Stream Monitoring in the Tributaries of Lake Simcoe: Fish

Technical Progress Series in Stream Monitoring: Report No. 1

Lake Simcoe Region
conservation authority

1.0 SUMMARY

As part of the Lake Simcoe Region Conservation Authority (LSRCA) tributary monitoring program, fish assemblages have been monitored since 2002 and water temperature data has been collected since 2003. The purpose of this monitoring program is to track the health of fish populations in the streams of the Lake Simcoe watershed and to assess spatial and temporal trends. According to the Index of Biotic Integrity (IBI) (Steedman 1988), the overall health of the fish populations in the Lake Simcoe basin is rated "good" with 58 species of fish captured (Appendix 1), slight declines in IBI scores and small reductions in the abundance and biomass of top level predators. Brook trout (*Salvelinus fontinalis*) are a keystone species in the Lake Simcoe watershed and can be used as a surrogate for the health of cold and cool water tributaries. Brook trout are restricted to streams with adequate cold water habitat, most of which originate in the Oak Ridges and Oro moraines. The health of warm water tributaries can be assessed by utilizing the IBI scores and the populations of sunfish species (Centrarchidae). Sunfish species are usually found in the lower sections of the streams where the water is warmer and the streams are larger.

A major contributing factor to the health of fish populations is summer water temperature. Water temperatures at warm and cool water sites are correlated to air temperatures while water temperatures at cold water sites are not as correlated to air temperature. The mean annual water temperatures at cool and warm water sites follow the same yearly fluctuations in mean air temperature closely. The mean annual water temperatures at cold water sites do not fluctuate with mean air temperature as much because they are buffered by groundwater inputs. There was a warming trend starting to emerge for mean water temperatures across all thermal regimes in the Lake Simcoe watershed over the eleven year study period. This was similar to warming trend in air temperatures in the Lake Simcoe watershed and across the globe.

Round goby (*Neogobius melanostomus*), an invasive species spreading throughout the Great Lakes Region, was first identified in the Lake Simcoe watershed in 2004 at the Pefferlaw River, and has since spread throughout Lake Simcoe and into the mouths of many tributaries. The presence of dams and lack of suitable habitat have prevented them from moving further upstream. Initial results suggest that round gobies are having a negative effect on the warm water fish communities in the lower reaches of many streams flowing into the lake. Continued monitoring is needed to document the effect this invasive species is having on native fish populations.

Generally, the tributary fish community in the Lake Simcoe Watershed can be considered healthy, but there is a trend towards declining biomass and abundance of top level predator populations. The IBI scores are declining only slightly as are the populations of brook trout and sunfish. Water temperatures are increasing slightly within the watershed. While the period of record is still too short to generate trends that are statistically significant, the changes that were observed have important implications that should be considered and incorporated into management and restoration strategies.

Building resilience to the pressures of increasing air temperatures, increasing urban development, and invasive species is imperative to protect cold water habitats and enhance cool and warm water habitats of the Lake Simcoe Watershed. Implementing stewardship opportunities is a key factor in building resilience into aquatic habitats.

1.1 RECOMMENDATIONS:

In order to monitor for changes in the tributaries of Lake Simcoe, a continued annual survey of the tributary fish community is recommended. These data will provide critical information on the changes to the tributaries' ecological status and water quality within the Lake Simcoe watershed. This data, along with the best management practices data, should be used to target areas in the watershed for stewardship works.

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2.0 INTRODUCTION

It is widely understood that biodiversity or biotic integrity is a measure of ecosystem health (Karr 1981). An aquatic ecosystem with good biotic integrity is typically a stream that is also in a good condition with few stressors impacting it. Alternatively if the biotic integrity is poor it is likely a result of stressors such as habitat fragmentation, flow alterations, habitat degradation or chemical influences that are affecting the biota. Alterations to the natural landscape originating from urban or agricultural land use changes are the stressors that often change the flow, habitat and chemistry of the watercourses. The fish community is one of the aquatic communities that are monitored for biotic integrity in the Lake Simcoe watershed. These communities within the tributaries of Lake Simcoe represent a variety of trophic levels (omnivores, herbivores, insectivores, planktivores and piscivores) and they are at or near the top of the aquatic food web. Top level predators in an aquatic ecosystem are sensitive to changes in habitat and environmental conditions. As these populations are relatively easy to monitor and are impacted by stresses such as habitat degradation and poor water quality, they can therefore be used to assess the environmental condition or “health” of the streams they inhabit.

2.1 Objectives of study

Since 2002, the Lake Simcoe Region Conservation Authority (LSRCA) has been monitoring tributary fish populations, their habitat and water temperature to assess the health of the aquatic ecosystem of Lake Simcoe watershed. In 2002 the main objective was to monitor the health at the outlets of each of the subwatersheds to assess impacts to the lake. In 2010, a reassessment of the routine monitoring program identified a data gap in the network and sites in the mid reaches and headwaters were added to the annual sampling regime. There are now 51 sites across the watershed to monitor the health of the tributary fish populations and assess the effects of stressors such as urban development and climate change. Fish population dynamics and water temperature have been monitored at all these sites. For this report, the sites have been categorized by thermal regime (cold, cool and warm water) and fish assemblage has been assessed at each of these categories.

2.2 Index of Biotic Integrity

One indicator of biodiversity is the Index of Biotic Integrity (IBI) for fish, developed in 1981 to assess small- to moderate-sized warm-water rivers in the United States (Karr 1981). This method was modified in 1988 for use in southern Ontario streams and used ten measures of fish community composition (Figure 1) to calculate an IBI score from nine (poor status) to 50 (very good) (Steedman, 1988). This index encompasses four general categories of community health: species richness, local indicator species, trophic composition, and fish abundance (Figure 1). Further modifications to the IBI were adapted in 2005 to include both warm and cold water fisheries for Lake Ontario tributaries in Ontario (OMNR, 2005). These modifications include the removal of the presence/absence of blackspot disease and the addition of a warm water category where cold water species such as brook trout would not be expected.

Species Richness:

- Number of native species
- Number of darter and/or sculpin species
- Number of sunfish and/or trout species
- Number of sucker and/or catfish species

Local Indicator Species:

- Presence or absence of brook trout (cold water stations only)
- Percent of sample as dace species

Trophic Composition:

- Percent of sample as omnivorous species
- Percent of sample as piscivorous species

Fish Abundance:

- Number of fish captured per minute of sampling

Figure 1: The nine measures of fish population health that form the Index of Biotic Integrity (IBI) as used for habitats in southern Ontario (OMNR 2005)

The modified IBI scores range from a low of nine (poor) to a high of 50 (very good), with four ranges to assess the quality of the fish population: poor, fair, good, and very good (Table 1).

Table 1: Modified Ontario Index of Biotic Integrity Scores for Fish Assemblage Health

IBI Score	Health of Fish Community
9 - 20	Poor
21 - 27	Fair
28 - 37	Good
38 -50	Very Good

This index is applicable in the Central Ontario region as we are in the same ecoregion (mixedwood plains) and have similar land uses (urban and agriculture) and topography (moraine headwater/lake basin) to the Lake Ontario tributary study.

2.3 Populations of Top Level Predators

One prominent indicator of a “healthy” stream is the presence of top level predator (piscivore) fish species. Having piscivores in the fish population is an indicator of good health as there is evidence of different trophic levels within the population. Brook trout (*Salvelinus fontinalis*) is the keystone species for the cold and cool water tributaries of Lake Simcoe. Sunfish (Centrarchidae) species including rock bass (*Ambloplites rupestris*), green sunfish (*Lepomis cyanellus*), pumpkinseed (*Lepomis gibbosus*), bluegill (*Lepomis macrochirus*), smallmouth bass (*Micropterus dolomieu*), largemouth bass (*Micropterus salmoides*) and black crappie (*Pomoxis nigromaculatus*) are indicators of the health of the warm water tributaries. Both of these species groupings are used in the IBI calculation to determine the health of the fish population at any given site. The majority of the brook trout populations inhabit cold, clear upland (Oak Ridges and Oro moraines) streams. Additional key habitat features include adequate refugia (e.g. log jams, deep pools and undercut banks) to provide shelter, food and suitable areas for reproduction. Historically, brook trout have had substantial populations in the head waters of Lake Simcoe tributaries with the lower sections being too warm and turbid (MacCrimmon and Skobe, 1970). It is in these lower sections that many species of sunfish are typically found. Different species of the sunfish family are known historically to inhabit Lake Simcoe and utilize the many tributaries for spawning and nursery habitat (MacCrimmon and Skobe 1970). It was noted that several streams between Barrie and Orillia, fed by streams originating in the Oro Moraine, supported self-sustaining populations of brook trout as recently as 1970 (MacCrimmon and Skobe, 1970). Bluff’s Creek in Oro-Medonte still has a stable population but there is only a small population in the headwaters of Hawkestone Creek. This is likely due to the presence of a number of dams and the lack of cold water habitat in the lower sections of Hawkestone Creek but further study is required to fully understand this system.

Calculating fish biomass and density over time is a well-known method of tracking trends in population (Waters 1999). The biomass and density have been calculated for all of the long-term monitoring sites in the watershed where brook trout and sunfish have been captured. Most of the brook trout are captured at cold water sites; however, there are also many cool water sites where these cold water fish are regularly captured.

2.4 Water Temperature

Water temperature is an important driver of fish populations. Healthy fish habitats need relatively stable water temperatures as well as clean, well-oxygenated water with available food. Temperature is one of the easier variables to measure and can determine what species of fish can inhabit certain watercourses. Brook trout seek temperatures below 20º C and require colder water (below 11.7º C) for reproduction (Scott and Crossman 1998). Streams that don't regularly exceed 20^{o}C are thermally stable as they are less affected by the air temperature and are considered cold water streams. The continual cold water inputs from ground water sources such as springs and seeps moderate the changes in water temperature. Moderately stable streams are termed cool water and are moderately affected by fluctuations in air temperature. Typical cool water species include rainbow darter (*Etheostoma caeruleum*) and pearl dace (*Margariscus nachtriebi*) and would occasionally include brook trout. The water temperature in unstable streams fluctuates with air temperature and is considered warm water. Normally brook trout are not captured in these systems but species such as fathead minnow (*Pimephales promelas*), largemouth bass, pumpkinseed and other members of the sunfish family are common. Water temperature has been monitored in the Lake Simcoe Watershed since 2003 using loggers that record hourly temperatures throughout the ice free season (May – October). These water temperatures are compared to air temperature to assess the thermal stability of the streams and classify fish habitat type.

3.0 METHODS

3.1 Site Description

The Lake Simcoe watershed (surface area = 3,400 km²) is located in the mixedwood plains ecoregion of south-central Ontario and drains into Lake Simcoe (surface area = 722 km²) in its center. The watershed is divided into 18 subwatersheds (Figure 4) that cross 23 municipal boundaries. Each subwatershed is centered on a tributary that feeds into Lake Simcoe. This includes two regional municipalities (York Region and Durham Region), Simcoe County, and the cities of Barrie, Orillia, and Kawartha Lakes. The watershed supports a population of over 450,000 people.

The Lake Simcoe watershed contains a number of significant natural features, including the Oak Ridges Moraine, Oro Moraine, and numerous woodland and wetland areas; as well as significant agricultural areas such as the Holland Marsh and other polders.

The Lake Simcoe watershed has been under environmental pressure since the arrival of European settlers in the early 1800s, although the most visible impacts have been observed in the second half of the 20th Century. The initial environmental changes included the removal of natural features to accommodate agriculture and the damming of watercourses in order to power saw and grist mills. The land use changes have continued and now, 200 years later, a significant proportion of the watershed has been changed from its natural state. With these have come numerous stressors including water quality degradation, particularly from the nutrient phosphorus, habitat loss and fragmentation, the introduction of invasive species, and climate change.

3.2 Site Selection

Two methodologies have been used for selecting sampling sites. The majority of the yearly effort is focused on sites for the routine monitoring network. The 14 subwatersheds that have routine monitoring sites are: Barrie Creeks (Hotchkiss Creek), Oro Creeks (Includes (Hawkestone Creek & Oro Creeks North), Ramara Creeks, Talbot River, Whites Creek, Beaver River, Pefferlaw River (includes Uxbridge Brook), Black River, Maskinonge River, East Holland River, West Holland River, Innisfil Creeks (includes Leonard's Creek and Sandy Cove Creek), Hewitt's Creek and Lover's Creek. A total of 51 routine monitoring sites have been selected to represent the subwatersheds of the Lake Simcoe watershed (Table 2). An attempt has been made to characterize each subwatershed by selecting headwater, mid-reach and outlet sampling sites for each tributary draining into Lake Simcoe. Some subwatersheds are under-represented in sampling effort due to the ephemeral nature of their streams. For example, many of the watercourses in the Ramara Creeks subwatershed dry up each summer due to the lack of ground water inputs, making it difficult to complete electrofishing surveys during the summer months.

