing warm water thermal refuge, providing vegetated habitat for phytophillic fish species, and providing habitat for reptiles and amphibians.

Figure 82: Tommy Thompson Park Cell 1 created wetland before (left) and after (centre). Project polygons are shown to the right. *(Photos: First Base Solutions 2002; City of Toronto 2015)*

July 2010

September 2019

Figure 83. Tommy Thompson Park Cell 1 wetland July 2010 and post-restoration September 2019. (Photos: TRCA 2010, 2019)

This site had a large amount of pre-restoration data from 1989-2002 and only two years of post-restoration data (TTP Cell 1 East 2016 and 2017). Due to Cell 2 construction, and high water in 2017, the fish gates were not open to Lake Ontario so these data represent fish that were essentially trapped in Cell 1. Pre-restoration data were collected using standard night runs while post-restoration data were collected during the day. Since surveys conducted during the day usually have a lower CPUE than night surveys, we would have expected to have had a lower CPUE in 2016 and 2017 but that was not the case. We actually might expect CPUE to be even higher than the data presented here if it were collected at night.

Piscivore CPUE appears to have increased temporally with these increases primarily caused by increases in Largemouth Bass CPUE. Largemouth Bass make up 70% of the piscivore CPUE at this site and are increasing in CPUE over time ($r=0.788$, $p<0.001$). Northern Pike had the second highest piscivore CPUE with 34 individuals caught between 1989 and 2017. Between 1 and 2 adult Bowfin were captured in 1996, 2000, 2001 and 2002 but in no other years. One adult Walleye was captured in 1996 and between 1 and 2 adult Smallmouth Bass were caught in 1997, 1998 and 2001. Northern Pike and Largemouth Bass were the only piscivores caught post-restoration. The only Northern Pike caught post-restoration was an adult (58 cm, 1.1 kg). Largemouth Bass caught post-restoration were exclusively juveniles suggesting that Cell 1 provides important nursery habitat for this species.

Forage CPUE has been variable at this site with low CPUE in the early 1990s, more variable CPUE until 2002, then generally higher in 2016 and 2017. The most common forage fish species were Pumpkinseed and Yellow Perch each comprising approximately 30% of the total forage CPUE between 1989 and 2017. Other important forage fish species included Bluegill, Bluntnose Minnow, Emerald Shiner, Golden Shiner and Rock Bass comprising between 5 and 8% of the total forage CPUE. Higher forage fish CPUE post-restoration was primarily due to a higher CPUE of Yellow Perch in 2016 and 2017.

Native species CPUE appeared to be lower post-restoration compared to pre-restoration but again, this may not be representing inter-annual variation post-restoration due to limited sampling. Native CPUE did increase periodically pre-restoration and these increases were primarily caused by a higher CPUE for specific species including Spottail Shiner, Emerald Shiner and Bluntnose Minnow in 1991 and 1995 and Pumpkinseed and Largemouth Bass in 1998. Only limited numbers of Bluntnose Minnow and

Pumpkinseed were found post-restoration and no Spottail Shiner or Emerald Shiner were found post-restoration. Largemouth Bass CPUE remains high post-restoration. Similar to the other metrics, the adjusted IBI appeared to be similar post-restoration although higher than some of the earliest years pre-restoration.

In addition to increases in Largemouth Bass CPUE, Brown Bullhead CPUE also increased significantly between 1989 and 2017 ($r=0.831$, $p<0.0001$). Gizzard Shad and Rock Bass CPUE declined significantly between 1989 and 2017 ($r=-0.798$, $p<0.001$ and $r=-0.701$, $p<0.01$, respectively). Spottail Shiner and White Perch had declines in CPUE that were approaching significance ($r=-0.500$, $p=0.058$ and $r=-0.481$, $p=0.070$, respectively).

There appeared to be a change in the dominant thermal regime of fish using this site in the mid-1990s from coolwater to warmwater. Coolwater species that had a lower CPUE or were lost included Emerald Shiner, Spottail Shiner and Gizzard Shad. Warmwater species that had a higher CPUE or were gained included Bowfin, Brown Bullhead, Largemouth Bass and Pumpkinseed.

The four Common Carp caught in 2016 and 2017 were all adults ranging from 50 to 61 cm in length and weighing between 1.6 and 3 kg. These individuals could have entered when the gates were opened in 2011 or transported by anglers. Common Carp are being actively excluded from Cell 1 based on a photograph taken in 2011 when the gate was opened to water flow by removing the stop logs (see photo below).

Figure 84: Common Carp attempting to enter Cell 1 from Cell 2 in Spring 2011, after the water control stop logs were removed. (TRCA 2011)

Fish communities appear to have changed at this site although again, several more years of post-restoration monitoring is recommended. The earliest years pre-restoration (1989-1993) had a higher CPUE of White Perch, Gizzard Shad, Rock Bass, Emerald Shiner and Spottail Shiner. The latest pre-restoration years available (2000-2002) had a higher CPUE of Northern Pike and Bowfin. Post-restoration years were characterized by a higher CPUE of several species including Largemouth Bass, Yellow Perch and Brown Bullhead.

This site would benefit from several more years of post-restoration monitoring to collect data representing inter-annual variation post-restoration and additional years of monitoring the effectiveness of the carp gates.

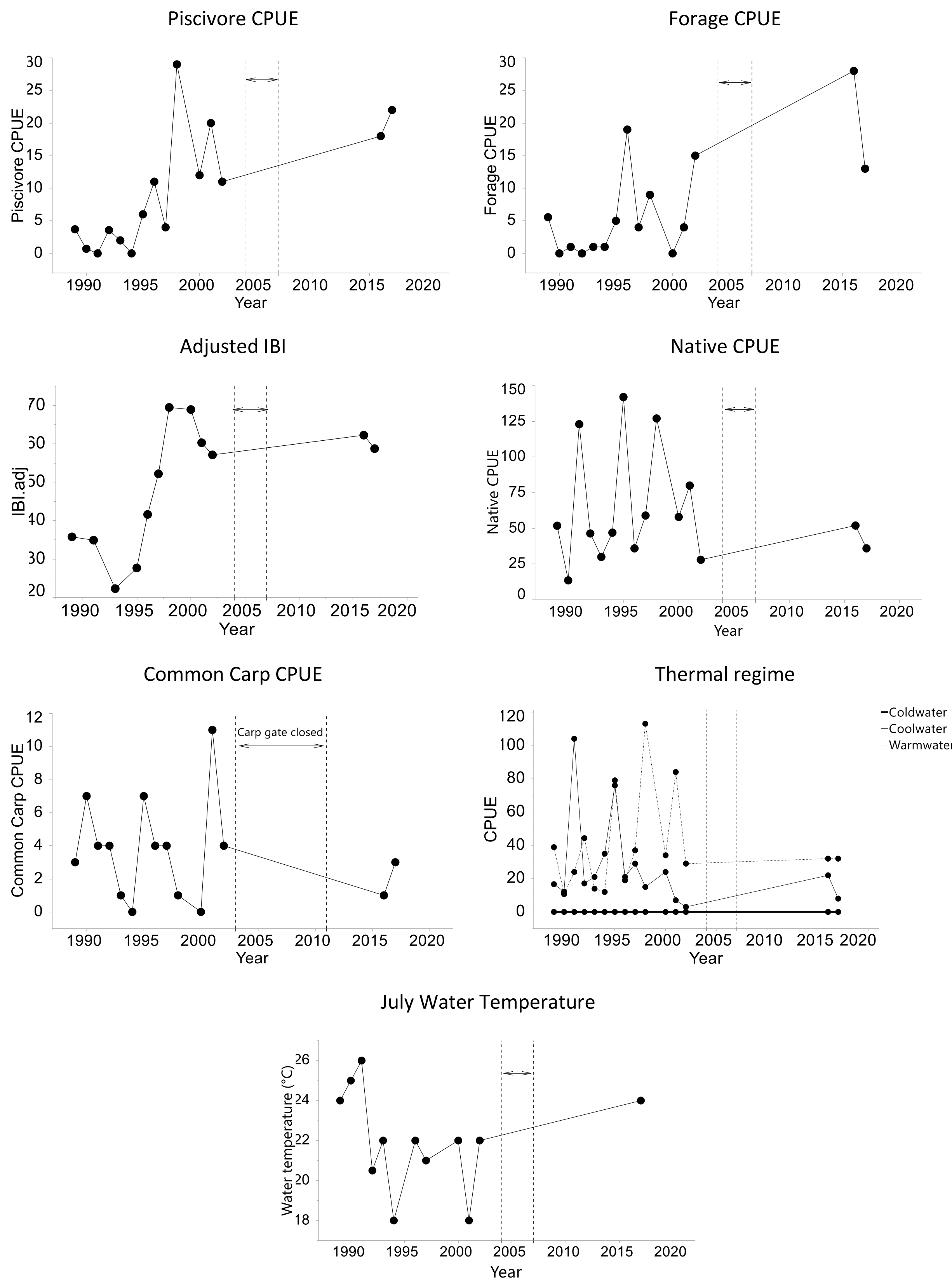


Figure 85: Cell 1 TWAHRS Assessment Metrics

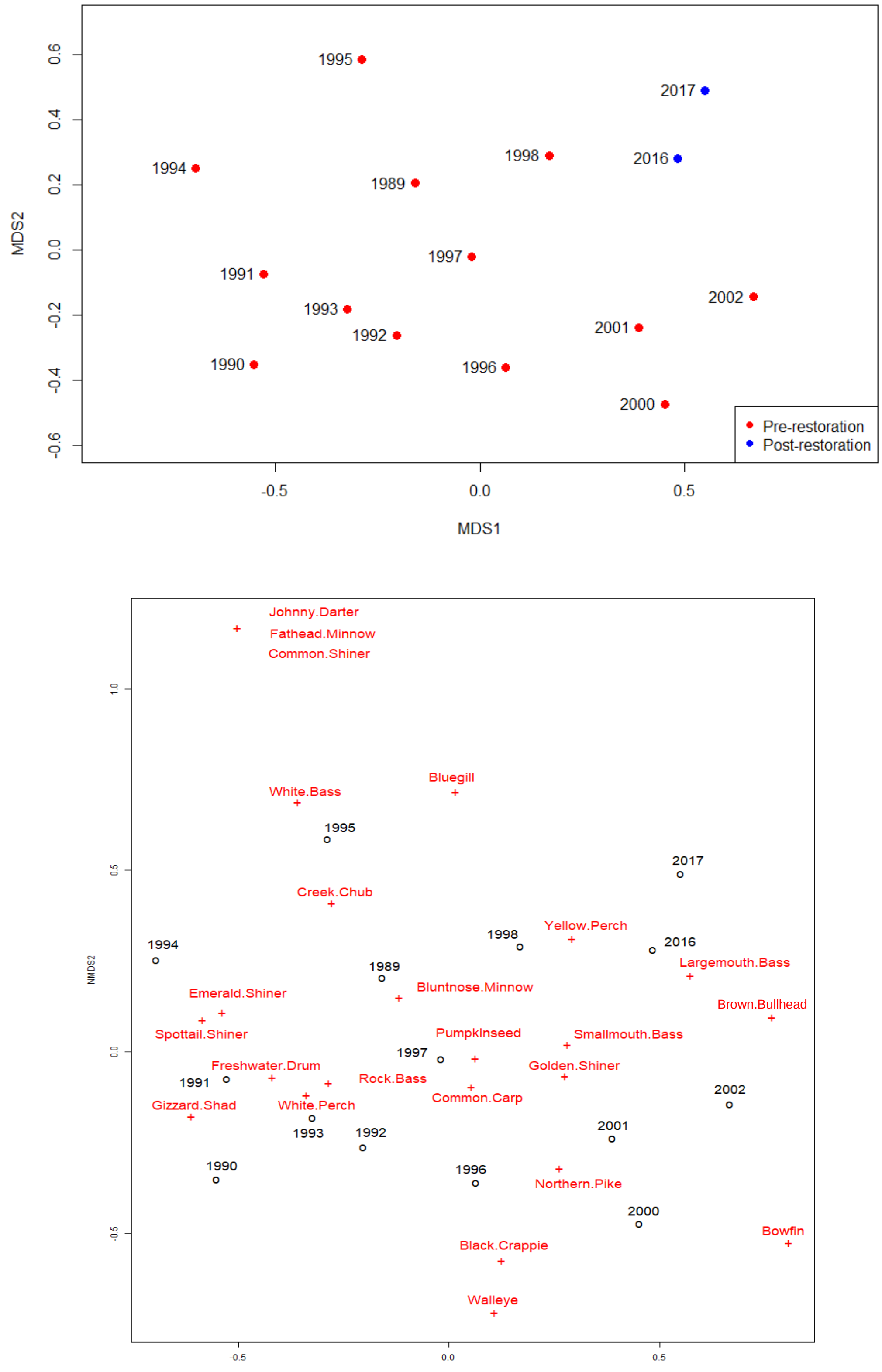


Figure 86: Cell 1 Community Ordination (Stress = 0.16)

3.6.1.1.2 Tommy Thompson Park Cell 2

The lessons learned through capping the CDF in Triangle Pond and Cell 1, culminated in a substantially quicker habitat restoration of Cell 2. The cell was isolated for construction in 2015, and by 2016 the major earthworks, habitat structures and plantings were in place and completed. Additional planting was conducted in 2017. The carp exclusion barrier and water control structure was installed in the spring of 2018. It remained closed to prevent fish and water passage and is anticipated to be opened in the spring of 2021, pending water levels. In 2019 due to high water levels threatening to overtop the berm, water was actively managed in Cell 2, and by de facto, Cell 1. Because the wetland berm is not impenetrable to water seeping, water was pumped out to maintain levels to promote native aquatic vegetation growth and establishment.

Both the terrestrial and aquatic habitats of Cell 2 were extensively seeded and planted. In the summer of 2016, aquatic plantings consisted of Nuttall's bur-reed (*Sparganium americanum*), hard-stemmed bulrush, black-fruited bulrush, soft-stemmed bulrush, and fragrant water lily, which were protected from waterfowl herbivory by snow fencing. Cattail seeds were spread during construction. In the fall of 2016, the shoreline and upland areas were seeded with a native grass dry mix comprising Indian grass (*Sorghastrum nutans*), little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardii*), and side-oats grama (*Bouteloua curtipendula*). Managing the water levels in 2018-2019 had the added benefit of allowing the planted aquatic macrophytes time to establish in the face of higher than typical water levels.

TWAHRS restoration actions at this site included installing a wetland berm (2015), shoreline vegetation zones, log tangles, reptile habitat (2015-2017), lowland riparian planting (2016), and a carp exclusion barrier (2018).

2012 2019 2018

Figure 87: Tommy Thompson Park Cell 2 Wetland creation project before (left) and after (centre). Project polygons are shown on the right. *(Photos: Airborne Sensing 2012; City of Toronto 2019)*

August 2016

June 2019

Figure 88: Cell 2 during riparian planting, left, and after restoration completed, right (Photos: TRCA 2016, 2019)

This site had a large amount of pre-restoration data from 1989-2014 and only two years of post-restoration data (TTP Cell 2 East 2017 and 2018). Post-restoration data do not reflect open access of fish to Lake Ontario, as the water control structure and carp exclusion barrier had not been opened at the time of publication. Pre-restoration data were collected using standard night-fishing runs while post-restoration data were collected during the day. Since surveys conducted during the day usually have a lower CPUE than night surveys, some of the lower catches (e.g. forage and native CPUE in 2017 and 2018) could have been due to changing sampling timing. We would expect CPUE for each variable to be higher than the data presented here. Cell 2 became hydrologically isolated from Lake Ontario during the summer of 2015.

Piscivore CPUE appears to have increased temporally with these increases primarily caused by increases in Largemouth Bass and Bowfin CPUE. Largemouth Bass made up 64% of the piscivore CPUE at this site and increased in CPUE over time ($r=0.542$, $p<0.01$). Largemouth Bass caught post-restoration were mostly juveniles (90%) suggesting that Cell 2 provides important nursery habitat for this species. Northern Pike had the second highest piscivore CPUE with 48 individuals caught between 1989 and 2018 including 2 adults caught in 2017. Bowfin CPUE was moderate in Cell 2 with 14 individuals caught between 1989 and 2018 and increased over time ($r=0.417$, $p=0.031$). The majority of Bowfin were caught between 2003 and 2014 but have not been caught post-restoration. Three adult Walleye were captured in Cell 2 with one caught in 1992, one in 2007 and one in 2008.

Forage CPUE appears to be increasing overall at this site with low CPUE in the early 1990s, and higher, yet more variable, CPUE between 2002 and 2018. Forage CPUE appeared to be lower post-restoration although more sampling is strongly recommended to collect data representing inter-annual variation. The most common forage fish species was Pumpkinseed comprising approximately 37% of the total forage CPUE between 1989 and 2018. Other abundant forage fish species included Spottail Shiner, Bluntnose Minnow, Rock Bass, Yellow Perch and Gizzard Shad ranging from 8 to 13% of the total CPUE. Yellow Perch CPUE increased temporally ($r=0.758$, $p<0.0001$), while Spottail Shiner CPUE decreased ($r=-0.406$, $p=0.036$).

Native species CPUE appeared to be lower post-restoration compared to pre-restoration but again, this may not be representing inter-annual variation post-restoration due to limited sampling or lack of access to Lake Ontario. Native CPUE was quite variable pre-restoration. CPUE was the lowest in 2004 and highest in 1999 and 2014 primarily due to high catches of Bluntnose Minnow, Pumpkinseed, Emerald

Shiner, Rock Bass and Yellow Perch. The adjusted IBI appeared to be increasing over time and has not dropped below 30 since 2006. Compared to Cell 1, the CPUE by thermal regime in Cell 2 has remained about equal for coolwater and warmwater species throughout the time period. Coolwater species primarily included Yellow Perch, Gizzard Shad, Rock Bass and Spottail Shiner. Warmwater species primarily included Pumpkinseed and Largemouth Bass.

The high Common Carp CPUE in Cell 2 in 2011 may have been caused by opening the stop log in the carp gate to Cell 1. Many carp were trying to enter Cell 1 (through Cell 2) in 2011 and were being excluded. The four Common Carp caught in 2017 and 2018 (after the berm was created) included three adults ranging from 58 to 65 cm in length and weighing between 2.6 and 4.6 kg and one juvenile almost at the adult stage (32 cm, 465 g). These carp were removed from Cell 2 and placed into Cell 3.

Fish communities appear to have changed at this site although again, several more years of post-restoration monitoring is recommended. The earliest years pre-restoration (1989-1998) had a higher CPUE of White Perch, Emerald Shiner, Bluntnose Minnow, Common Shiner and Spottail Shiner. White Perch have declined significantly between 1989 and 2018 ($r=-0.592$, $p<0.01$). Post-restoration years were characterized by a higher CPUE of several species including Largemouth Bass, Golden Shiner, Brown Bullhead and Yellow Perch. Brown Bullhead CPUE increased significantly between 1989 and 2018 ($r=0.393$, $p=0.043$) with this correlation strongly affected by a CPUE of 28 in 2018. Black Crappie CPUE also increased significantly ($r=0.437$, $p=0.023$) although it was only found in low numbers in 2014 and 2018.

Overall, this site would benefit from several more years of post-restoration monitoring to collect data representing inter-annual variation post-restoration. As well, it is recommended to open the cell to Lake Ontario to promote exchange of isolated fish populations within Cells 1 and 2, and to allow for these newly created wetlands to act as a source of nursery habitat for Toronto's phytophilic fish. Opening is anticipated in 2021 pending water levels.

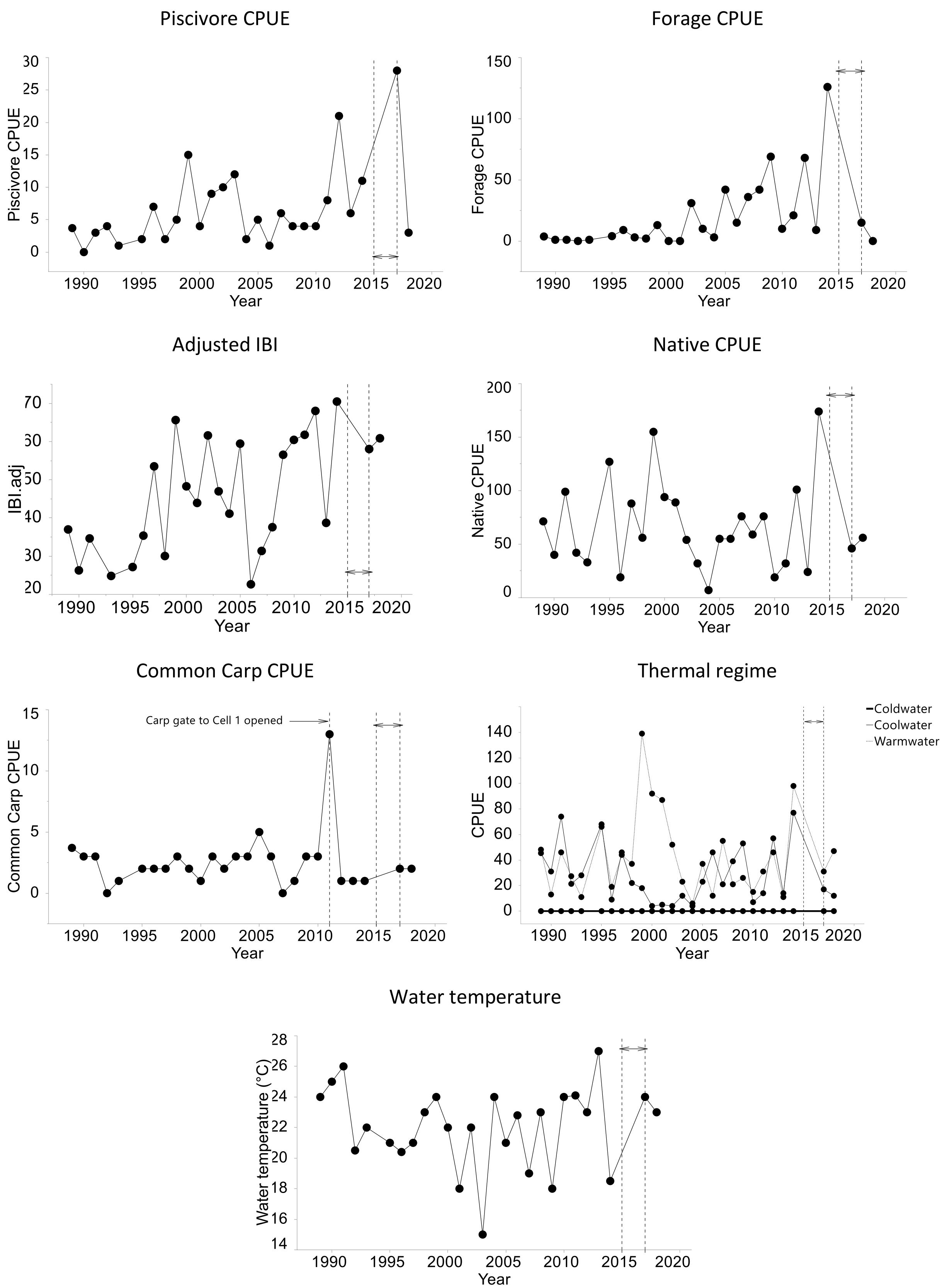


Figure 89: Cell 2 TWAHRS Assessment Metrics

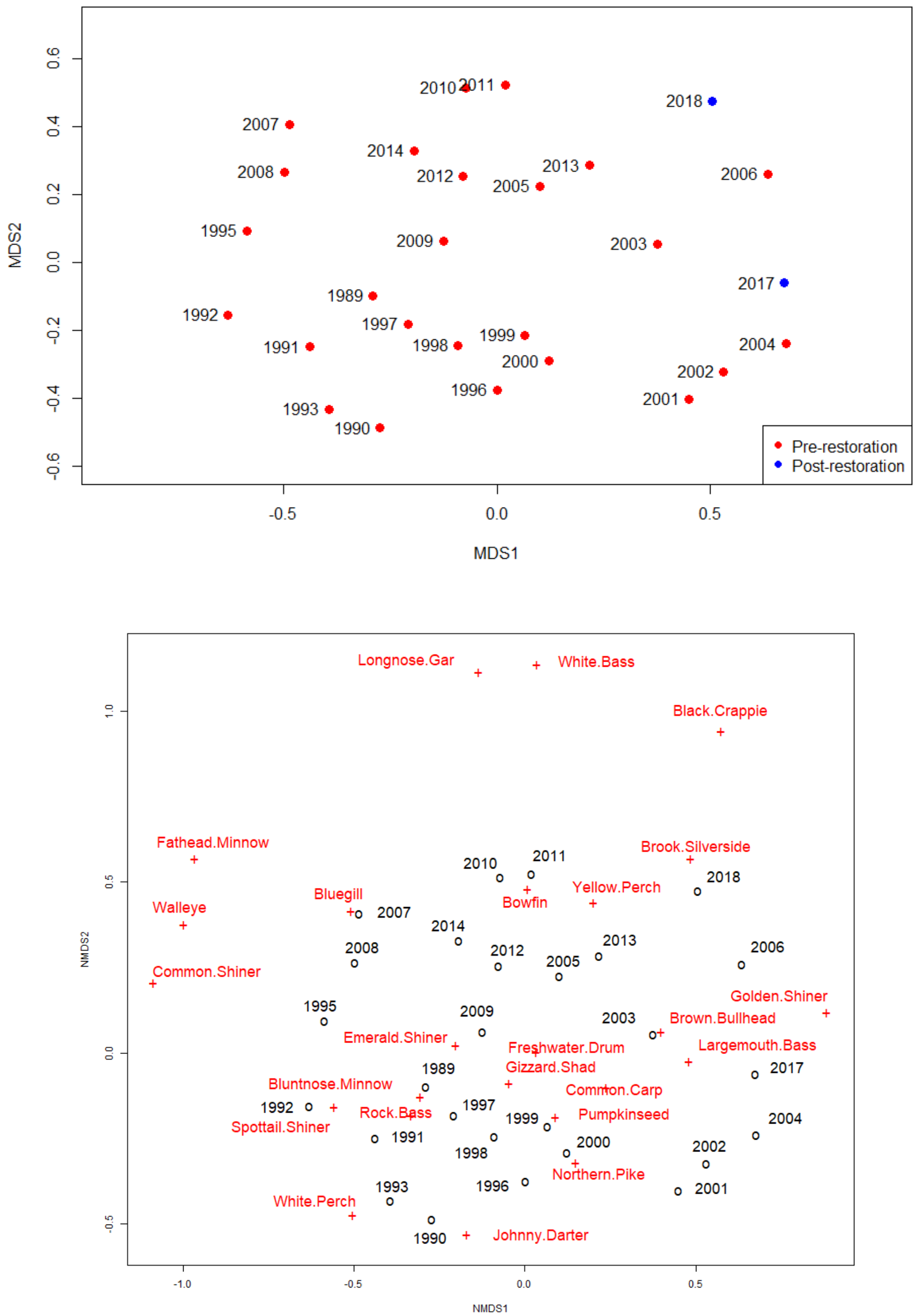


Figure 90: Cell 2 Community Ordination (Stress = 0.22)

Cell 1 and Cell 2 Summary

In summary, the TWAHRS restoration actions in Cell 1 and Cell 2 were successful in creating warmwater wetlands. The communities shifted from opportunistically present pelagic coolwater catches of White Perch and Gizzard Shad, or species that associate with bare sandy shorelines such as Spottail Shiner, to a resident warmwater and nursery community, evidenced by the number of juvenile fish captured post-restoration.