Table 2: Routine monitoring sites by subwatershed

Subwatershed	Number of Routine Monitoring Sites
Barrie Creeks	1
Beaver River	5
Black River	5
East Holland River	5
Hewitt's Creek	2
Innisfil Creeks	2
Lover's Creek	4
Maskinonge River	3
Oro Creeks	3
Pefferlaw River	9
Ramara Creeks	1
Talbot River	1
West Holland River	9
White's Creek	1
Total	51

The second methodology involves a smaller subset of sampling sites randomly selected for subwatershed characterization each year. These sites are selected randomly based on geology, slope, and stream order. Attempts are made to rotate through the subwatersheds of Lake Simcoe to characterize each of them on a 10 year cycle. These sites are sampled once and give a snapshot of the conditions across a subwatershed at one point in time. These sites have only been included in this report to assess the spatial trends and have not been used for the analysis of the routine monitoring sites.

3.3 Fish Collection Methodology

Fisheries population and assemblage data is collected in the tributaries of Lake Simcoe at 51 routine monitoring sites and 10-15 subwatershed planning sites each year in one or two specified subwatersheds. To reduce sampling bias the same sampling equipment has been used (backpack electrofishers), permanent site boundaries have been set, the same number of electrofishers and netters have been used at each site, the single pass method was employed at each site and the effort (seconds/m^2) has remained relatively similar from year to year. The stunned fish are collected in containers until the entire site has been electrofished. Once done the fish are sorted by species. Piscivores are weighed and measured individually and the insectivore, detritivores and herbivores are counted and bulk weighed. All fish are released after processing with the exception of invasive species. If a new invasive species is captured at a site it is dispatched humanely and kept for confirmation of identity. Site lengths were also standardized to include at least one full crossover sequence and be at least 40m in length. It was noted that effort (sec/m^2) varied from year to year (Figure 2) due to staff turnover. Even with consistent training for new staff it is challenging to get new staff to keep consistent effort from year to year. The biomass and density calculations have been normalized using effort to remove this bias from the samples.

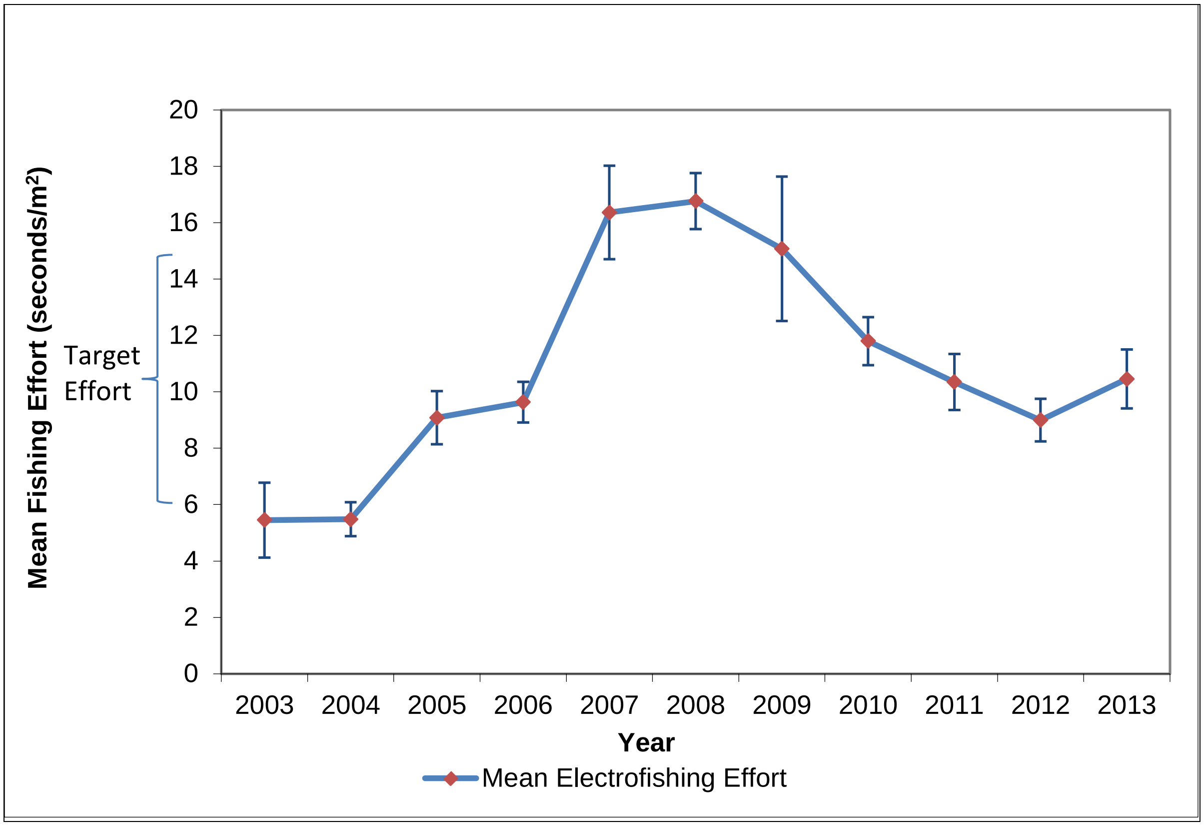

Figure 2: Yearly mean of electrofishing effort at Routine Sites across the Lake Simcoe watershed between 2003 and 2013

The power used for the electofisher(s) at each site was standardized to approximately 1000 watts. This varied slightly due to differences in conductivity at sampling sites and the limitations of the sampling gear (depending on the type of electrofisher that was used). The standardized methods mentioned above are only a small part of the full protocol that LSRCA has adopted. The full protocol is outlined in the Ministry of Natural Resource's Ontario Stream Assessment Protocol (Stanfield 2013).

3.4 Temperature Methodology

Each year between 2003 and 2013, Onset Hobo Tidbit and Pendant temperature loggers were deployed in Lake Simcoe watercourses for the period from May to October. From 2010 to 2014, 51 loggers have been deployed each year at routine sites, with another 10-15 deployed for localized subwatershed studies. Loggers are set to record temperature hourly throughout this timeframe.

3.5 Data Analysis Methodology

IBI

The Index of Biotic Integrity (IBI) is used to assess the health of the fish community at any given site in the watershed. Both individually weighed and measured fish data and bulk weighed fish data are extracted from the fish database and copied into and Excel spreadsheet that assesses the composition of the fish samples. This spreadsheet assesses four general categories of community health: species richness, local indicator species, trophic composition, and fish abundance. Species richness is divided into numbers of native species, numbers of darter and sculpin species, number of sunfish and trout species and number of sucker and catfish species. The local indicator species include presence or absence of brook trout (cold water stations only) and the percent of the sample as dace species. Trophic composition compares the percent of the sample with omnivorous species and piscivorous species. Each of these categories is given a weighted score and these scores get added up to give a score to assess the health of the fish population at a given sampling site. The scores range from 9 to 50 with 9 being the least healthy site and 50 being the healthiest.

Brook Trout and Sunfish Biomass

Biomass and density of brook trout and sunfish were used to compare trends in fish population between years and between sampling sites. Biomass is a measure of the weight (grams) of fish over an area (m^2) of stream and the density of fish is the number of fish in an area (m^2) of stream. The data was corrected for catch per unit effort (CPUE) to make it easier to compare the data between years and sites.

Temperature

To assess the thermal stability of sites the measured water temperatures are compared to air temperatures using the Stoneman and Jones methodology (Stoneman and Jones 1996). This method compares daily maximum water temperatures and daily maximum air temperatures on one day after 3 days of consecutively hot days (above 24.5ºC) that is collected in the months of July and August. The nomogram outlined in this methodology is used to assess if the water is thermally stable (cold), moderately stable (cool) or unstable (warm) (Stoneman and Jones1996).

The long-term trends of these temperatures have been assessed by tracking the daily maximum air and water temperatures for the months of July and August. For each site the mean daily maximum temperatures are calculated for these two months each year. This method of assessing water temperatures is the standard for southern Ontario and is employed by numerous other Conservation Authorities as well as Trout Unlimited Canada (D'Amelio 2010, CVC 2013).

4.0 Results and Discussion

4.1 Spatial Distribution

Fish were sampled at 470 tributary sites between 2002 and 2013 and water temperatures were recorded at 356 locations (Figure 3 & 4). The tributaries of Lake Simcoe are diverse with 58 fish species (Appendix 1) being captured in the watershed between 2002 and 2013.These sites have been sampled to enable each subwatershed to be characterized for Lake Simcoe Conservation Authority's subwatershed plans. There are some subwatersheds that still require a focused effort to fill data gaps (e.g. Talbot River). The plan is to sample these areas over the next few years with a focus on a specific subwatershed each year.

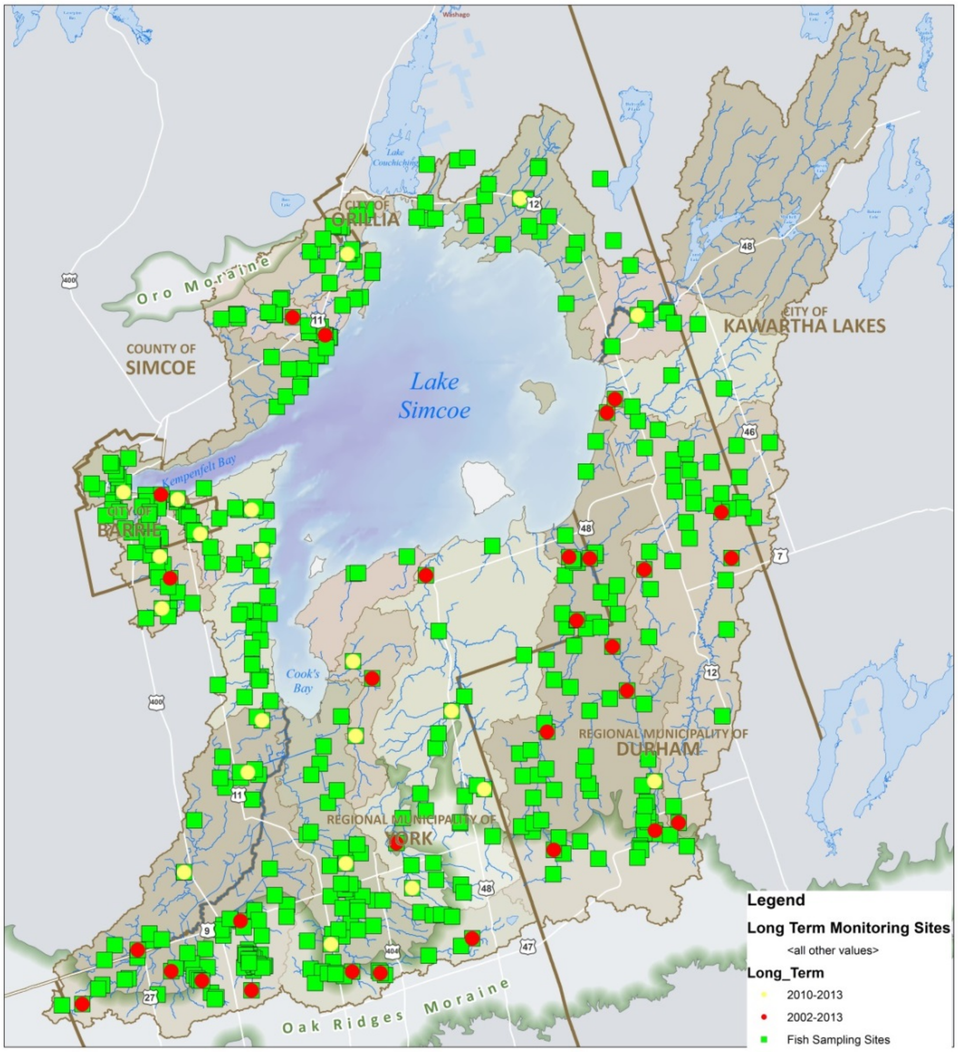

Figure 3: 470 Fish monitoring sites in the tributaries of the Lake Simcoe watershed sampled 2002-2013.