In Cell 1, 4,941 m^2 of aquatic and 63,869 m^2 of riparian plantings and seedings took hold to produce a well-vegetated wetland community. In Cell 2, the aquatic macrophyte plantings totaled 6,674 m^2 and 69,597 m^2 of riparian area was planted and seeded with native vegetation. The flora is an integral part of the overall functioning of the interface between TTP's terrestrial and aquatic ecosystems.

Although it was not possible to create 95% confidence ellipses for either wetland due to too few post-restoration data points, through examining the species trends it is evident that the fish community shifted between pre- and post-restoration time periods. At both sites, Spottail Shiner declined significantly, while warmwater fishes such as Largemouth Bass and Brown Bullhead increased significantly. Generally, the habitat shifted from one that is used transiently by pelagic fish to one used by resident cool and warmwater fish.

Carp gates were shown to be an effective method of reducing carp CPUE in the newly constructed wetlands. Provided that high water levels do not overtop the typical bank height of 76 masl, the gates are effective at excluding adult-sized Common Carp from entering the wetland to breed and forage. In years post barrier opening we would expect carp catches to be at their peak due to the ideal habitat conditions, but the opposite is seen in Cell 1. More data are needed to empirically show the gate's effectiveness in Cell 2, once the stop logs are removed and fish are allowed free passage.

Cell 1 and Cell 2 exhibited opposite trends as is typically seen within the Toronto waterfront, where historic high catches of piscivores and many other fish species peaked in the early 1990s (TRCA 2018). At these two sites, CPUE of key metrics examined, such as piscivores, forage fish, and IBI, were lowest in the 1990s, and gradually increased to their highest points either immediately pre- or post-restoration. This shift can primarily be attributed to the cessation of use as an active CDF, the subsequent growth of aquatic vegetation, and the habitat restoration initiatives undertaken here through TWAHRS directives. We anticipate that the resident wetland fish community will thrive once the wetlands are fully connected to the lake year round.

3.6.1.2 Tommy Thompson Park – Embayment D

Embayment D was constructed in the mid-1970s from hydraulic dredging disposal operations associated with the creation of the Outer Harbour. It was one of the smaller open embayments and is the first embayment on the northwest side of the park, about 1 km from the entrance.

Before full restoration, Embayment D was a sheltered wetland similar in orientation and configuration to Embayments A, B, and C, opening directly into Toronto's Outer Harbour area. In this way it differs from Cells 1, 2 and 3, which are one body of water further removed from exposure, wind and wave action, and upwellings of the harbour. The embayment consisted of sand and silty substrate with a complete absence of aquatic vegetation and an abundance of algae on the shorelines.

Prior to formal restoration, test plots of vegetation were installed in Embayment D, to ensure that submerged and emergent aquatic vegetation would establish. Aquatic macrophytes such as northern wild rice and arrowhead (*Sagittaria* spp.) were planted and protected from waterfowl herbivory and carp action with snow fence and silt curtains.

Figure 91: Early aquatic planting in Embayment D, 2005. (Photo: TRCA 2005)

The coastal wetland restoration at Embayment D was implemented under the TTP Master Plan. Initiated in the spring of 2012, this project was considered compensation for PortsToronto's East Endikement Project at TTP. As a result, the HAAT model was run for before and after benefits of the proposed restoration, which featured several TWAHRS techniques.

The embayment received the wetland berm treatment, as well as a carp exclusion barrier. Aquatic vegetation, such as northern wild rice, fragrant water lily, and hard- and soft-stemmed bulrush, were planted. Several log tangles, cribs, and log piles litter the shoreline toward the landform. Pea gravel was deposited along the shoreline and around log tangles to function as spawning shoals. Six habitat islands were constructed outside of the wetland berm, to further protect the wetland and create sheltered backshore areas where vegetation could establish.

The wetland was isolated from the lake in the spring of 2012. All restoration activities were completed by the end of 2014. The wetland was kept isolated the following year, to allow the aquatic plants time to establish. The carp exclusion barrier and water control structure was opened in the spring of 2016. Due to the height of the wetland berm, Embayment D has been overtopped by high lake levels in 2017 and 2019, potentially allowing spawning carp to enter the wetland.

Restoration goals for the interior of Embayment D included increasing submerged and aquatic vegetation from pre-existing conditions, preventing adult Common Carp from entering the newly restored wetland, and providing suitable habitat, including nursery and juvenile rearing habitats, for warm and coolwater species. The goals of the habitat islands were to provide shelter from wake and wave action, and to provide terrestrial habitat for reptiles, amphibians and colonial waterbirds.

Figure 92: Tommy Thompson Park Embayment D restoration project before (left) and after (centre). Project polygons are shown at right. (Photos: First Base Solutions 2011; City of Toronto 2018)

It was difficult to determine the effectiveness of restoration with respect to fish community response at this site because there was only one year of post-restoration electrofishing data (2016). Piscivore CPUE was higher during the one year post-restoration consisting of higher catches of Largemouth Bass (25 individuals) and Northern Pike (5 individuals). Northern Pike CPUE increased between 2003 and 2016 although the results were only approaching significance (r=0.655, p=0.078). Largemouth Bass were almost exclusively juvenile fish except for one adult. Similarly, the Northern Pike were all juvenile fish except for one adult. Juvenile Largemouth Bass were caught previously in 2003, 2004, 2005 and 2011 but only one adult Northern Pike was caught prior to 2016 (no juveniles). Other piscivores using this site included one adult Bowfin and one adult Smallmouth Bass in 2004.

Forage fish CPUE did not appear to increase or decrease post-restoration although post-restoration data are very limited (only 2016). Forage fish that were present each year in high abundance included Pumpkinseed and Yellow Perch comprising 21% and 15% of the total forage CPUE respectively. Bluntnose Minnow was the most abundant forage fish species comprising 49% of the total forage CPUE. The CPUE for Bluntnose Minnow decline significantly between 2003 and 2016 (r=-0.903, p<0.01) and this species has not been caught since 2008. Several other forage fish species were either present or more abundant prior to 2008 including Brook Stickleback, Emerald Shiner, Gizzard Shad, Johnny Darter, Spottail Shiner and Threespine Stickleback with both Johnny Darter and Spottail Shiner CPUE declining significantly (r=-0.733, p=0.039 and r=-0.791, p=0.019, respectively).

Embayment D primarily consisted of warmwater species such as Bluntnose Minnow and Pumpkinseed although there was also a good coolwater component including primarily Spottail Shiner and Yellow Perch. Bluntnose Minnow decline may be related to a loss of habitat since this species is known to avoid heavily vegetated areas (Scott and Crossman 1998). The coolwater community has also shifted from primarily Spottail Shiner to Yellow Perch, Rock Bass and Northern Pike.

Native species CPUE also did not appear to increase or decrease post-restoration although again, post-restoration data were very limited. Brown Bullhead were fairly abundant at this site compared to other sites with multiple individuals caught almost every year consisting of approximately 25% juvenile individuals. The adjusted IBI followed a similar temporal pattern to both the forage and native species CPUE patterns. It was higher prior to 2008, the lowest in 2008, then went up again post-2008.

Non-native species at this site included one Sea Lamprey (*Petromyzon marinus*) in 2011 and multiple Common Carp. Common Carp CPUE appeared to be slightly lower after the gate was installed in 2012 although CPUE was lower in 2009. There was only one year of post-restoration data and more data are needed to assess the long-term effectiveness of the carp gates. It is important to note for future assessments that in both 2017 and 2019 water levels in Lake Ontario reached record levels and flowed over the carp gates making them ineffective.

Future assessments of this site would benefit from additional annual electrofishing surveys conducted during the month of July and at night.

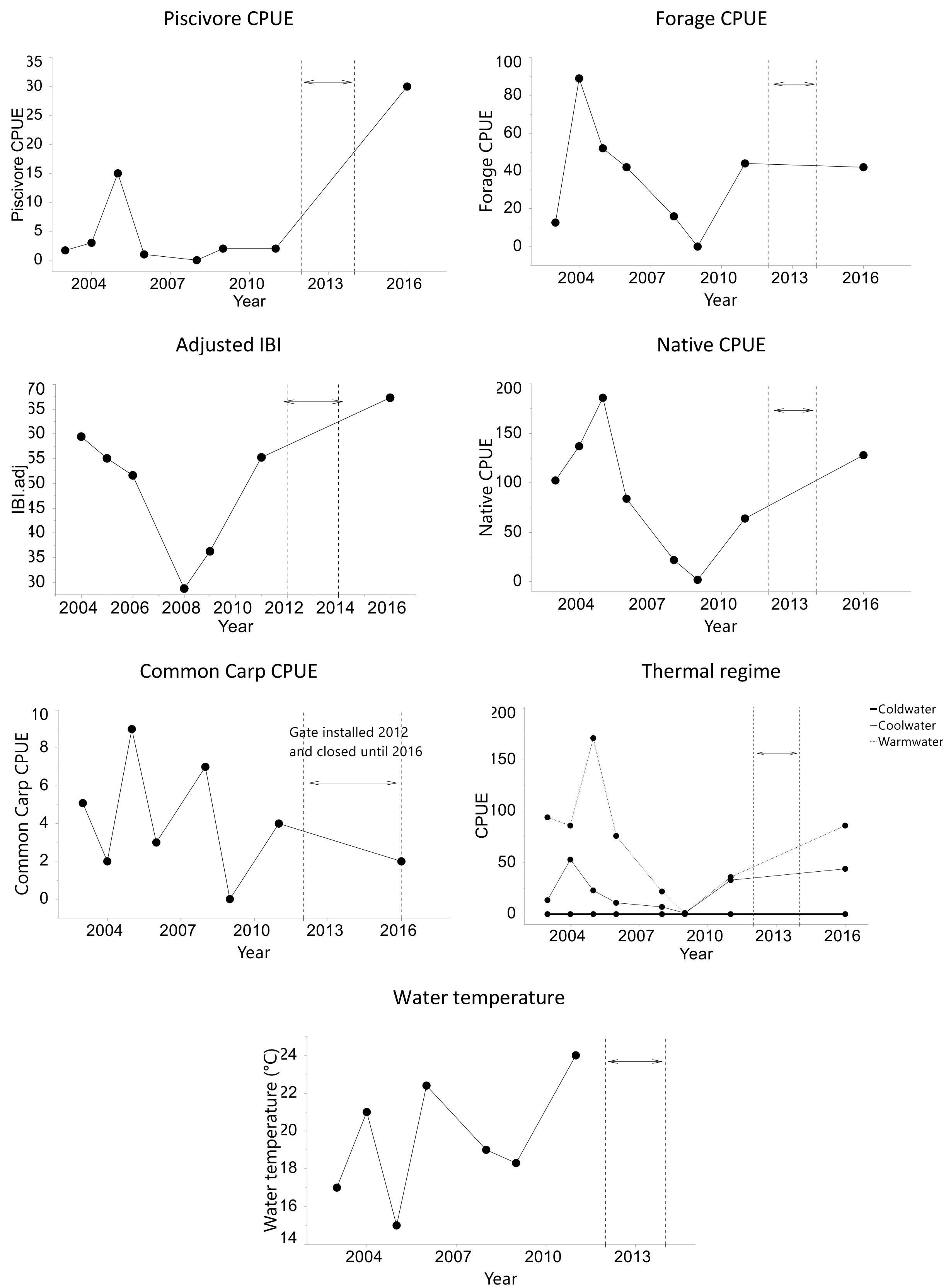


Figure 93: Embayment D TWAHRS Assessment Metrics

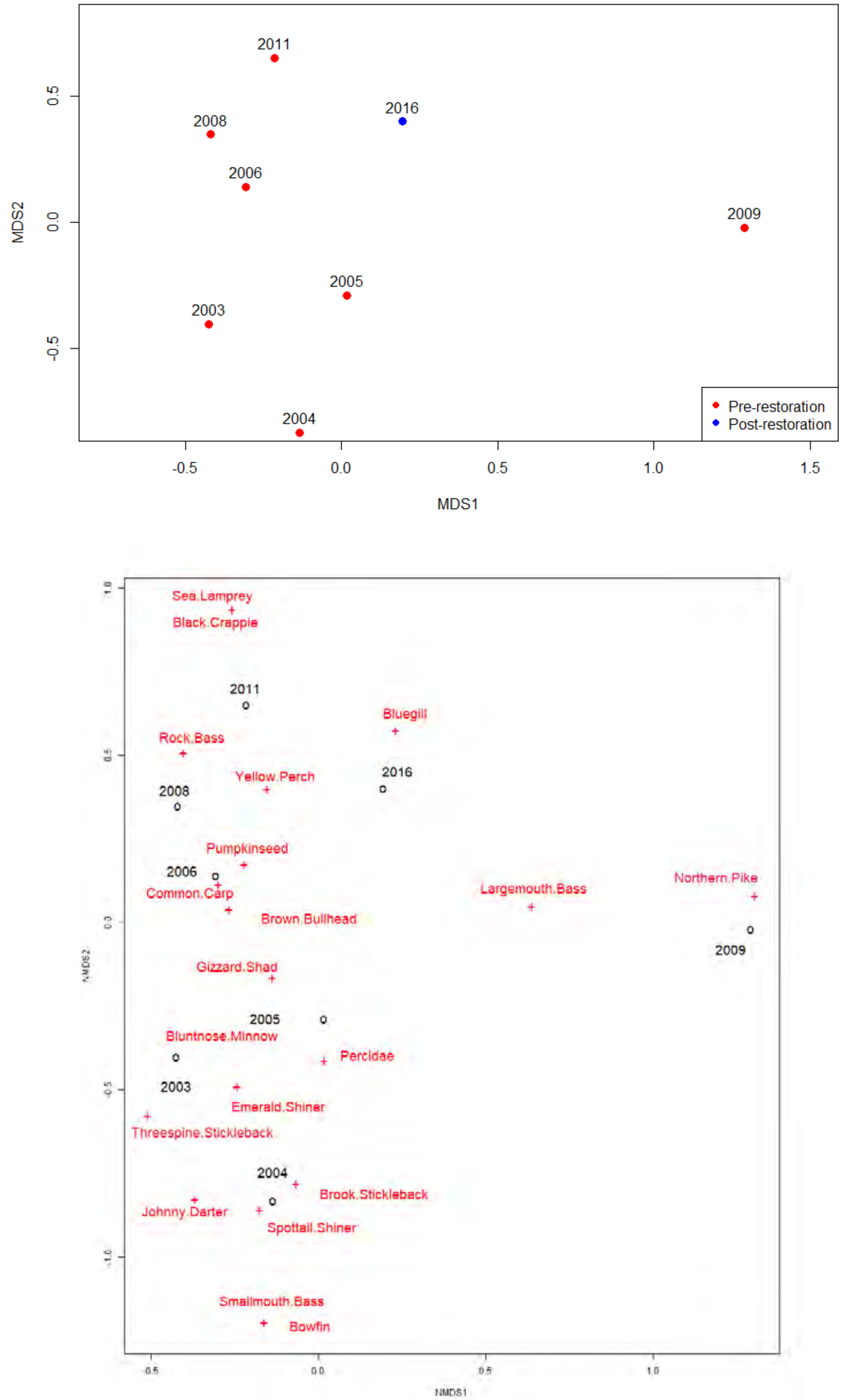


Figure 94: Embayment D Community Ordination (Stress = 0.06)

Table 10: Habitat Area Summaries for Embayment D

Restored Area	TWAHRS Techniques Used	Area Planted (m^2)	Total Area Restored (m^2)	Increase in Shoreline Length (m)
Embayment D	Wetland Berms, *Carp Exclusion Barriers*, Constructed Islands, Aquatic Vegetation, Complex Shoreline Profile Improvements, Shoreline Vegetation Zones, Shoreline Shoals, Anchored Logs, Log Piles, Log Tangles, *Log Cribs*	390	71,610 – aquatic 19,825 - terrestrial	1,355 (115% increase)

Restoration efforts at Embayment D effectively restored 71,610 m^2 of aquatic habitat through both direct (plantings, shoals, structures) and indirect (sheltering effects of wetland berms and habitat islands) mechanisms. The shoreline length available for fish usage increased by 115% from pre-restoration conditions. The fish community responded to the conversion from an open embayment to a coastal wetland. As with other wetland conversions, the use of this site by Bluntnose Minnow decreased, likely due to their aversion to heavily vegetated habitats. Piscivore catches peaked post-restoration, and the community was comprised of juvenile Largemouth Bass and Northern Pike, indicating fish use of Embayment D as nursery and juvenile rearing habitat for phytophyllic spawning species. IBI also peaked post-restoration, due primarily to Centrarchid and piscivore submetrics. Embayment D continues to be used by warm and coolwater species, accomplishing thermal guild restoration targets.

Although additional years of monitoring are required to confirm the decrease in Common Carp, the carp exclusion barrier was shown to be effective through limiting new adult carp from entering Embayment D and utilizing the newly restored wetland habitat. Additional management, such as active water level control, may be required in high lake level events to prevent carp from entering when lake levels overtop the wetland berm.

3.7 Fisheries Analysis – Sheltered Embayment Habitat Scale

3.7.1 Pooled assessment of habitat restoration effectiveness

Pooled assessments were not conducted for estuary, coastal wetland and open coast habitats due to a low sample size of estuaries, limited post-restoration data at coastal wetlands and limited IBI data pre-restoration at open coast sites due to variable sampling effort. Embayment habitats had a sufficient number of years pre- and post-restoration for a pooled assessment although there was variability in the number of electrofishing runs/sites by year. Due to this variation, embayment habitats were only assessed using data from four years pre-restoration and four years post-restoration that were consistently available at six sites: TTP North East Shore, TTP South Shore, TTP Embayment A, Marina Del Ray, Donut Island and Hearn Generating Station. A paired t-test was used to determine if the change in the adjusted IBI score or individual IBI metrics between the pre- and post-restoration time periods were significantly different from zero.

There was a significant increase in the adjusted IBI score post-restoration with an average increase of 6.6 points (t_5=2.81, p=0.037). None of the individual IBI metrics changed significantly (all p>0.05) between the pre- and post-restoration time periods but there were several directional changes (although not significant) that contributed to the difference in the adjusted IBI scores. IBI metrics that were higher post-restoration included Centrarchid richness, generalist percent biomass, native biomass, native count, non-native percent biomass, non-native richness and piscivore biomass. IBI metrics that were lower post-restoration included native Cyprinid richness, intolerant richness, native species richness, non-native percent count and specialist percent biomass.

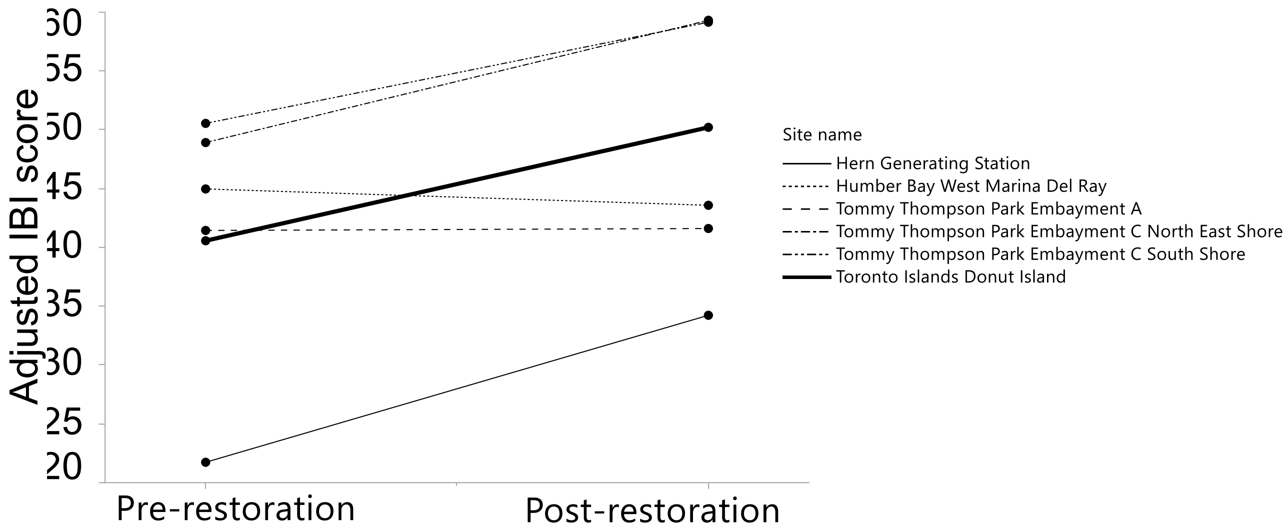


Figure 95: Average adjusted IBI scores pre- and post-restoration at six restored embayments.

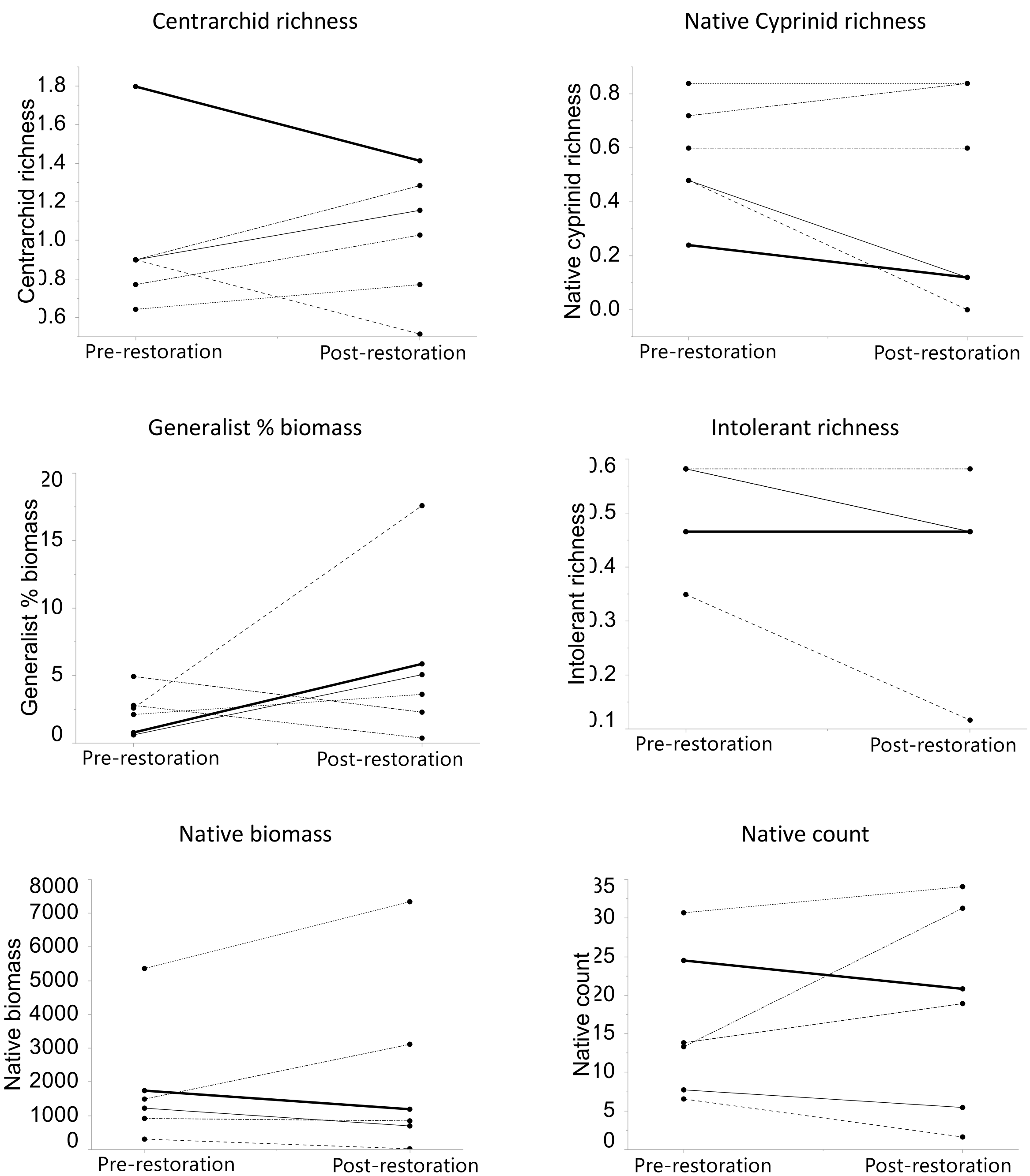
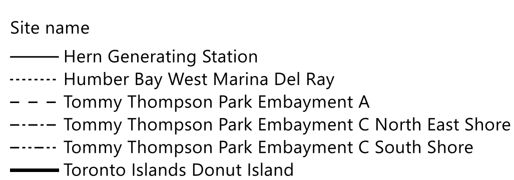


Figure 96: IBI metrics from restored embayments. There were several sites that overlapped for intolerant richness making the individual lines difficult to see (Marina del ray and Donut 0.46 to 0.46 and Hern and TTP North Shore 0.58 to 0.46). The legend below can be used for each metric.



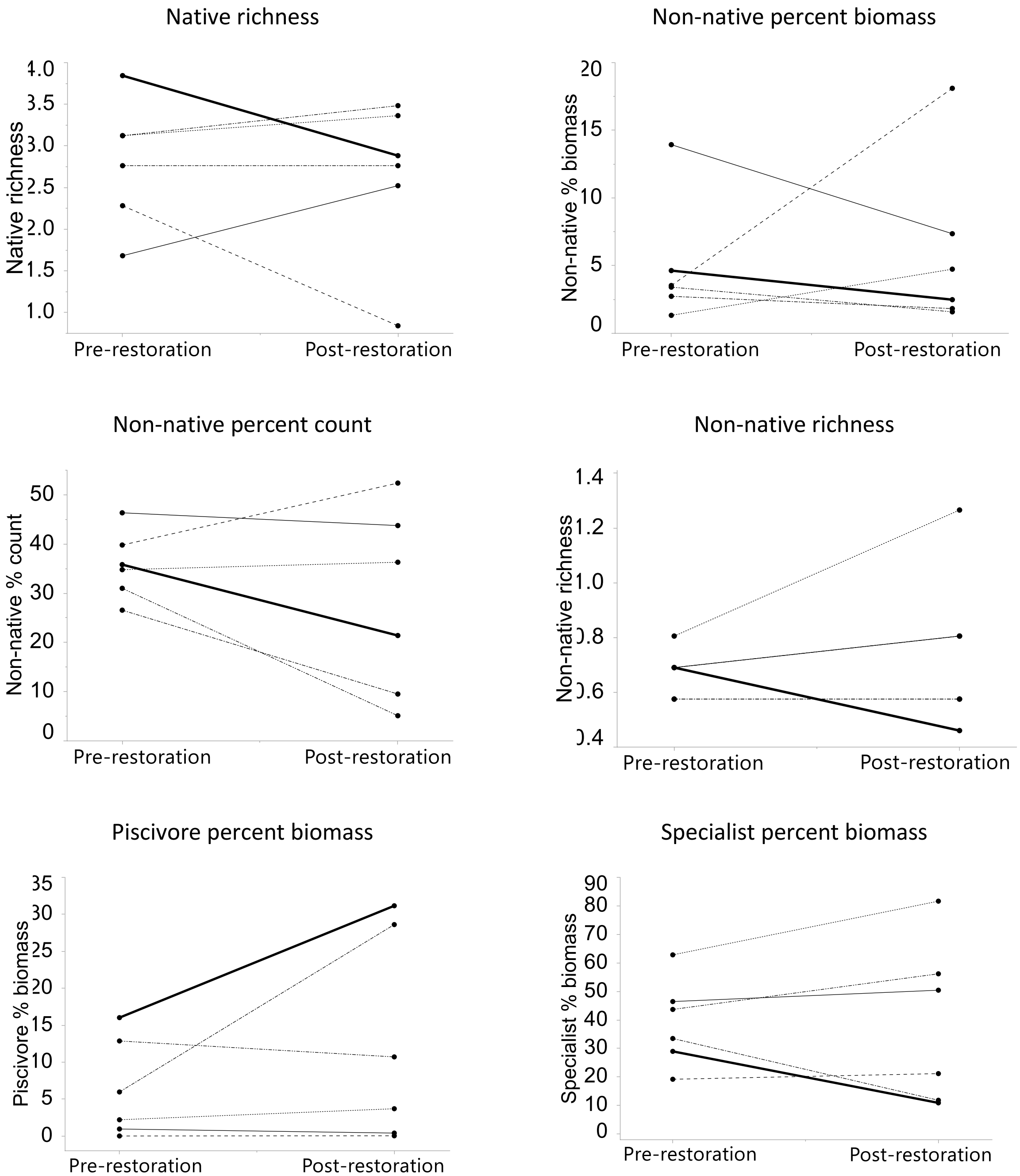


Figure 97: IBI metrics from restored embayments. There were several sites that overlapped for non-native richness making the individual lines difficult to see (Emb A and North Shore 0.57 to 0.57 and Hern and South Shore 0.69 to 0.80). The legend below can be used for each metric.