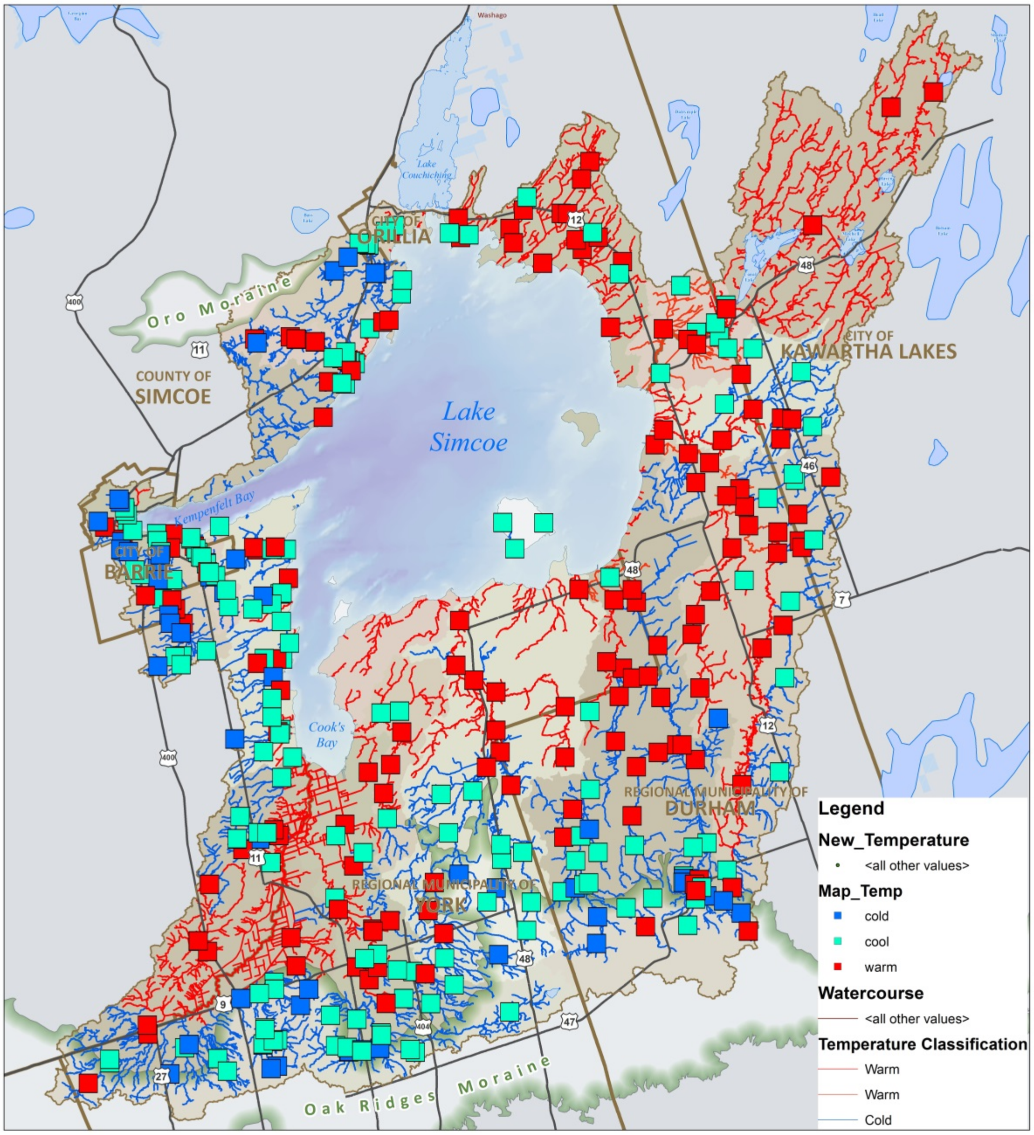

Figure 4: 356 Temperature monitoring sites in the Lake Simcoe watershed monitored 2003-2013

The Index of Biotic Integrity (IBI) scores were determined by the presence and absence of sensitive species, which included brook trout for cold water sites and sunfish species for warm water sites. High scores (better) are associated with high diversity, the capture of indicator species such as brook trout, suckers and sunfish species. Lower scores (worse) are associated with sites where the diversity is low and where these indicators are not captured.

The mean IBI scores map (Figure 5) show that there are clusters of the different scores. There are groupings of sites with a “good” score along the headwaters of the West Holland, Pefferlaw and Uxbridge subwatersheds. These sites lie on the

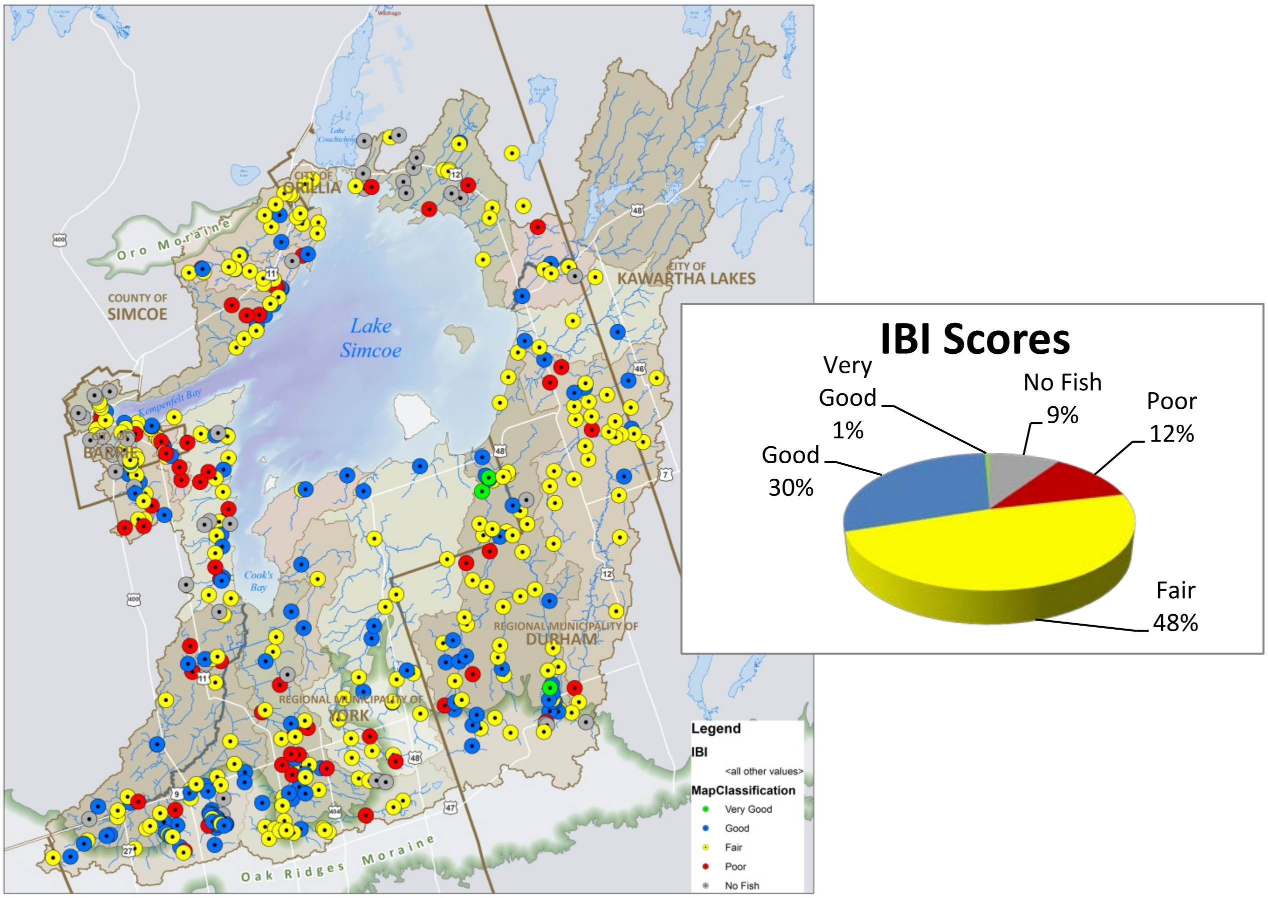

Figure 5: IBI Scores for fish sampling sites in the Lake Simcoe Watershed that were sampled between 2002 and 2013

Oak Ridges Moraine and their scores are primarily driven by the capture of brook trout. There is a high number of sites in the Barrie area with fish being absent from the samples, likely due to the highly urbanized subwatersheds with little or no storm water controls; periods of flashy, highly turbid flow; and little to no vegetation in the riparian buffer zones. Many of these urban streams have been straightened or piped underground which is also not conducive to healthy fish populations. Also of note is the proportion of the different IBI categories across the Lake Simcoe watershed (Figure 5); there are few “Very good sites” (38 +) with the majority of sites within the watershed being “Fair” (21 - 27).

Taking a closer look using the IBI scores from all of the sampling sites it can be noted that the health of the fish population is fairly good with 79% of our sites being categorized as Very Good, Good or Fair. Only 21% of the sites were rated Poor or didn’t have any fish captured.

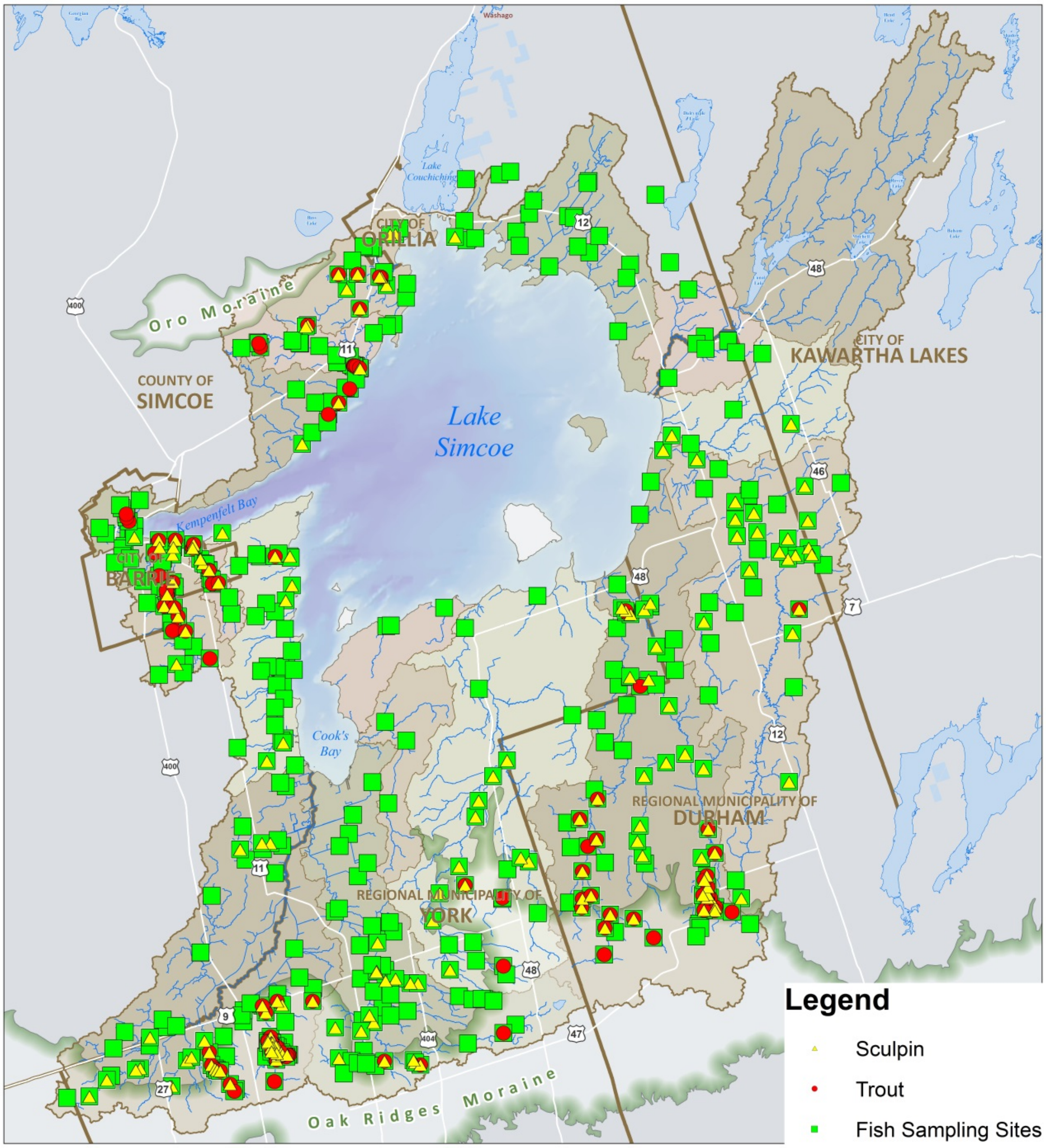

Figure 6: Sites with cold water fish captures in the Lake Simcoe watershed, 2002-2013.

Cold water tributaries are delineated on the map as blue lines (Figure 4). This data set was created using historic mapping from the Ministry of Natural Resources and current records where the LSRCA have collected brook trout and mottled sculpin (Figure 6) as well as using current water temperature monitoring data (Figure 4) from the LSRCA. Areas on or directly downstream of the Oak Ridges and Oro Moraines show the most significant populations of cold water fish (Figure 6). The other subwatersheds of note are the Lovers and Hewitts Creeks near Barrie.