Site name

- Hern Generating Station
- Humber Bay West Marina Del Ray
- Tommy Thompson Park Embayment A
- Tommy Thompson Park Embayment C North East Shore
- Tommy Thompson Park Embayment C South Shore
- Toronto Islands Donut Island

4 DISCUSSION

This paper summarized changes in fish communities at restored sites on the Toronto waterfront to evaluate the Toronto Waterfront Aquatic Habitat Restoration Strategy. In addition to evaluating the success of the Strategy, this study contributes to filling a knowledge gap identified in the scientific literature. Many studies have assessed the effects of changes in habitat on fish communities either comparatively (restored vs. reference) or through habitat removals (Smokorowski and Pratt 2007) while programs that quantitatively monitor the results of management decisions on fish communities are rare (Roni et al. 2014). Fish populations and communities on the Toronto waterfront have changed over the past 30 years both at restored sites and unrestored sites and varied among habitat type. These changes suggest that while restoration projects create or maintain fish habitat across the Toronto waterfront, fish populations may also be affected by many other factors affecting the larger Lake Ontario ecosystem. Those factors may include invasive species, shoreline development and active construction sites, altered food webs, artificial lighting and climate change.

It is important to remember that these data only included night-fishing data from the month of July to facilitate consistency of temporal comparisons. Data collected during other months are more limited and less consistent from site-to-site and year-to-year; however, examining these data could provide additional information about site use by other fish species and seasonality of use. It is also important to remember that this analysis excluded White Sucker, Rainbow Smelt, Alewife, American Eel (*Anguilla rostrata*), Lake Trout and Round Goby in an attempt to control for species with known increasing or decreasing population trends to isolate the effect of restoration. The presence and abundance of these species at restored sites could provide additional information on competition, predation and food resources. Also, the presence of species with decreasing population trends at a restored site may indicate that the site is helpful for population persistence.

The following sections summarize the results from the restored sites compared to the reference sites for each habitat type. Sites are compared using descriptors such as low, moderate and high CPUE or abundance for specific fish species. Low generally refers to CPUEs of 2 or less occurring infrequently over the time period monitored. Low does not refer to species that were absent or only occurred once. Moderate was variable based on species but in general, moderate for Largemouth Bass describes a CPUE between approximately two and eight in multiple years. For Northern Pike or Bowfin, moderate would be slightly lower since they rarely occurred in these numbers (e.g. CPUE of 1-5). Moderate for generally more abundant species (Pumpkinseed, Yellow Perch, Spottail Shiner, Emerald Shiner) would refer to a CPUE of between approximately 5 and 15 in multiple years. High CPUE generally refers to any values above these. We also related the findings of this study to previous literature in the following sections where possible.

4.1 Estuary habitat summary

Few estuary sites were available for assessment and only included Lower Don River South as a reference site compared to Humber River Estuary and Marie Curtis. There were some general findings and conclusions that can be drawn from these sites. The reference site generally had fewer species over all years (10 species) compared to Humber (23 species) and Marie Curtis (23 species). This could be due to many factors including the quality of the site, restoration activities or the number of years monitored which was lower and in a more limited time range at the Lower Don River than the Humber River Estuary and Marie Curtis.

All estuaries had a similar occurrence of Common Carp, 2 of 3 estuaries had significant declines in Spottail Shiner and a peak in Emerald Shiners during the middle of the sampling time period between approximately 2009 and 2011. Estuaries supported primarily coolwater species such as Emerald Shiner, warmwater species such as Common Carp and very few coldwater species. The Humber River Estuary that had the estuary hooks installed was unique because it had more shiner and minnow species than the other estuaries and a higher CPUE of these species. The Humber River Estuary was also unique because of the appearance of Rock Bass which was directly related to the restoration date. No Rock Bass were found in the Lower Don and were only found infrequently and with a low CPUE (<2) at Marie Curtis.

The increase in fish species heterogeneity at the Humber River Estuary hooks is consistent with the findings of Granados et al. (2012) that evaluated changes in the fish community at this site between 1989 and 2010. The current assessment within this document included additional data from 2011 to 2018 that were not included in Granados et al. (2012) and found that the fish community changed yet again 5-10 years post-restoration. These changes in community structure may represent changes in the substrate several years post-restoration including sedimentation (silting in) that may have occurred in later years.

The decline in Spottail Shiner at estuary sites along with many other restored and reference sites of all habitat types is a concern. Spottail Shiner are a coolwater species with a widespread distribution throughout Canada and the northern United States and are considered to be one of the most important forage Cyprinids in Canadian lakes (Scott and Crossman 1998). Spottail Shiner spawn over sandy shoals in June or July and feed on algae, zooplankton and aquatic insect larvae with larger individuals also feeding on conspecific eggs/larvae (Scott and Crossman 1998). Emerald Shiner have also had more recent declines although their numbers seem to fluctuate. Scott and Crossman (1998) mention periodic concerns by biologists and fishermen over the scarcity of Emerald Shiner although conversations with retired fishermen suggest that periods of scarcity are often followed by periods of great abundance. If Spottail Shiner populations have similar characteristics to Emerald Shiner populations leading to dynamic catches, we would expect to see catches increase again in the next few years. Reasons for declines of Spottail Shiner are speculative and may include decreasing amounts of sandy shoreline, issues with parasitic infections associated with colonial waterbirds or food web relationships with invasive species (e.g. Round Goby). Decreasing CPUE could also be an artifact due to an environmental variable associated with electrofishing sampling such as wind/wave action which was not accounted for in this study. Future monitoring, research and analysis should be conducted to monitor further changes in Spottail Shiner populations and/or identify the cause of these declines.

Although this assessment only compared a limited number of sites, the restoration at the Humber River Estuary appears to have created habitat for several fish species including Rock Bass, shiners and minnows.

4.2 Coastal wetland habitat summary

Three large coastal wetlands were included in this assessment and no reference site was considered due to a lack of reference coastal wetlands in the Toronto Region. There were many similarities among these sites along with a few differences. They all supported warmwater and coolwater fish communities with Cell 1 shifting from coolwater species to more warmwater species. There were significant increases in Largemouth Bass CPUE in both Cell 1 and Cell 2. Largemouth Bass consisted of primarily juvenile fish. Embayment D had a more limited time period for assessment but the CPUE of Largemouth Bass was also moderate (CPUE ~6 per year) at this site consisting of primarily juvenile fish. Northern Pike and Bowfin CPUE were moderate (CPUE ~2-3 per year) in Cell 1 and Cell 2 compared to the other habitat types.

Northern Pike and Bowfin CPUE were low in Embayment D but Northern Pike CPUE did increase in the one year post-restoration.

Pumpkinseed CPUE was high at all three restored coastal wetland sites throughout the entire time period. Yellow Perch CPUE was also high at all three sites while an increasing trend was found for Cell 2. Emerald Shiner and Spottail Shiner did not have similar temporal patterns in CPUE as estuaries except for declines in Spottail Shiner that were found in all three coastal wetlands. Bluntnose Minnow had a high CPUE in the earliest years pre-restoration at Embayment D although CPUE has declined significantly. Embayment D appears to be very important habitat for juvenile Brown Bullhead compared to any other site and CPUE increased in both Cell 1 and Cell 2.

Wetland restoration at TTP has been extensive including infilling of embayments, creating berms, installing carp gates, adding log tangles and aquatic plantings. These activities have created warmer embayments with aquatic vegetation and structural heterogeneity necessary for supporting a diverse fish community (Smokorowski and Pratt 2007). Numerous habitat features are important for fish (e.g. depth, temperature, substrate, etc.); however, aquatic macrophytes are one of the most important factors predicting fish communities in Great Lakes coastal wetlands (Jude and Pappas 1992, Randall et al. 1996, Uzarski et al. 2005, Cvetkovic et al. 2010). Some of the most abundant species in these wetlands included those that require aquatic macrophytes for spawning such as Largemouth Bass, Pumpkinseed and Yellow Perch (Eakins 2020). There was also a shift in dominant thermal guild over time from coolwater species to warmwater species in Cell 1 suggesting that as the cell was filled and bermed, the water temperature rose changing environmental conditions. The addition of wood (log tangles) may have further enhanced the habitat for Largemouth Bass since previous studies have shown that adding wood can increase spawning success and winter survival in this species (Miranda and Hubbard 1994, Hunt and Annett 2002). Species that may not be benefitting overall from the wetland restoration include Spottail Shiner (previously discussed), Gizzard Shad, Rock Bass, White Perch and Bluntnose Minnow each of which had declining trends in at least one of the restored wetlands. Declines in these species could be due to many factors such changing habitat type (e.g. Bluntnose Minnow are known to avoid heavily vegetated areas; Scott and Crossman (1998)), predation by the increasing Largemouth Bass population or isolation from the lake. Several of these species are being supported through restoration elsewhere along the waterfront such as Bluntnose Minnow appearing only post-restoration at the Humber River Estuary hooks and increasing Rock Bass populations at restored open coast sites.

It is still too early to assess the effectiveness of installing carp gates for these restored wetlands using electrofishing data although evidence from field visits indicate that the gates are excluding Common Carp (e.g. many Common Carp were seen trying to enter Cell 1 and were being blocked). Common Carp are benthivorous feeders and their presence can negatively affect water quality, aquatic macrophytes and zooplankton communities (Lougheed et al. 1998). Common Carp exclusion has been effective for improving water quality and submerged plant growth at other restored wetlands in Lake Ontario such as Cootes Paradise Marsh (Lougheed et al. 2004). Grass Carp (*Ctenopharyngodon idella*) are a non-native species introduced to the southern United States in 1963 to control aquatic vegetation but have since escaped and moved up the Mississippi River towards the Great Lakes (Dibble and Kovalenko 2009, DFO 2017). Grass Carp are generalist herbivores and can have considerable negative effects on submerged aquatic vegetation (Dibble and Kovalenko 2009). The likelihood of Grass Carp establishing populations in Lake Ontario is considered to be very likely by 2026 (DFO 2017). Two Grass Carp were captured in Cell 2 in 2015 during de-watering suggesting that the restored wetlands at TTP would be used by the species. The use and maintenance of carp gates installed to withstand large fluctuations in water levels will be increasingly important if/when this species establishes populations within the next decade.

These results suggest that restored coastal wetlands provide important nursery habitat for many species (primarily Largemouth Bass and Brown Bullhead) and very important foraging habitat for top-order piscivores including Northern Pike and Bowfin likely due to the abundance of forage fish such as Pumpkinseed and Yellow Perch. Embayment D specifically appears to be unique in providing nursery habitat for Brown Bullhead. Declines in Bluntnose Minnow were found only in Embayment D while declines in Spottail Shiner were found in all three restored coastal wetlands.

4.3 Embayment habitat summary

There were 10 embayment habitat sites assessed along with 1 reference embayment (Toronto Islands Sunfish Cut). Embayment habitats generally had between 15 and 27 species although the number of species often varied with the number of years the site was surveyed (10 to 26 years). The reference embayment site, Sunfish Cut, had 22 years of data and recorded 25 species.

There was a high number of Pumpkinseed, Yellow Perch and Rock Bass at Sunfish Cut. Yellow Perch occurred relatively consistently over the entire time period but both Pumpkinseed and Rock Bass CPUE declined significantly. Piscivores occurred with a moderate abundance and included primarily Largemouth Bass and Northern Pike, although Bowfin occurred in low numbers but fairly consistently. Emerald Shiner peaked in 2006-2009 and Spottail Shiner CPUE declined significantly and were not caught post-2007. Common Carp were found in a moderate abundance and consistently occurred over the time period. Bluntnose Minnow and Brown Bullhead also occurred in moderate abundance. Freshwater Drum were caught in low numbers but relatively consistently. One Brook Silverside, a native coolwater specialist species intolerant to high turbidity, was caught at Sunfish Cut.

Embayments typically had no coldwater species except for the restored Humber Bay West sites (Superior Ave/Marina del Ray) that supported several coldwater species and this was likely due to the more open coast nature of these embayments. Embayments typically contained cool and warmwater species often with lower catches of warmwater species. The most abundant coolwater species included Emerald Shiner, Yellow Perch, Gizzard Shad, Rock Bass, Northern Pike and Spottail Shiner. The most abundant warmwater species included Pumpkinseed, Bluntnose Minnow, Largemouth Bass, Brown Bullhead and Common Carp.