4.2 Long Term Trends

The purpose of the routine sampling sites is to characterize each subwatershed showing trends in temperature and the health of the fish population over time. Sites have been selected to represent the headwaters, mid-reach, and outlet of each subwatershed to give an overview of the health of each system (Figure 7). There are a total of 51 routine monitoring sites within the Lake Simcoe watershed. The number of sites in each subwatershed varies due to catchment size and flow regime. Of these sites 30 were first sampled in 2002 or 2003, and in 2010 another 21 sites were added bringing the total of number of routine sites to 51.

Trends in the IBI scores, brook trout biomass, brook trout density, sunfish biomass, sunfish density and water temperatures have been analyzed for the 12 year period between 2002 and 2013. The data has been analyzed and is presented in four categories: watershed wide conditions (section 4.3.); cold water site conditions (section 4.4.); cool water site conditions (section 4.5.); and warm water site condition (section 4.6.). Cold water sites contain thermal habitat ideal for brook trout and the average daily summer maximum temperatures are approximately 14ºC. Cool water sites contain thermal habitat that is not ideal but tolerable for brook trout with average daily summer maximum temperatures of 18ºC. Warm water sites contain thermal habitat that could support brook trout for short periods of time but average daily summer maximum temperatures are too warm at 23ºC. The warm water sites may not provide tolerable temperatures for brook trout but the thermal regime is ideal for sunfish. The water temperatures of each site have been assessed using the Stoneman and Jones' nomogram to classify stream thermal stability (Stoneman and Jones 1996).The watershed wide conditions utilize all of the 51 routine sites while cold / cool / warm categories use subsets of the sites for each of the three thermal regimes.

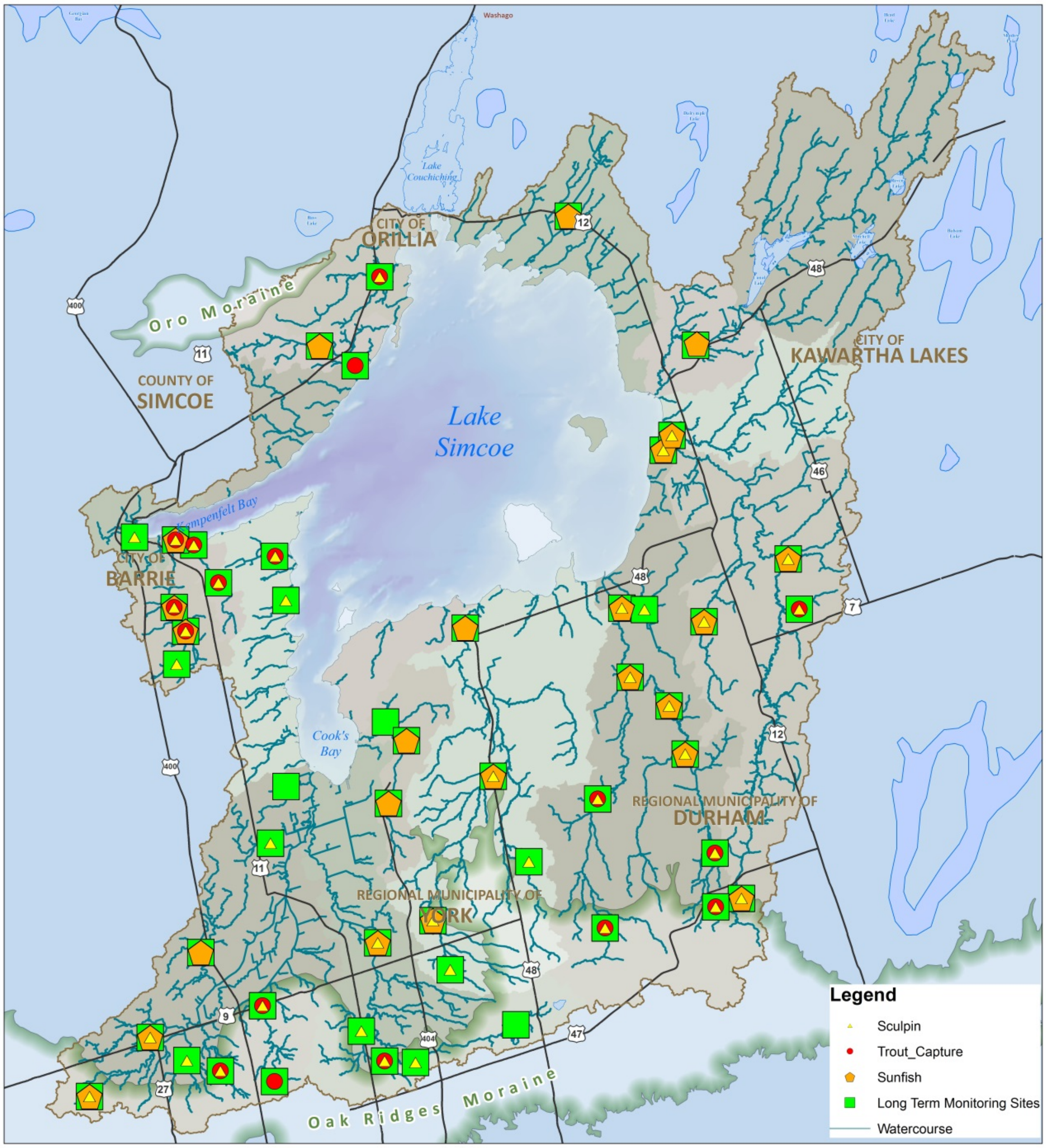

Figure 7: Routine monitoring sites for assessing long term trends in temperature and fish community health

4.3 Watershed Wide Conditions

4.3.1 Index of Biotic Integrity

The Index of Biotic Integrity (IBI) is a measure of the health of the fish community that assesses the species captured in a standard fish sample from one sampling site. The diversity of fish is one of the metrics used by the IBI. Within the tributaries of Lake Simcoe 58 species (Appendix 1) have been captured; of these, 45 are native to the watershed and 13 are naturalized non-native species. In comparison there are 128 native species in the lakes and rivers of Ontario and 17 naturalized species (MNR 2014). The Upper Thames River watershed has 90 species that have been captured (UTRCA 2014) and 80 species have been found in the Grand River Watershed (GRCA 1998). These comparators are large riverine systems flowing into the Great Lakes whereas the Lake Simcoe watershed is comprised of many smaller stream sized watersheds flowing into a smaller lake. The Lake Simcoe watershed is a unique watershed with a diverse fish population.

Thirty two of the 51 routine monitoring sites within the watershed have a period of record sufficient to support long term trends. Of these sites 38% (12 sites) are showing slight improvements with increasing IBI scores and 62% (20 sites) are showing slight declines with decreasing scores. Only one of these sites was showing a significant trend this being a decreasing score. Overall the IBI scores are fairly stable with only a slightly decreasing trend in the yearly mean of all of the routine sites between 2002 and 2013 (Figure 8) with an $R^2 = 0.06$. The mean IBI scores of the routine sites range from good to fair during the period of 2002 to 2013.

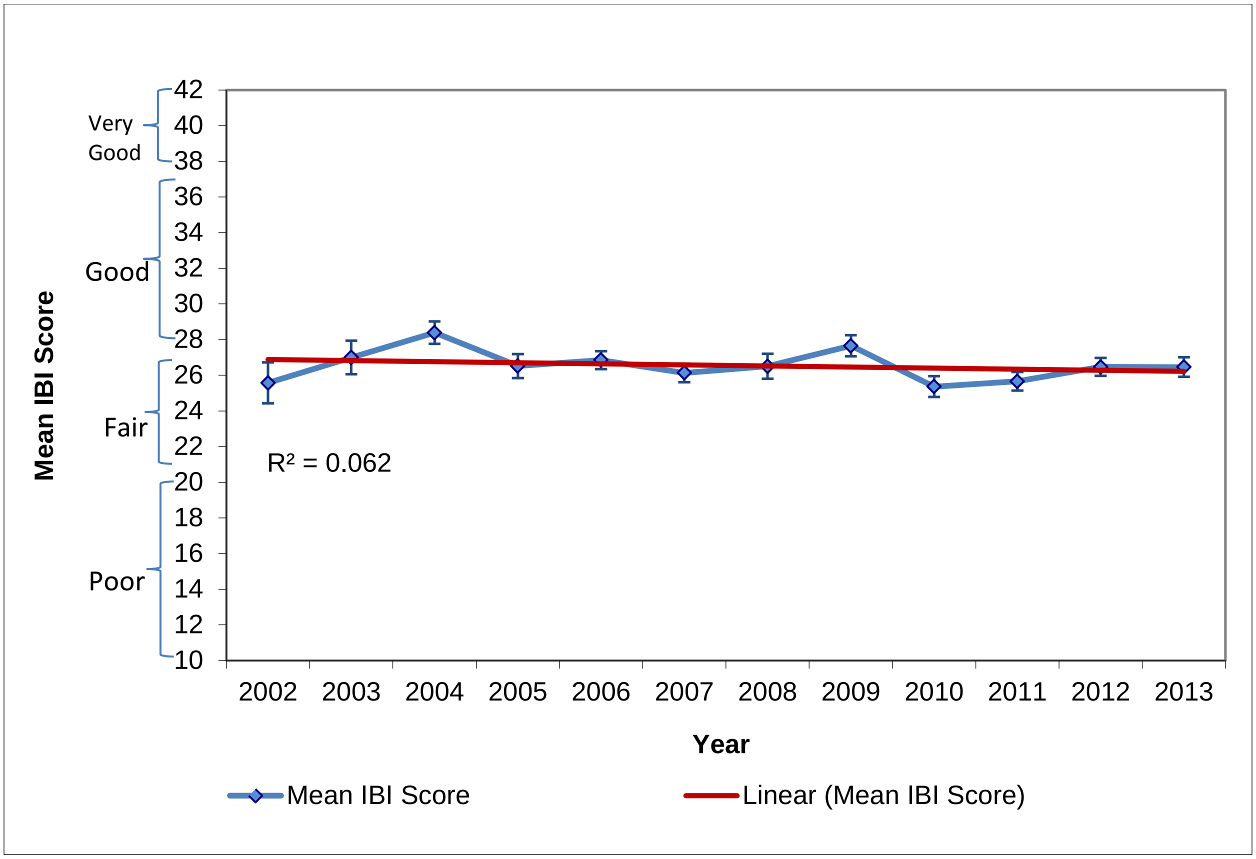

Figure 8: Mean IBI Scores for tributary fish communities from routine monitoring sites in the Lake Simcoe watershed (2002-2013) with Standard Error Bars

4.3.2 Top Level Predator Populations

Brook trout are a keystone species for the Lake Simcoe watershed and are indicative of where we have the most pristine cold water stream conditions. This species is only found on a regular basis where the streams are cold, clean, and have well vegetated buffers. Additionally, brook trout require cold water upwellings typical of moraine features (e.g. the Oak Ridges and Oro moraines) for a number of key life processes. Mottled sculpin, another species requiring cold water stream habitat, are also indicative of brook trout habitat (Scott & Crossman 1998). Brook trout populations are showing a decline in the Lake Simcoe watershed, a trend also being seen in many populations of Lake Ontario, including the Credit River Watershed (CVC 2013). Urbanization and loss of cold water habitats are the key contributors to the declines in populations. The brook trout populations monitored in the Lake Simcoe Watershed are showing a very small decline in both biomass (R^2 = 0.00) (Figure 9) and density (R^2 = 0.02) (Figure 10) over the 10-year period of record. The 2003 sampling year was omitted from the trend analysis as there were only seven sites sampled and the catch per unit effort (CPUE) was low. When the 2003 data was corrected for CPUE, this increased the biomass resulting in an increased trend. Despite Brook Trout not demonstrating a significant decline, the trend is negative and continue monitoring of these populations, especially with increases in urban development, is recommended.

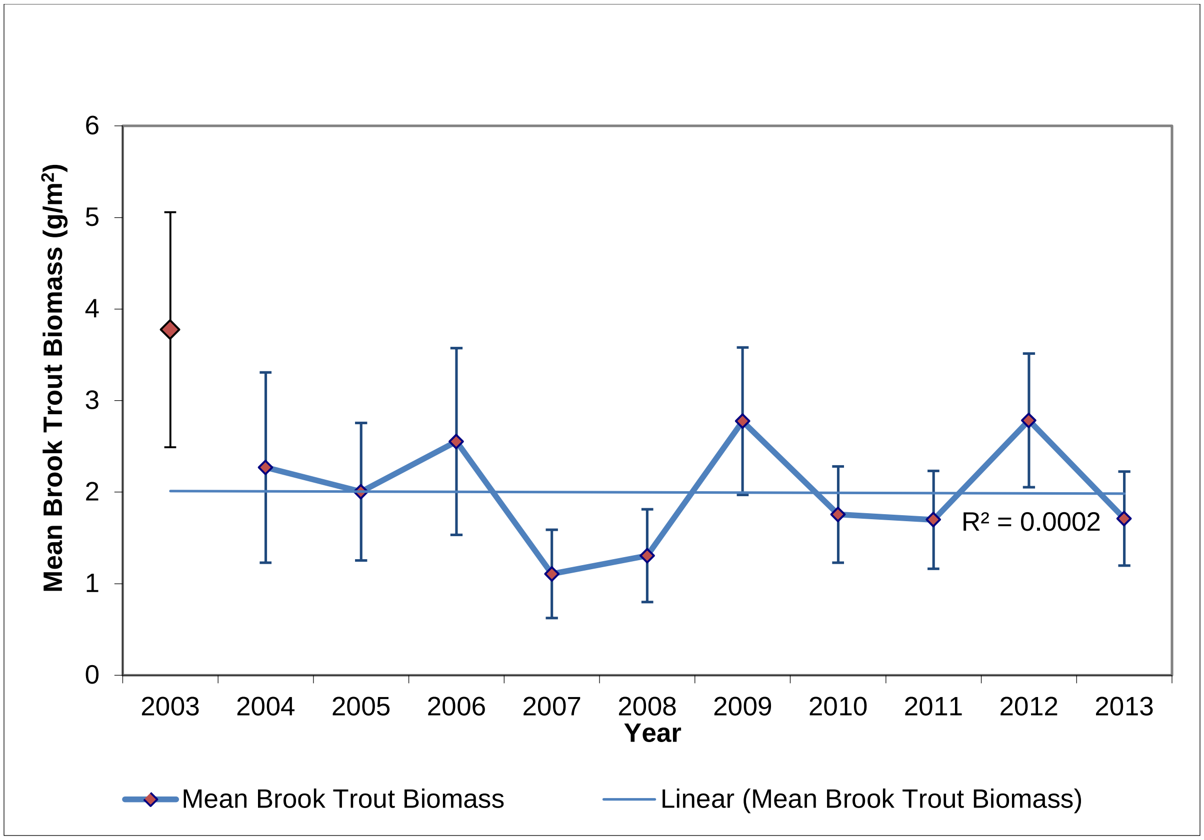

Figure 9: Mean brook trout biomass at 19 routine sites showing standard error for years 2003 to 2013 for the tributaries in the Lake Simcoe watershed

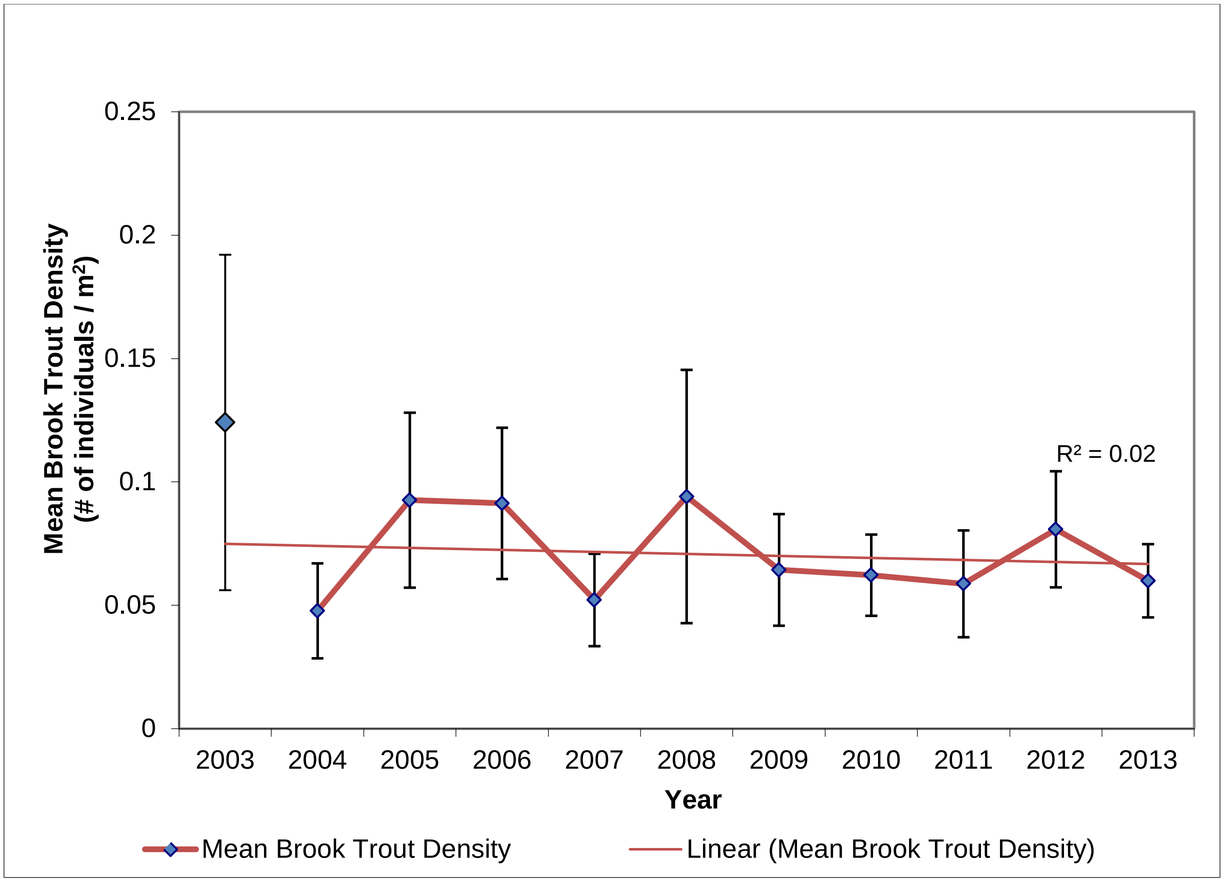

Figure 10: Mean brook trout density at 19 routine sites showing standard error between the years of 2003 and 2013 for tributaries in the Lake Simcoe watershed

Of the 14 subwatersheds, eight have records of brook trout from the LSRCA routine monitoring sites between 2002 and 2013: Oro Creeks, Beaver River, Pefferlaw River, East Holland River, West Holland River, Innisfil Creeks, Hewitt's Creek and Lover's Creek. Biomass has increased in two subwatersheds (Beaver River & Lover's Creek), has decreased in four subwatersheds, and two subwatersheds do not have a long enough period of record to determine trends (Table 3).

Of the 51 routine monitoring sites only 17 have records of brook trout capture. Of these six sites do not have enough data to analyze the long term trends (Table 3). Six sites are showing a trend of increasing biomass and five are showing a trend of declining biomass (Table 3).

Table 3: Trends in brook trout biomass across the watershed

Subwatershed	Trend of the Mean Biomass of sites in each Subwatershed	Number of Sites with Increasing Biomass	Number of Sites with Decreasing Biomass	Number of Sites with Insufficient Data	Total # With Brook Trout Capture	Total # routine monitoring sites
Beaver River	Increasing	1	0	0	1	5
East Holland River	Decreasing	0	1	0	1	4
Hewitt’s Creek	Not Enough Data	0	0	2	2	2
Innisfil Creeks	Not Enough Data	0	0	1	1	2
Lover’s Creek	Increasing	2	0	1	3	4
Oro Creeks	Decreasing	0	1	1	2	3
Pefferlaw River	Decreasing	1	2	1	4	9
West Holland River	Decreasing	2	1	0	3	8
Total of All Sites	Decreasing	6	5	6	17	33

Sunfish species are top level predators and environmental indicators for warm water tributaries of Lake Simcoe. This group of species indicate where there is good water quality, warm temperatures, sufficient habitat and adequate forage fish populations. The sunfish populations being monitored in the Lake Simcoe tributaries are showing a small decline in both biomass (R^2 = 0.08) (Figure 11) and density (R^2 = 0.32) (Figure 12) over the 10-year period of record. Note that the 2003 sampling year was omitted from the trend analysis as there were only five sites sampled and calculated CPUE was low. As with the cold water sites above, when the data was corrected for effort this increased the biomass and caused 2003 to be an outlier. Sunfish demonstrated a non-significant decline but are starting to show a downward trend in the populations. Continued monitoring these sites as declining water quality due to increasing urbanization may have an effect on this family of fish.

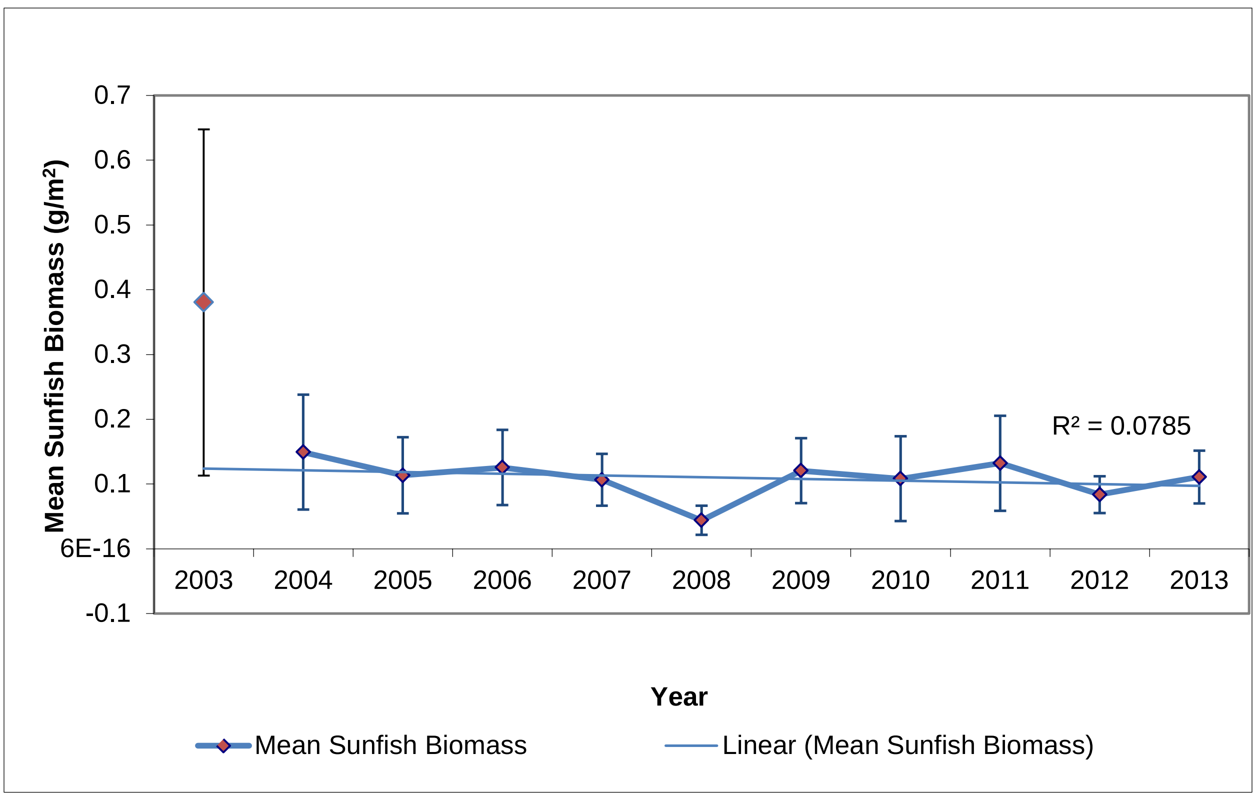

Figure 11: Mean Sunfish Biomass at 25 Routine Sites showing standard error between the years of 2003 and 2013 for tributaries in the Lake Simcoe watershed