Restored embayment habitats had similar qualities as the reference site although there was some variability. Emerald Shiner were found in all restored embayment sites and peaked in CPUE at 7 of 10 sites sometime between approximately 2005 and 2014, with 2 sites having a second peak in approximately 1995-1997. Spottail Shiner were found at all restored sites although occurred in low abundance at six sites. Of the four sites where they were found in higher numbers, CPUE declined significantly over the time period. Many of the restored embayment sites also had high Pumpkinseed, Yellow Perch and Rock Bass CPUEs throughout the time period similar to the reference site but there was some variability. Pumpkinseed were found with the highest CPUE at the sites related to TTP or the Toronto Islands while the Humber Bay West and Hearn Generating Station sites had low numbers or none at all. Pumpkinseed CPUE was declining at four sites associated with TTP: Embayment A, North East Shore, North West Footpad, and South East Footpad and these were the same four sites that had declines in Spottail Shiner. Rock Bass CPUE decreased significantly at two restored sites related to TTP similar to the reference site (Embayment A, North East Shore) and increased at three others (Superior Ave, Marina del Ray, South Shore). Yellow Perch were found in high numbers at several of the restored sites similar to the reference site. The restored sites with moderate to high Yellow Perch CPUE included Embayment A, Embayment C's North East Shore and South Shore, Marina del Ray, and Donut Island. Four of these restored sites also had increasing Yellow Perch CPUE including Embayment B, Embayment C's North East Shore and South Shore, and Donut Island. Bluntnose Minnow CPUE decreased significantly at 3 of 10 restored sites (Embayment A, Embayment C's North East Shore and North West Footpad) although did not decrease significantly at the reference site.

Most of the restored sites had a lower piscivore CPUE compared to the reference site although again, there was some variability. The most commonly occurring and abundant piscivores were Largemouth Bass and Northern Pike and they had moderate CPUEs at the reference site. Donut Island was the only restored site with higher CPUEs for these species and were highest between 1999 and 2008 just prior to restoration. Many of these were juvenile fish suggesting very important nursery habitat similar to Cell 1 (a restored coastal wetland). Both TTP Embayment C's North East Shore and South Shore had moderate Largemouth Bass and Northern Pike CPUEs similar to the reference embayment also consisting of many juvenile fish. Bowfin were found fairly consistently in low numbers at both Sunfish Cut and Donut Island but were found infrequently at Embayment C's North East Shore, South Shore and South East Footpad. Walleye and Smallmouth Bass were only found at a few sites and in low numbers. Donut Island was the only restored site containing Brook Silverside and it was found in multiple years. Common Carp were consistently caught at all embayment sites but were generally caught in low to moderate abundance. Common Carp CPUE decreased significantly at the two Humber Bay West sites: Superior Ave and Marina del Ray.

There was an increase in the average adjusted IBI score for embayment habitats based on the pooled assessment. This increase was primarily due to higher Centrarchid richness (primarily Pumpkinseed, Largemouth Bass and Rock Bass), native biomass and count (including Yellow Perch) and piscivore biomass (mostly Largemouth Bass and Northern Pike). These results are consistent with several of the findings from the individual site assessments. Several of the IBI metrics were lower post-restoration including native Cyprinid richness (echoing site-specific declines and subsequent absence of Spottail Shiner and Emerald Shiner), intolerant richness (again likely reflecting the decline of Spottail Shiner) and declines in specialist percent biomass (may be due to declines in Pumpkinseed, Emerald Shiner and Spottail Shiner).

Embayment habitats were restored using various techniques to increase structural heterogeneity. The overall improved IBI score post-restoration in embayment habitats suggests that there has been a general improvement in ecosystem quality and biological integrity (Minns et al. 1994). This improvement represents movement towards an ecosystem capable of supporting and maintaining "a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region" (Karr 1981). Even though the movement of the average IBI was positive (41.4 to 48.0), the average IBI value post-restoration still indicates a degraded ecosystem based on other lake-wide IBI assessments (e.g. Hoyle et al. 2018). Hoyle et al. (2018) reported a similar IBI value for Toronto Harbour (average 45.1; range 40-49) based on boat electrofishing data collected between 2006 and 2016. Even though the values reported here are similar to Hoyle et al. (2018), restoration appears to have improved IBI values at several sites even above the range reported by Hoyle et al. (2018): TTP Embayment C North East Shore 48.9 to 59.3; TTP Embayment C South Shore 50.1 to 59.2; Donut Island 40.6 to 50.2. While average values continue to represent a degraded system compared to other areas of Lake Ontario, the overall improvement in IBI score and the occurrence of higher IBI scores than previously reported at individual sites suggests a positive response of fish communities to habitat restoration.

Overall, restored embayment sites consisted of primarily Pumpkinseed, Yellow Perch, Rock Bass, Largemouth Bass, Spottail Shiner, Emerald Shiner and Common Carp in the highest CPUEs. Many of the restored sites had a lower CPUE for these species compared to the reference site although increasing CPUEs of Yellow Perch and many juvenile piscivores at the restored sites is encouraging. Declines in Spottail Shiner and potentially Emerald Shiner were also identified at reference and restored embayment habitat sites. There was an overall increase in adjusted IBI scores post-restoration based on the pooled assessment of embayment sites.

4.3.1 Toronto Harbour boat slip summary

Several slips were used in this assessment including four restored slips (Spadina, Peter, Rees and Simcoe) and one reference slip (York Quay). In general, all slips had fewer species than estuaries and coastal wetlands ranging from only 1 species caught at Simcoe Slip to 14 species at York Quay. Variability in species richness among slips could be due to variation in the number of years surveyed ranging from 4 years for Simcoe Slip to 13 years for York Quay. Simcoe Slip was quite different from the other three restored slips because July night-fishing data from four years of monitoring only captured one Emerald Shiner. Slips were used by primarily coolwater species including Emerald Shiner, Northern Pike, stickleback and Yellow Perch. The reference slip, York Quay, appeared to have had a higher CPUE of warmwater fish (specifically Common Carp) than the restored slips.

One of the most consistent observations was the use of York Quay, Spadina, Peter and Rees slips by large adult Northern Pike. While not included in other assessments, we considered the Alewife data removed for this assessment to determine if Northern Pike occurrence could be related to the occurrence of Alewife. The occurrence of Alewife appeared to be related to the occurrence of Northern Pike along with low water temperatures. It is possible that when lower July water temperatures occur, Alewife schools move inshore into slips and are subsequently ambushed by Northern Pike aware of these movements. Even though Northern Pike were using these slips, CPUE was decreasing at two of the slips although correlations were based on low occurrence data. Other than Northern Pike, Emerald Shiner were the only other species found in all the slips although in variable/low numbers.

Common Carp were using both York and Peter Slips. Both Peter and Rees Slips had stickleback caught in moderate CPUEs compared to other species. The occurrence of these species could be due to a nearby source population along with the presence of suitable nesting habitat (small twigs and other plant debris) due to the restoration efforts. Spadina Slip had moderate CPUEs of Yellow Perch compared to the other slips and this could be due to the proximity of the Spadina Slip to a source wetland in addition to successful restoration efforts at this site.

The boat slips examined in this study were one of the most heavily human-modified habitat types with completely armoured walls (e.g. seawalls) and many overwater structures (e.g. docks). These habitats generally had the fewest species and this is consistent with the findings of other studies (Munsch et al. 2017). The use of boats slips by Northern Pike in Toronto Harbour has already been examined by Veilleux et al. (2018). Veilleux et al. (2018) found that there was both spatial and seasonal variability in slip use by Northern Pike with indications that pike were spending most time at the mouth of the slips. The data from this study provides further supporting evidence of use of boat slips by Northern Pike and that their occurrence may be related to the occurrence of Alewife during cooler summer water temperatures. Several unconventional options could be implemented to further restore altered boat slips such as textured seawalls and light-penetrating pier/dock surfaces (Munsch et al. 2017).

Overall, restored slips provide habitat for fewer species than other habitat types and species occurrence may be related to the proximity to source populations and as long as suitable habitat occurs in the slip. Restored slips may also be providing foraging habitat for Northern Pike that appear to be exploiting Alewife using the slips during cooler summer water temperatures.

4.4 Open coast summary

There were four open coast sites assessed along with one reference site, East Point Natural Shoreline. The four open coast sites included Port Union Armourstone West, Port Union Armourstone East, Port Union Natural Shoreline and Scarborough Shoreline at Meadowcliffe. In general, the open coast sites had fewer species compared to estuary, coastal wetland and embayment habitat types. Open coast fish communities consisted of a different suite of species including more pelagic and coolwater species such as Lake Chub, Trout-perch and Longnose Dace along with several non-native cold/coolwater species such as Rainbow Trout, Brown Trout and Chinook Salmon. Logperch, a warmwater species, were also found frequently at open coast sites. The reference site had very few species and in very low CPUEs (often only a single occurrence of a species) including Rainbow Trout, Brown Bullhead, Lake Chub, Common Shiner, Gizzard Shad, Common Carp and Emerald Shiner. Restored open coast habitat sites often contained all the species found at the reference site plus about 10 additional species not found at the reference site. Most notable was the moderate to high CPUE of Smallmouth Bass at the restored Port Union sites. Smallmouth Bass were not found at the open coast reference site and were caught in only limited numbers in any other habitat type. Rock Bass were also found with a low to moderate CPUE at the restored Port Union sites and were not found at the open coast reference site. The restored Port Union open coast sites also had declines in Spottail Shiner along with the presence of one or two peaks in Emerald Shiner CPUE (1997 and 2010-2013). Emerald Shiner were exceptionally abundant at Scarborough Shoreline Meadowcliffe with an average CPUE of 36 and two years with very high CPUEs (138 and 177).

The increased use of some restored open coast sites by Smallmouth Bass and Rock Bass in this study is not unique although studies with long-term monitoring data are limited. Creque et al. (2006) monitored fish community composition and abundance at both an artificial reef (granite rock) and a nearby reference site before and after construction in Lake Michigan. The artificial reef attracted more Smallmouth Bass and Rock Bass than the reference site and Smallmouth Bass occurrence was strongly related to warmer water temperatures and also wider areas of the reef (Creque et al. 2006). Artificial reefs were not part of this study, which only considered shoreline armouring with boulders/riprap. There is a large amount of evidence that shoreline armouring alters fish communities changing composition from species preferring soft substrates to those preferring hard substrates (Munsch et al. 2015). Shorelines hardened with riprap/boulders also create prime habitat for Round Goby, an aggressive invasive species not well monitored using boat electrofishing (Vanderploeg et al. 2002, Polačik et al. 2008).

Overall, the restored open coast sites at Port Union had fish communities including both the offshore species characteristic of the open coast reference site along with Smallmouth Bass and Rock Bass not found at the reference site. Spottail Shiner were declining at two of the restored Port Union sites and Emerald Shiner have declined in recent years at all of the restored open coast sites. Scarborough Shoreline at Meadowcliffe did not support large populations of Smallmouth Bass and Rock Bass similar to the Port Union restored sites but did support some of the largest Emerald Shiner CPUEs of any site assessed.

5 RECOMMENDATIONS ON TECHNIQUE EFFECTIVENESS

Each project was unique in that different combinations, quantities and scales were implemented to suit on-the-ground conditions and management objectives. Through this analysis, it is evident that both single-use technique projects can be effective, as well as multi-technique projects.

5.1 Coastal Wetlands

The most evident shifts in fish communities, as well as the most evident gains in desired outcomes, were seen in coastal wetland habitat projects. This applies to both wetland creation and wetland restoration projects. It is evident that the use of the wetland berm technique was a demonstrably effective technique promoted in the TWAHRS document.

Carp exclusion barriers, an extension of the wetland berm technique, were shown to be effective at the intended water levels. It is recommended to practice water control management in existing sites allowing aquatic vegetation to establish in the early stages of restoration. Water level management in early stages allows seed banks to establish to make them more resilient to future water level changes. The ability to manage water levels during these historic high water levels has proven to be beneficial to establishing a successful wetland in the early restoration stages.

Finally, for new carp exclusion barriers being constructed, it is recommended to build both the berm and the gate elevation to account for record water levels. An example of this can be seen at the South West cove of the Cherry Street landform project within the Don Mouth Naturalization Project. Establishing barriers withstanding of record water levels is recommended in the face of two prescient threats: variability in local conditions due to climate change, and emerging invasive species threats such as Grass Carp.

5.2 Open Coast

Open coast is the most common habitat type across the Toronto region. Beach headland systems were implemented as a modified version of the TWAHRS technique surcharged groynes. These structures are shown to be effective for aspects of TWAHRS targets, namely increasing predator occurrence and supporting native forage stocks.

The supplementing of cobble, gravel and boulder is likely acting as effective spawning substrate for open coast species, despite our inability to assess this using nearshore electrofishing data. These habitat restoration techniques satisfy broad lake management objectives, including enhancing spawning and nursery habitat by installing cobble shoals and points for Lake Trout, Whitefish and Herring.

5.3 Estuary

Although few in number, estuary projects address some of the key historic hardening and erosion control actions leading to historical losses of natural habitat. The high estuary hooks in the Humber River were demonstrably effective for introducing substrate variability and for creating quiescent areas for small bodied fish; however, concerns over siltation over the longer term need addressing. Hooks are recommended to continue to be used, including implementing low estuary hooks in less energetic systems.

Shoreline shoals do not appear to have a measurable effect using the methods proposed in this study. It is possible that restoration of the historically depleted aggregate in historically hardened shorelines carries benefits for spawning and foraging at a scale that was not perceptible using the methods here.

Although not studied directly, the combination of created and restored coastal wetlands in an estuary system or drowned rivermouth are recommended going forward. These techniques have been adopted into the design of the Don Mouth Naturalization Project.