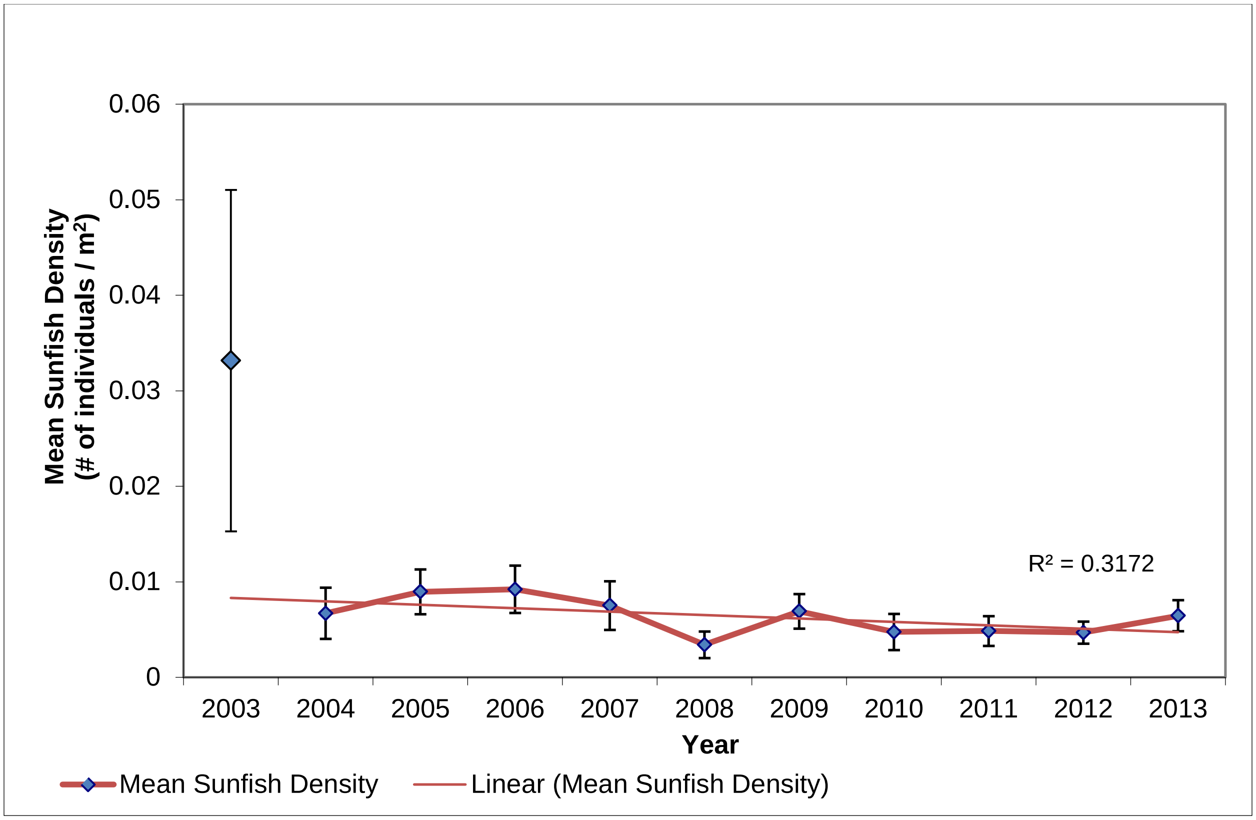

Figure 12: Mean Sunfish Density at 25 Routine Sites showing standard error between the years of 2003 and 2013 for tributaries in the Lake Simcoe watershed

Of the 14 subwatersheds, 11 have records of sunfish from the LSRCA routine monitoring sites between 2002 and 2013: Black River, Oro Creeks, Beaver River, Maskinonge River, Pefferlaw River, East Holland River, West Holland River, Ramara Creeks, Talbot River, Whites Creek and Lover's Creek. Biomass is increasing in two subwatersheds (Oro Creeks & West Holland River), is decreasing in seven subwatersheds, and three subwatersheds do not have a long enough period of record to determine trends (Table 4).

Of the 51 routine monitoring sites, 25 have records of sunfish capture. Although nine of these sites do not have enough data to analyze the long term trends (Table 4), seven sites are showing a trend of increasing biomass and nine are showing a trend of declining biomass (Table 4).

Table 4: Trends in sunfish biomass across the watershed

Subwatershed	Trend of the Mean Biomass of sites in each Subwatershed	Number of Sites with Increasing Biomass	Number of Sites with Decreasing Biomass	Number of Sites with Insufficient Data	Total # With Sunfish	Total # routine monitoring sites
Beaver River	Decreasing	1	2	1	4	5
Black River	Decreasing	1	1	1	3	5
East Holland River	Not Enough Data	0	0	1	1	4
Lover’s Creek	Decreasing	0	1	2	3	4
Maskinonge River	Decreasing	0	1	1	2	3
Oro Creeks	Increasing	1	0	0	1	3
Pefferlaw River	Decreasing	3	2	0	5	9
Ramara Creeks	Not Enough Data	0	0	1	1	1
Talbot River	Not Enough Data	0	0	1	1	1
West Holland River	Increasing	1	1	1	3	8
White’s Creek	Decreasing	0	1	0	1	1
Total of All Sites	Decreasing	7	9	9	25	44

4.3.3. Water Temperatures

The mean daily maximum water temperatures of all of cold water routine sampling sites in the tributaries of Lake Simcoe are not strongly correlated with air temperatures (r^2 = 0.00). This would be due to the combination of groundwater inputs and shading from natural vegetation. However, the warm water and cool water routine sites have mean daily water temperatures that are highly correlated to mean daily maximum air temperatures with r^2= 0.79 and r^2=0.85 respectively. A comparison of average daily maximum (May to October) air and water temperatures across all of our routine monitoring sites in the watershed showed a slight trend towards increasing temperatures over the 11 years they were collected (Figure 13). Linear regression indicated that this slight trend towards increases in air and water temperatures was very weak with an r^2 = 0.08 for air and an r^2 = 0.27 for water. This is a relatively short data set when assessing climate trends, however it does coincide with longer records from other areas and indicates a possible stressor that should be monitored. Climate change models use decadal averages rather than yearly averages with data spanning over 160 years (IPCC 2013). If the climate change models are correct and the air temperature continues to rise we will likely see a corresponding increase in water temperatures in the streams (Ficke et al 2005). This will put stress on the cool and cold water fish populations of Lake Simcoe tributaries. Urbanization and agricultural intensification can also increase the water temperatures by removing stream side trees and shrubs that shade the stream from the hot summer sun. Increased impervious land cover can also increase the temperature of runoff entering the stream during rain events. This can be mitigated by planning communities utilizing the practices of low impact development (LID) before areas are built out and best management practices in agriculture. LID retrofits, tree and shrub planting programs, and other stewardship initiatives can be implemented in areas across the watershed.

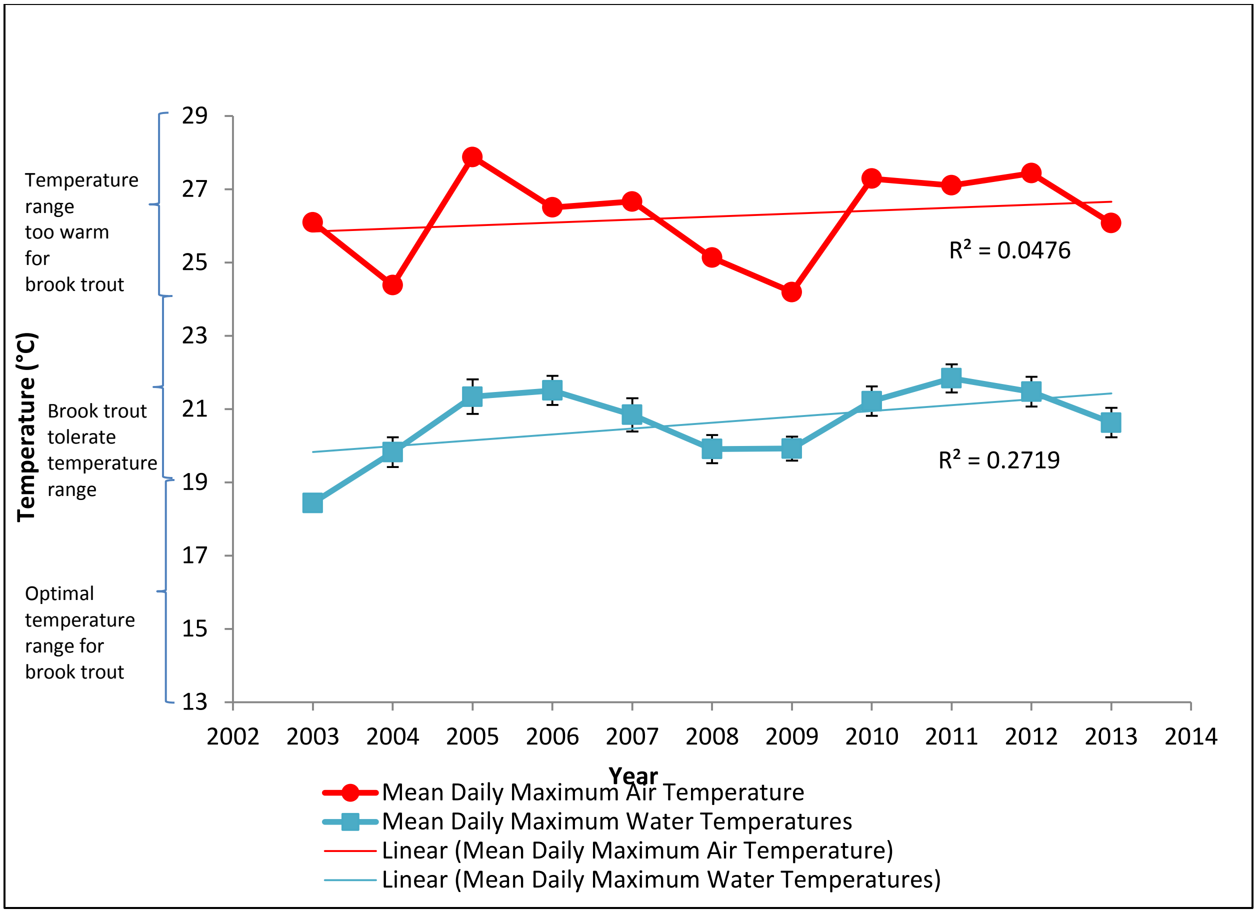

Figure 13: Mean summer air and water temperatures for all 51 routine sites across the watershed

Of the 14 subwatersheds studied, there were five that show a trend of increasing water temperature, four show decreasing trends with the remaining five subwatersheds not having a sufficient period of record for analysis (Table 5).

Of 51 sites in these subwatersheds, there are 32 sites with sufficient data and 19 with data sets too short for trend analysis. Of the 32 sites with sufficient data, 69% (22 sites) are showing slight increasing temperature trends and 31% (10 sites) are showing slight decreasing temperature trends. Only one site in the headwaters of the West Holland River subwatershed is showing a statistically significant (r^2=0.76) warming trend.

Table 5: Temperature Trends in the 14 Subwatersheds with the Lake Simcoe watershed

Subwatershed	Subwatershed Trend	Number of Sites with Increasing Daily Maximum Water Temperatures			Number of Sites with Decreasing Daily Max Water Temperature			Number of Sites with Insufficient Data			Total
		Warm	Cool	Cold	Warm	Cool	Cold	Warm	Cool	Cold	
Barrie Creeks	Insufficient Data	0	0	0	0	0	0	0	1	0	1
Beaver River	Increasing	4	1	0	0	0	0	0	0	0	5
Black River	Decreasing	1	0	0	1	0	0	1	2	0	5
East Holland River	Increasing	0	2	0	0	0	1	1	1	0	5
Hewitt's Creek	Insufficient Data	0	0	0	0	0	0	0	2	0	2
Innisfil Creeks	Insufficient Data	0	0	0	0	0	0	0	2	0	2
Lover's Creek	Decreasing	1	0	0	1	0	0	1	1	0	4
Maskinonge River	Increasing	1	0	0	0	0	0	1	1	0	3
Oro Creeks	Decreasing	1	1	0	0	0	0	0	0	1	3
Pefferlaw River	Decreasing	4	0	1	1	3	0	0	0	0	9
Ramara Creeks	Insufficient Data	0	0	0	0	0	0	1	0	0	1
Talbot River	Insufficient Data	0	0	0	0	0	0	1	0	0	1
West Holland River	Increasing	1	2	0	1	2	1	1	1	0	9
White's Creek	Increasing	1	0	0	0	0	0	0	0	0	1
Total of All Sites		14	6	1	4	5	2	7	11	1	51
		21			11			19			

Temperature trends were recorded between sites where brook trout were captured every year, where brook trout were captured occasionally, and where brook trout were not captured (Figure 14). As expected, the coldest sites with a mean daily maximum water temperature of 17°C were the 10 sites with yearly brook trout capture (Figure 14). The cool water sites with a mean daily maximum water temperature of 21°C were the seven sites where brook trout were captured occasionally. The warmest sites with a mean daily maximum water temperature of 22°C were the 34 sites where brook trout weren't captured. The sites where brook trout are never captured are the warmest and are close to the upper limits of "Brook trout Tolerate Temperature Range" (Figure 14). The sites where brook trout are caught intermittently are on average 1°C cooler than the sites were brook trout aren't captured. These intermittent sites are where brook trout can tolerate the warmer temperatures for short periods of time before moving on to colder sites

The cold sites where brook trout are captured yearly are on average 4°C colder than the sites with intermittent captures and 5ºC colder than sites not recording brook trout. These sites are colder due to the influence of cold water springs and seeps that contribute groundwater to the stream. Many of these cold water sites are along the Oak Ridges and Oro Moraines in the subwatersheds of West Holland, East Holland, Black River, Pefferlaw River, Beaver River and Oro Creeks. While there are a few other cold water sites in the Lake Simcoe watershed they are more localized and are not associated with any large geological formations such as the moraines. The Oak Ridge Moraine Conservation Plan is working to protect these sensitive areas from urbanization and other land uses that affect these cold water areas in the subwatershed on the southern end of the Lake Simcoe watershed.

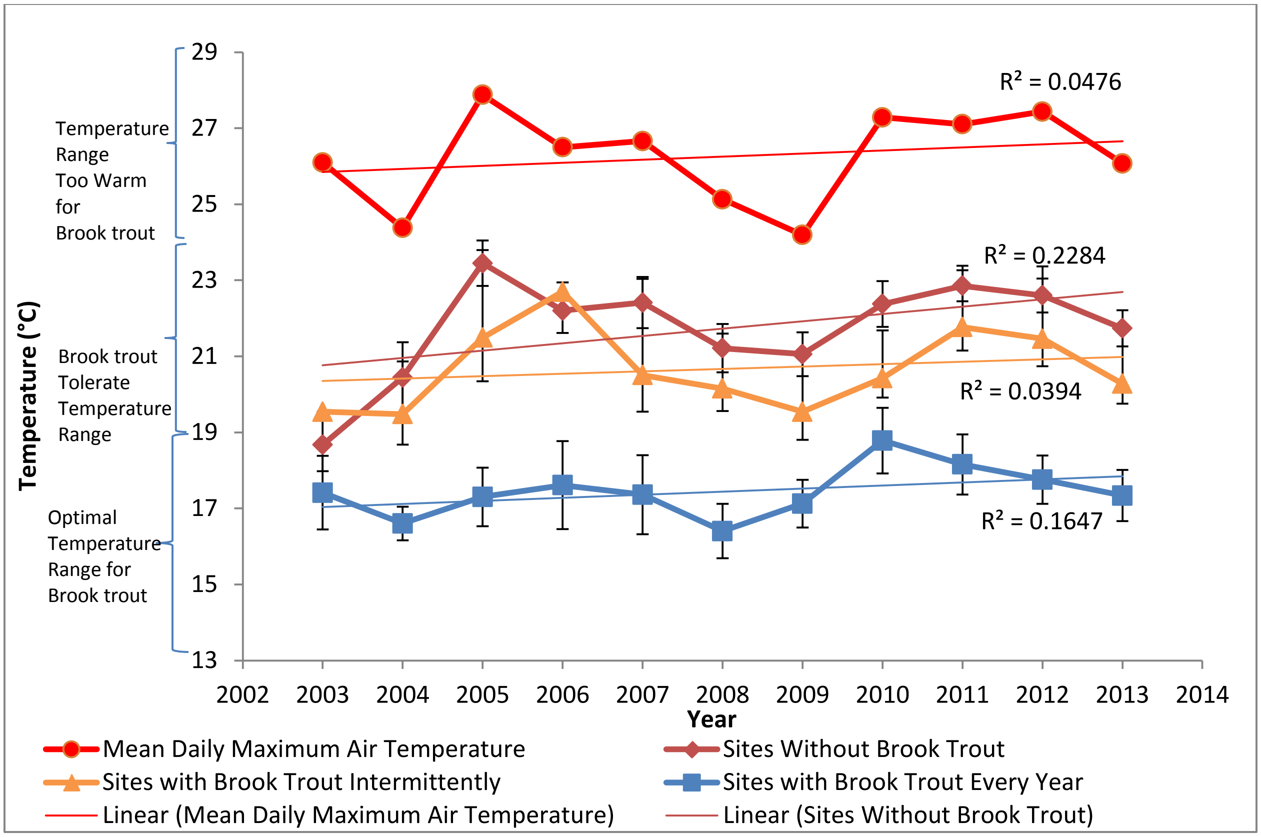

Figure 14: Trends (2003-2013) in air temperatures (red circles) and water temperatures at 51 sites in the Lake Simcoe Watershed with brook trout capture every year (blue squares), occasionally (orange triangles), or never (red diamonds)

4.4 Cold Water Site Conditions

Brook trout were captured at all four routine cold water monitoring sites every year. Out of the cold water subset, two sites are of note as one is in an urban area and one is in a more rural setting but they both have similar habitats and fish assemblages. The first site is East Holland River 09, a site in the East Holland River subwatershed in the Town of Aurora and the second site is Uxbridge Brook 103, a site in the Pefferlaw River subwatershed just upstream of the Town of Uxbridge (Figure 15). Both of these sites have similar sandy/muck substrates with good flow and healthy groundwater inputs. These sites have catchments that are within the Oak Ridges Moraine. Both sites have similar fish assemblages that are predominantly brook trout and mottled sculpin with low numbers of other species. The catchment for East Holland River 09 (4.5 km^2) is much smaller than Uxbridge Brook 103 (17.5 km^2). East Holland River 09 is in the middle of a highly developed area with both high density residential and industrial land uses within the upstream catchment area. The upstream catchment for Uxbridge Brook 103 is mostly natural forest and wetland with some low density residential development and agriculture in the headwaters. The site on the East Holland River has been sampled between 2003 and 2013. The Uxbridge Brook site was first sampled in 2005 and then between 2007 and 2013.

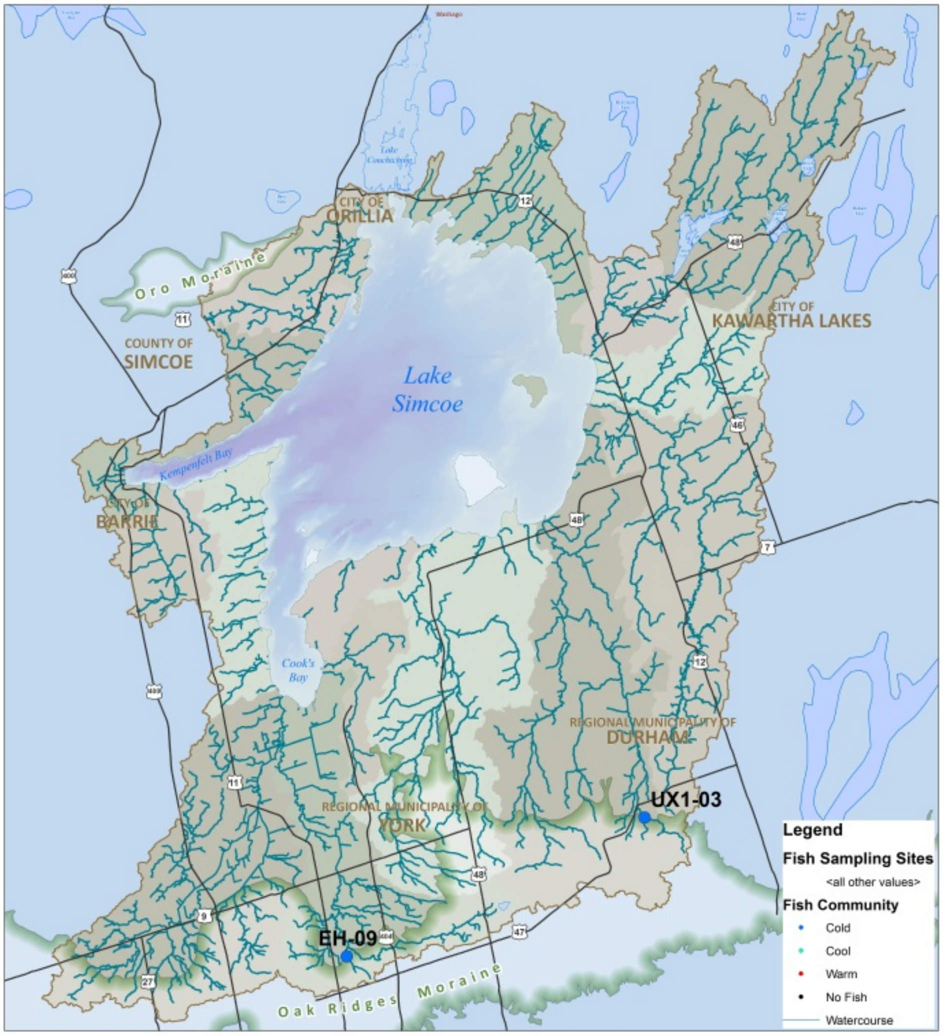

Figure 15: Comparison of two cold water sites in the Lake Simcoe Watershed East Holland River (EH-09) and Uxbridge Brook (UX1-03)

4.4.1. Index of Biotic Integrity

The trend of the mean IBI score for all four of the routine cold water sites is decreasing slightly with an $r^2 = 0.01$ (Figure 16). The mean of the cold water IBI scores is Good with a score of 28. The overall mean of the entire routine data set is Fair with a score of 27. This is not surprising as cold water species such as brook trout and mottled sculpin are scored highly in the IBI analysis when there is a good diversity of fish from other trophic levels. The IBI scores for the East Holland River site at Aurora are more stable and stay in the Good category with scores between of 29 (good) to 33 (good). The Uxbridge Brook site has more variability in IBI scores with scores between 23 (fair) and 31 (good). One year of note for site Uxbridge Brook 103 is 2007; the IBI score for this year is the lowest on record for both of these sites. Brook trout were captured at this site which increases the IBI score but the diversity was low with only three species of fish captured, which caused the low IBI score. The IBI scores are much better for site East Holland River 09 than the scores for site Uxbridge Brook 103 despite the more intensive land use around the Aurora site. East Holland River 09 has 44% of the upstream catchment having natural heritage features as its dominant land use, and Uxbridge Brook 103 has 53% natural heritage features as its primary land use. The protection afforded by the buffered area of forest and wetland between the stream and the development has kept the fish populations at the East Holland site healthy. There are ponds upstream and downstream of Uxbridge Brook 103 preventing fish from moving into and out of this stretch of stream so that fish cannot migrate to reproduce or utilize other habitats that are necessary during different life stages. This can reduce biodiversity and can have a negative effect on IBI scores.

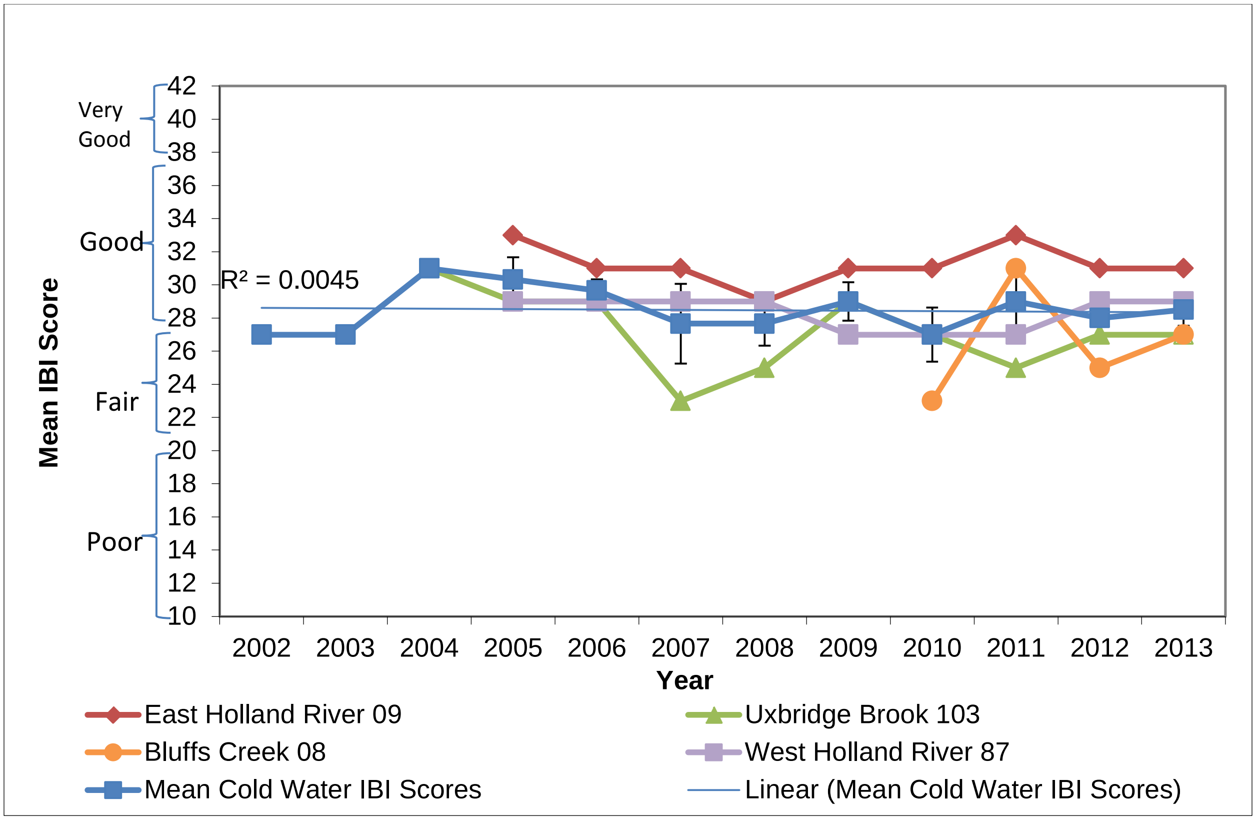

Figure 16: Mean IBI Scores for four cold water routine monitoring sites in watershed between 2002 and 2013

4.4.2. Brook Trout

The trend for the brook trout mean biomass at all four of the routine cold water sites is showing a decline with an $r^2 = 0.42$ (Figure 17), but the densities at these same sites are showing only slight declines with an $r^2 = 0.01$ (Figure 18).