5.4 Sheltered Embayment

The most successful sheltered embayment projects used a combination of TWAHRS techniques that were suited to the site-specific conditions. It is recommended to continue to creatively combine TWAHRS techniques in the many sheltered and exposed embayment habitats in the Toronto region.

Additionally, it is recommended to continue to soften and naturalize historically hardened shorelines by removing non-natural materials using techniques such as live staking, anchored logs, and softer shoreline shoals. This technique was shown to be effective at the Hearn Generating Station recreational node.

Despite most TWAHRS-projects occurring in the sheltered embayment habitat type, it is recommended that sheltered and exposed embayments continue to be restored for cool and warmwater species due to the historical depletion and general deficiency of these habitat types across the Toronto AOC.

Forage species responded to the shoal, woody material and cover treatments within the slips of Toronto’s Inner Harbour. These new species provided ample opportunities for predator species to forage. As dockwalls are repaired and repurposed, management organizations should encourage Inner Harbour Quay Treatment implementation both in slips and along dockwalls.

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7 APPENDIX 1: TWAHRS RESTORATION PROJECTS ASSESSED INCLUDING RESTORATION ACTION/DATE AND REFERENCE SITES BY HABITAT TYPE.

Habitat type	TWAHRS restoration or reference	Site name	Restoration action	Electrofishing run station name	Restoration start date	Restoration end date
Open coast	Reference	East Point Natural Shoreline	n/a	East Point Natural Shoreline	n/a	n/a
Open coast	TWAHRS	Port Union Phase I	Surcharged groynes	Port Union Armourstone West	2002	2006
Open coast	n/a	Port Union Armourstone East	None; located between Port Union Phase I and II sites	Port Union Armourstone East	n/a	n/a
Open coast	TWAHRS	Port Union Phase II	Surcharged groynes	Port Union Natural Shoreline East	2008	2012
Open coast	TWAHRS	Western Beaches Rowing Facility	Surcharged revetment	Dragonboat - Outer breakwall	2006	2007
Open coast/sheltered embayment	TWAHRS	Western Beaches Rowing Facility	Surcharged revetment	Dragonboat - Inner breakwall	2006	2007
Open coast	TWAHRS	Ontario Place West Channel	Surcharged revetment	Dragon Boat Control - Outer Breakwall	2015	2015
Open coast/sheltered embayment	TWAHRS	Ontario Place West Channel	Surcharged revetment	Dragon Boat Control - Inner Breakwall	2014	2014
Open coast	TWAHRS	Meadowcliffe	Surcharged groynes	Scarborough Shoreline Meadowcliffe	2011	2013
Sheltered embayment	Reference	Toronto Islands Sunfish Cut	n/a	Toronto Islands Sunfish Cut	n/a	n/a
Sheltered embayment	TWAHRS	Mimico Waterfront Park Project Phase I	Constructed Islands	Humber Bay West Superior Ave	2006	2008
Sheltered embayment	TWAHRS	Mimico Waterfront Park Project Phase II	Wetland berm, shoreline vegetation	Humber Bay West Marina Del Ray	2011	2012
Sheltered embayment	TWAHRS	Embayment C North East Shore	Log tangles, boulder piles	Embayment C North East Shore	2010	2010
Sheltered embayment	TWAHRS	Embayment C South Shore	Berm, anchored logs, log piles, aquatic plantings	Embayment C South Shore	2010	2011
Sheltered embayment	TWAHRS	Embayment C North West Footpad	Sand fill, rover stone, rock, gravel shoals, boulder clusters, aquatic plantings	Embayment C North West Footpad	1996	1998, 2008
Sheltered embayment	TWAHRS	Embayment C South East Footpad	Complex, sand fill, riverstone, rock gravel, banks graded, log tangles, boulders	Embayment C South East Footpad	1996	2011
Sheltered embayment	TWAHRS	Embayment A	Constructed islands, wetland vegetation complex	Tommy Thompson Park Embayment A	2009	2009
Sheltered embayment	TWAHRS	Embayment B	Constructed islands, wetland vegetation complex	Tommy Thompson Park Embayment B	2010	2011
Sheltered embayment	TWAHRS	Lake Ontario Park	Surcharged shoreline, anchored logs	Hern Generating Station	2015	2015
Sheltered embayment	TWAHRS	Toronto Islands Donut Island	Complex wetland shoreline improvements, wetland vegetation zones	Toronto Islands Donut Island	2013	2013
Sheltered embayment - slip	Reference	York Quay	n/a	Toronto Harbour York Quay	n/a	n/a
Sheltered embayment - slip	TWAHRS	Rees Slip	Surcharged shoreline, log tangles (wave deck)	Toronto Harbour Rees Slip	2009	2009
Sheltered embayment - slip	TWAHRS	Simcoe Slip	Surcharged shoreline, log tangles (wave deck)	Toronto Harbour Simcoe Slip	2009	2009
Sheltered embayment - slip	TWAHRS	Spadina Slip	Surcharged shoreline, log tangles (wave deck)	Toronto Harbour Spadina Slip	2008	2008
Sheltered embayment - slip	TWAHRS	Peter Slip	Surcharged shoreline	Toronto Harbour Peter Slip		
Coastal wetland	TWAHRS	Tommy Thompson Park Cell 1	Wetland berm, shoreline vegetation zones, log tangles	Tommy Thompson Park Cell 1 East (pre-restoration runs called "Tommy Thompson Park Cell 1")	2004	2007
Coastal wetland	TWAHRS	Tommy Thompson Park Cell 2	Wetland berm, shoreline vegetation zones, log tangles	Tommy Thompson Park Cell 2	2015	2017
Coastal wetland	TWAHRS	Tommy Thompson Park - Embayment D	Wetland berm, constructed island, shoreline vegetation zones, log tangles	Tommy Thompson Embayment D	2012	2014
Estuary	Reference	Lower Don River South	n/a	Lower Don River South	n/a	n/a
Estuary	TWAHRS	Humber Groynes	Estuary hooks	Humber River Mouth Estuary East Side	2008	2008
Estuary	TWAHRS	Marie Curtis Park Phase I	Shoreline surcharge	Etobicoke Creek Marie Curtis Park	2012	2012
Estuary	TWAHRS	Marie Curtis Park Phase II	Shoreline surcharge	Etobicoke Creek Marie Curtis Park	2017	2018

8 APPENDIX 2: SPECIES CLASSIFICATION TABLES

Table 2.1. Forage fish species used to assess pre- and post-restoration changes in forage fish CPUE.

Alewife	Logperch
Banded Killifish	Longnose Dace
Black Crappie	Mottled Sculpin
Blacknose Dace	Northern Pearl Dace
Bluegill	Pumpkinseed
Bluntnose Minnow	Rainbow Darter
Brook Silverside	Rainbow Smelt
Brook Stickleback	Rainbow Trout
Central Mudminnow	River Chub
Central Stoneroller	Rock Bass
Common Shiner	Rosyface Shiner
Creek Chub	Round Goby
Emerald Shiner	Rudd
Fathead Minnow	Sand Shiner
Freshwater Drum	Spotfin Shiner
Gizzard Shad	Spottail Shiner
Golden Shiner	Threespine Stickleback
Green Sunfish	Trout-perch
Hornyhead Chub	White Bass
Iowa Darter	White Perch
Johnny Darter	White Sucker
Lake Chub	Yellow Perch

Table 2.2. Native and non-native fish species used to assess pre- and post-restoration changes.

Native species			**Non-native species**
American Brook Lamprey	Gasterosteidae	Percidae	Alewife
American Eel	Gizzard Shad	Pumpkinseed	Brown Trout
Atlantic Salmon	Golden Shiner	Quillback	Chinook Salmon
Banded Killifish	Green Sunfish	Rainbow Darter	Coho Salmon
Black Crappie	Hornyhead Chub	Rainbow Smelt	Common Carp
Blacknose Dace	Johnny Darter	Rock Bass	Cyprinidae
Bluegill	Lake Chub	Sand Shiner	Goldfish
Bluntnose Minnow	Lake Trout	Shorthead Redhorse	Goldfish x Common Carp hybrid
Bowfin	Lake Whitefish	Smallmouth Bass	NoCatch
Brook Silverside	Largemouth Bass	Spotfin Shiner	Rainbow Trout
Brook Stickleback	*Lepomis* sp.	Spottail Shiner	Rosyface Shiner
Brown Bullhead	Logperch	Threespine Stickleback	Round Goby
Burbot	Longnose Dace	Trout-perch	Rudd
Common Shiner	Longnose Gar	Walleye	Sea Lamprey
Creek Chub	Mottled Sculpin	White Bass	White Perch
Emerald Shiner	Northern Pearl Dace	White Sucker	
Etheostoma sp.	Northern Pike	Yellow Bullhead	
Fathead Minnow	*Notropis* sp.	Yellow Perch	
Freshwater Drum			

Table 2.3. Fish species and thermal regime based on Eakins (2020).

Coldwater	Coolwater		Warmwater
Alewife	American Eel	Longnose Dace	Bigmouth Buffalo
American Brook Lamprey	Banded Killifish	Mooneye	Bluegill
Atlantic Salmon	Black Crappie	Mottled Sculpin	Bluntnose Minnow
Brook Trout	Blackchin Shiner	Ninespine Stickleback	Bowfin
Brown Trout	Blacknose Dace	Northern Brook Lamprey	Brook Silverside
Burbot	Blacknose Shiner	Northern Pearl Dace	Brown Bullhead
Chinook Salmon	Blackside Darter	Northern Pike	Channel Catfish
Coho Salmon	Brassy Minnow	Northern Redbelly Dace	Common Carp
Lake Chub	Bridle Shiner	Quillback	Fathead Minnow
Lake Trout	Brook Stickleback	Rainbow Darter	Freshwater Drum
Lake Whitefish	Central Mudminnow	Redside Dace	Golden Redhorse
Longnose Sucker	Central Stoneroller	River Chub	Goldfish
Rainbow Smelt	Chestnut Lamprey	River Redhorse	Grass Carp
Rainbow Trout	Common Shiner	Rock Bass	Grass Pickerel
Round Whitefish	Creek Chub	Round Goby	Green Sunfish
Slimy Sculpin	Emerald Shiner	Rudd	Largemouth Bass
Trout-perch	Fallfish	Sea Lamprey	Logperch
	Fantail Darter	Silver Lamprey	Longnose Gar
	Finescale Dace	Silver Redhorse	Mimic Shiner
	Gizzard Shad	Smallmouth Bass	Muskellunge
	Golden Shiner	Spottail Shiner	Northern Hog Sucker
	Hornyhead Chub	Tessellated Darter	Pumpkinseed
	Iowa Darter	Threespine Stickleback	Rosyface Shiner
	Johnny Darter	Walleye	Sand Shiner
	Lake Sturgeon	White Sucker	Shorthead Redhorse
		Yellow Perch	Spotfin Shiner
			Stonecat
			Tadpole Madtom
			White Bass
			White Crappie
			White Perch
			Yellow Bullhead

9 APPENDIX 3: TEMPORAL CHANGES IN FISH COMMUNITIES AT REFERENCE SITES

9.1 Reference site 1: East Point Park Natural Shoreline

Restoration: None

We compared historical data (1991, 1996, 1997) to current data (2017, 2018, 2019) by grouping years in these two time periods instead of using year as a continuous variable due to a limited number of night-fishing samples. We compared data between time periods using t-tests for Alewife CPUE (2-sample t-test) and White Sucker CPUE (1-sample t-test), although the non-parametric Wilcoxon test was used for comparing species richness. Means are reported for all variables. We used July night fishing data for each year except for 2017 which only had June data available.

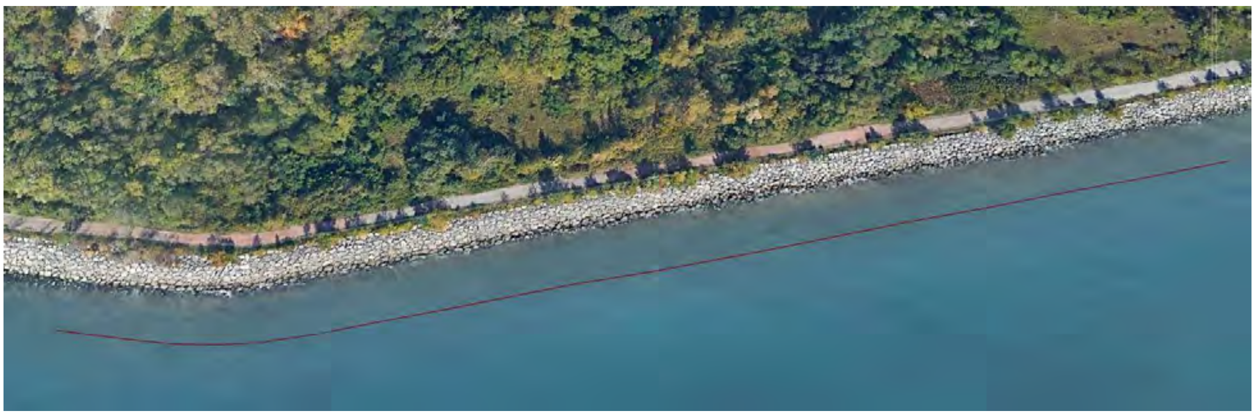
Fish communities have changed at East Point Park Natural Shoreline between historical (1991, 1996, 1997) and current (2017, 2018, 2019) time periods. There were significantly fewer species in the current data (1 species) compared to the historical data (4.7 species; χ^2_1=4.5, p=0.034). In addition to changes in species richness, there were also significant decreases in the CPUE of Alewife and White Sucker. Alewife CPUE was significantly lower in the current data (12 individuals) compared to the historical data (67 individuals; t_4 = 3.99, p = 0.016). No White Suckers were caught in the current time period compared to an average of 4 individuals in the historical data (t_2=3.05, p = 0.046) with White Suckers being caught in all historical years. This is a limited sample size, and these comparisons should be made cautiously although they reflect trends observed at other open coast reference sites. There was no significant effect of year on water temperatures (χ^2_1=0.33, p=0.564) although, this data set is very small and may not represent general changes in Lake Ontario water temperatures.

Table 3.1: Species and associated CPUE at East Point Park Natural Shoreline comparing historical (1991, 1996, 1997) and current electrofishing data (2017, 2018, 2019) from July night fishing runs. Water temperature during electrofishing is shown next to year.

Species (CPUE per 1000 seconds)					
1991 (13°C)	1996 (?)	1997 (18°C)	2017 (21°C)	2018 (23°C)	2019 (12°C)
Alewife (60)	Alewife (92)	Alewife (50)	Alewife (17)	Gizzard Shad (2)	Alewife (18)
White Sucker (6)	White Sucker (2)	Emerald Shiner (43)			
Lake Chub (2)	Gizzard Shad (1)	Common Carp (3)			
Rainbow Trout (2)	Common Shiner (1)	White Sucker (3)			
American Eel (1)					
Brown Bullhead (1)					

9.2 Reference site 2: Scarborough Shoreline South Marine Drive

Restoration: Armourstone wall (1987)



Alewife, Brown Trout, Rainbow Smelt and White Sucker CPUE decreased significantly between 1989 and 2018. Water temperatures have increased from 1989 to 2018 with regression results approaching significance (R^2=0.201, p=0.082).

Table 3.2: Temporal trends in CPUE between 1989 and 2018 and statistical results for selected fish species at Scarborough Shoreline South Marine Drive sampled during July night fishing runs.

Species	**Temporal trend**	**Spearman's ρ**	**P value**
Alewife	Decrease*	-0.420	0.083*
Brown Trout	Decrease*	-0.464	0.053*
Common Carp	None	-0.044	0.862
Emerald Shiner	None	0.170	0.500
Rainbow Smelt	Decrease*	-0.497	0.036**
Round Goby	Increase*	0.4724	0.048**
White Sucker	Decrease*	-0.487	0.040**

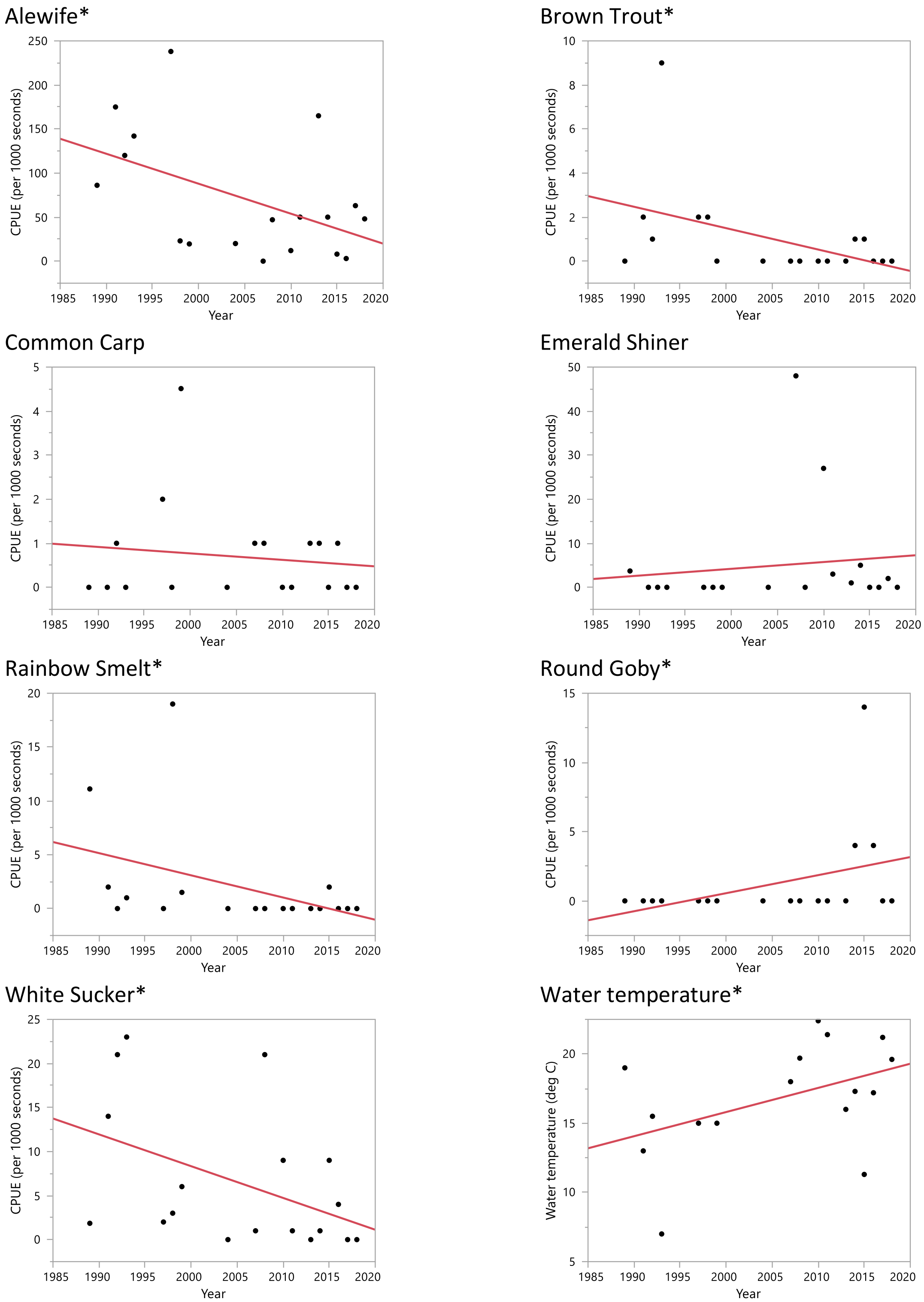


Figure 3.1: Temporal trends in CPUE between 1989 and 2018 and statistical results for selected fish species at Scarborough Shoreline South Marine Drive sampled during July night fishing runs (* indicates a significant trend p<0.10).

9.3 Reference site 3: Colonel Sam Smith Outer Breakwall

Restoration: Armoured shoreline (1975)

There were limited data from the 1990s for July night fishing therefore this analysis may not comprehensively reflect conditions from that decade. We examined temporal trends in CPUE for five species with sufficient occurrence between 1993 and 2019 during July night fishing including Alewife, Round Goby, White Sucker, Lake Chub and Emerald Shiner. Non-parametric correlations (Spearman's ρ) were used. We also examined changes in CPUE using October night fishing data due to its availability at this site although we did this by comparing two time periods: historical (1993-1995, 1999) and present (2015-2017) due to a lack of continuous data.

White Sucker CPUE (per 1000 seconds) decreased significantly between 1993 and 2019 during July night fishing. There was no significant change in water temperature at this site during July night fishing (R^2=0.10, p=0.322).

Table 3.3: Temporal trends in July night fishing CPUE between 1993 and 2019 and statistical results for selected fish species at Colonel Sam Smith Outer Breakwall.

Species	**Temporal trend**	**Spearman's ρ**	**P value**
Alewife	None	-0.346	0.247
Emerald Shiner	None	-0.437	0.136
Lake Chub	None	0.093	0.763
Round Goby	None	-0.081	0.793
White Sucker	Decrease*	-0.819	<0.001*

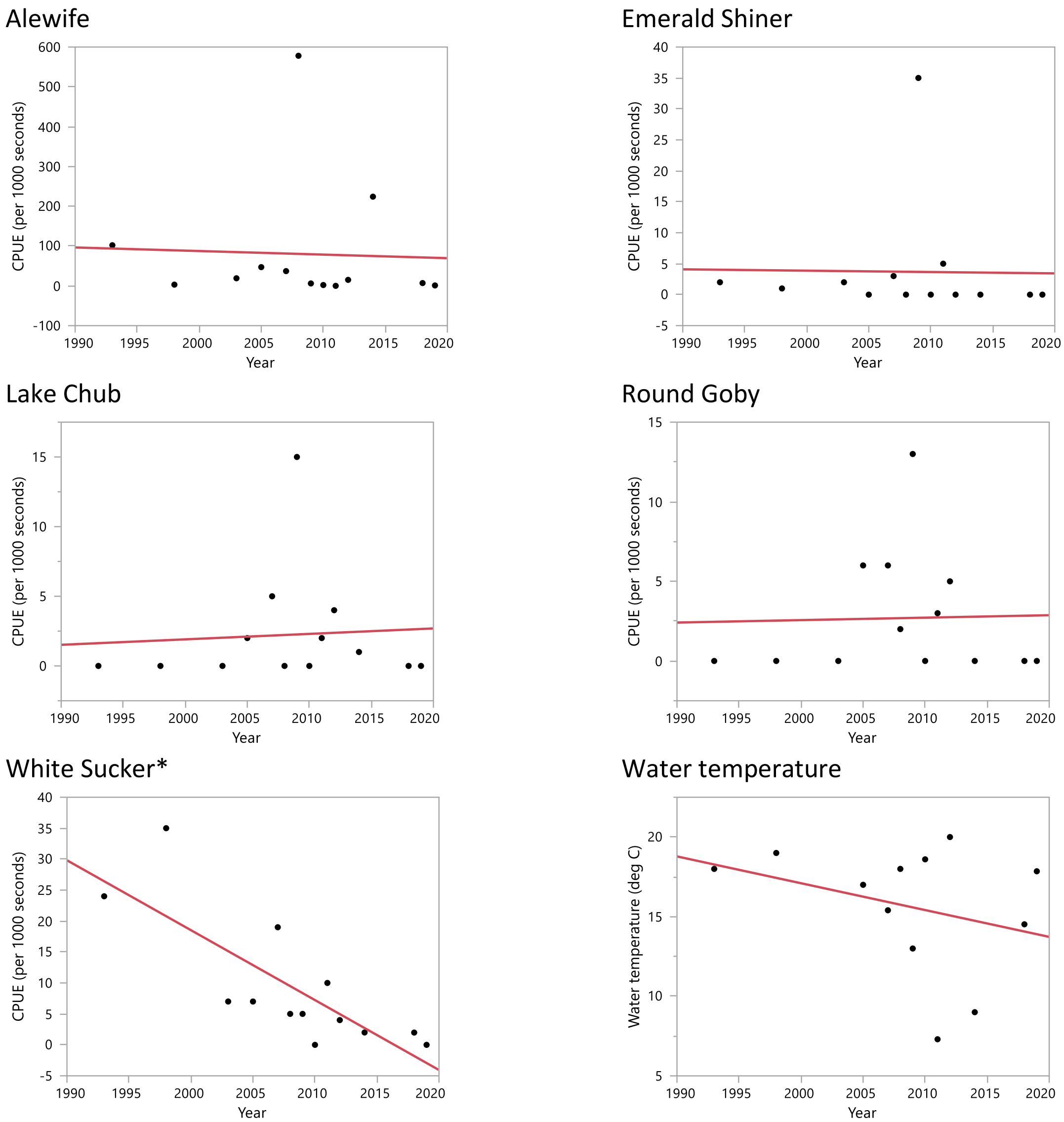


Figure 3.2: Temporal trends in July CPUE between 1993 and 2019 and statistical results for selected fish species at Colonel Sam Smith Outer Breakwall (* indicates a significant trend p<0.001)

There were several noticeable differences in the fish communities sampled in October when comparing the historical and current time periods. There was a significant decrease in White Sucker CPUE between historical (25 individuals) and current (2 individuals) time periods ($\chi^2_1=4.58$, p=0.032). Brown Trout, Lake Trout, Rainbow Smelt were often caught in the historical time period but were absent in the current data. Round Goby was only found in the more recent time period and this occurrence relates specifically to its invasion timing in Lake Ontario. There was no change in average species richness between historical (5.5 species) and current (3 species) time periods ($t_5=1.41$, p=0.218). Insufficient water temperature data were collected during runs for statistical comparisons.

Table 3.4: Species and associated CPUE at Colonel Sam Smith Outer Breakwall comparing historical (1993, 1994, 1995, 1999) and current October night fishing data (2015, 2016, 2017). Water temperature during electrofishing is shown next to year.

Species (CPUE per 1000 seconds)						
1993 (8°C)	1994 (?)	1995 (?)	1999 (9°C)	2015 (?)	2016 (16°C)	2017 (5°C)
Brown Trout (1)	Brown Trout (1)	Alewife (42)	Lake Chub (4)	Alewife (1)	Brook Stickleback (1)	Lake Chub (21)
Lake Chub (1)	Lake Trout (16)	Brown Trout (3)	Lake Trout (3)		Gizzard Shad (2)	Round Goby (1)
Rainbow Smelt (1)	White Sucker (22)	Common Carp (7)	Mottled Sculpin (1)		Lake Chub (1)	White Sucker (5)
Spottail Shiner (1)		Emerald Shiner (84)	Pumpkinseed (1)		Round Goby (1)	
White Sucker (23)		Largemouth Bass (7)	White Sucker (9)		Smallmouth Bass (1)	
		Rainbow Smelt (3)				
		Rainbow Trout (3)				
		Shorthead Redhorse (13)				
		White Sucker (45)				

Summary of temporal changes at reference sites

Fish communities have changed at reference sites since the 1990s and CPUE changed significantly for several species. White Sucker, Rainbow Smelt and Alewife CPUE decreased and Round Goby CPUE increased temporally. There were also declines in species richness. These species were removed from the habitat restoration analysis along with American Eel and Lake Trout which have also decreased temporally (although American Eel abundance has increased recently, numbers remain low; MNRF 2019). Brown Trout and Emerald Shiner were considered for exclusion; however, support in our data and MNRF (2019) were not considered sufficient for removal. We also removed these species from the forage fish species list.

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