When comparing sites Uxbridge Brook 103 and at East Holland River 09 the biomass and density of brook trout fluctuate from year to year but on average there are more brook trout at Uxbridge Brook 103 than at East Holland River 09 (Figures 17 and 18). The mean biomass of brook trout for all of the years of sampling for Uxbridge Brook 103 is 5.53 (g/m^2) and 4.72 (g/m^2) for East Holland River 09. The Uxbridge Brook site has the highest mean biomass of any of the routine monitoring sites. The mean density of brook trout for all the sampling years for Uxbridge Brook 103 is 0.25 (individuals/m^2) and 0.10 (individuals/m^2) for East Holland River 09. Again, the Uxbridge site shows the highest brook trout density of any of the routine monitoring sites.

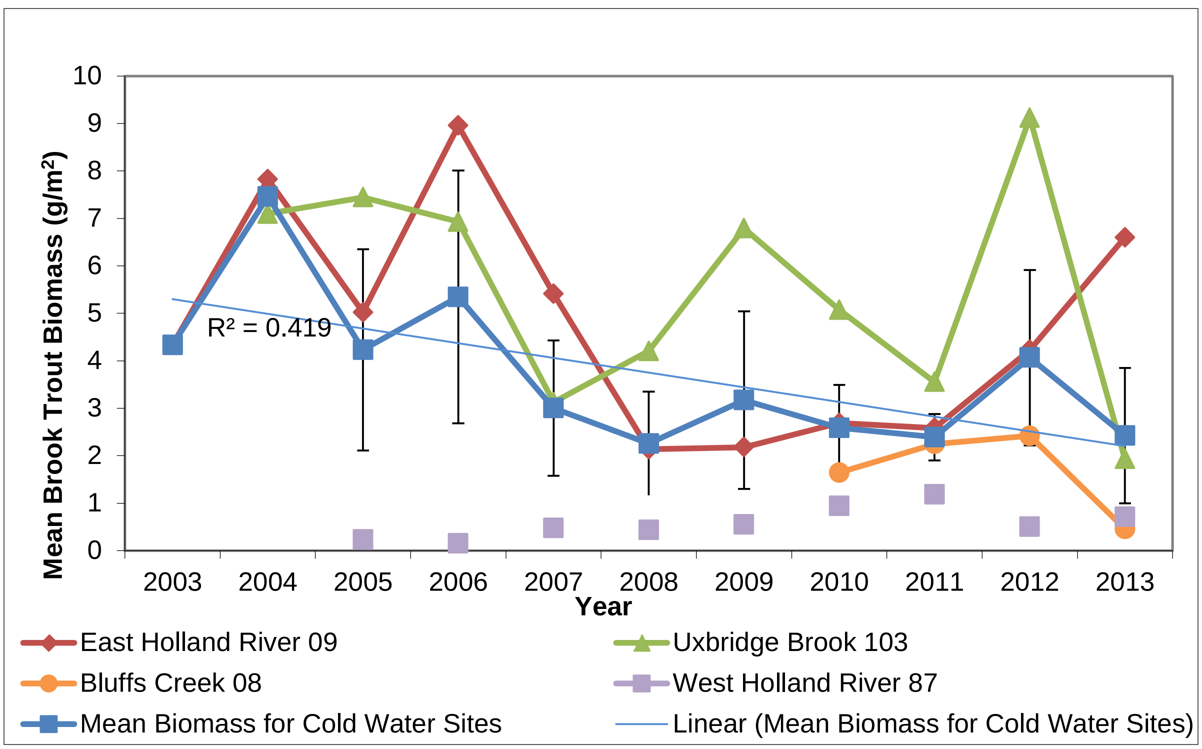

Figure 17: Mean brook trout biomass for four cold water routine monitoring sites in the Lake Simcoe watershed between 2003 and 2013

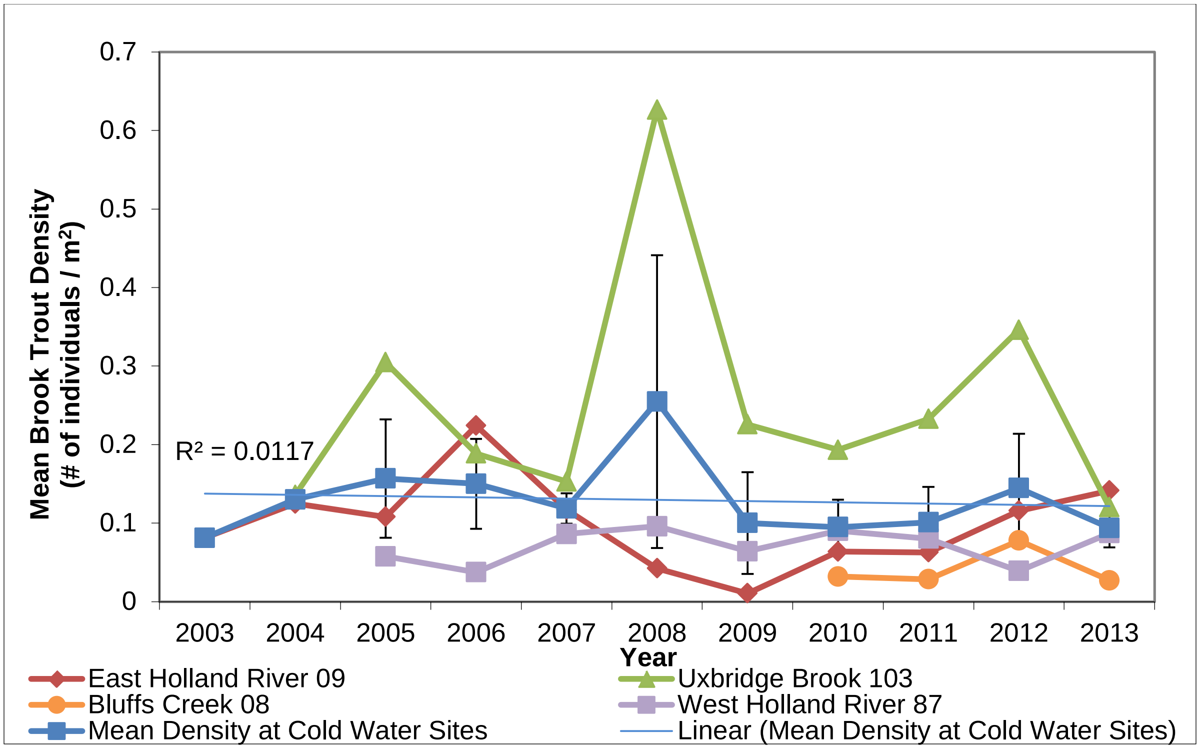

Figure 18: Mean brook trout density for four cold water routine monitoring sites in the Lake Simcoe watershed between 2003 and 2013

The cold water temperatures at these sites make them productive sites for brook trout. The cold water sites have higher mean density (0.13 g/m^2) and biomass (3.75 individuals/m^2) of brook trout than the rest of the routine monitoring sites with brook trout. Cold water is one of the key habitat factors habitat features for brook trout survival.

4.4.3. Temperature

At all four of the routine cold water sites there is a slight increasing trend in the mean water temperature with an $r^2 = 0.09$ (Figure 19). Both Uxbridge Brook 103 and East Holland River 09 have similar water temperatures with average daily maximums of 15.3 °C and 15.8 °C respectively. Both sites are only slightly colder than the mean temperature for all of the cold water sites (16.0°C). The water temperatures at these sites are fairly stable, which is evidence of cold groundwater entering into these systems (Figure 19).

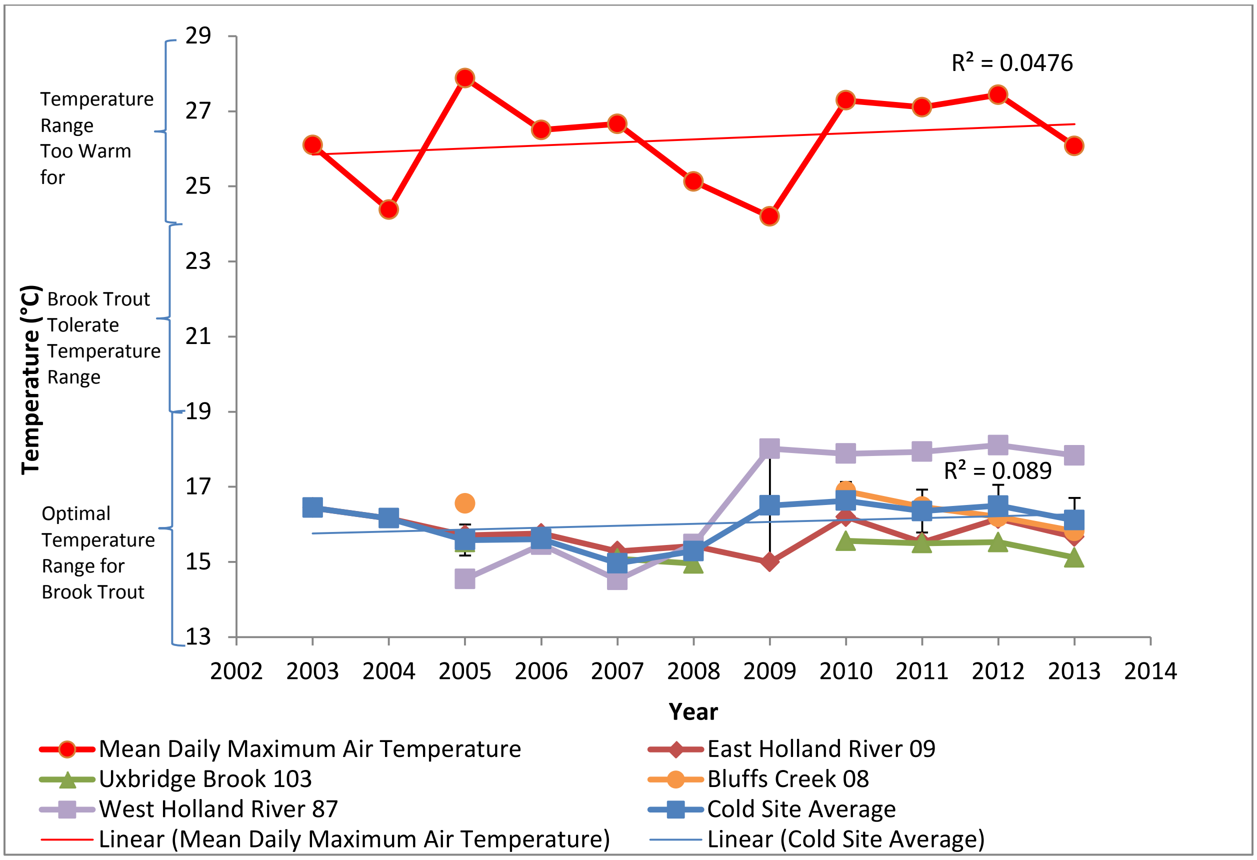

Figure 19: A comparison of mean daily maximum air and water temperatures of the four cold water routine monitoring sites in Lake Simcoe watershed between 2003 and 2013

These cold water areas are very sensitive and need to be protected and enhanced where possible. Stewardship initiatives to remove online ponds, plant vegetative buffers and treat storm water at a site level will help maintain cold water attributes.

4.5. Cool Water Site Conditions

Cool water streams can provide habitat for warm, cool and cold fish species. There are 23 cool water sites in our routine data set and of these we capture brook trout at eleven at least some of the time. Two cool water sites with similar catchment sizes and thermal regimes are Hawkestone Creek 122 in the Hawkestone Creek subwatershed and Pefferlaw River 104 in the Pefferlaw River Subwatershed (Figure 20). Hawkestone Creek 122 has a catchment of 40 km^2 and Pefferlaw River 104 has a catchment of 32 km^2 but these two sites have different thermal regimes, very different substrates and slightly different land uses. Both of these sites have upstream catchments that are dominated by natural heritage features as their primary land use with Hawkestone Creek 122 having 56% and Pefferlaw River 104 having 41%. The Hawkestone site is in the centre of the town of Hawkestone with direct influences from residential properties as well as having barriers to fish passage both upstream and downstream of the site. The substrate at the Hawkestone site is a mix of cobble, bolder, rubble and gravel. Hawkestone Creek 122 doesn’t have undercuts or log jams but does have many spaces between and under boulders for fish to hide The Pefferlaw site is just downstream of a golf course in the Village of Siloam. There was a barrier to fish passage that was bypassed in 2012. The dam removal has also changed the thermal regime from being a cool water site to a cold water site. In contrast the substrate at the Pefferlaw site is a mix of sand and muck. Pefferlaw River 104 has great habitat for brook trout with many undercut banks and log jams. A high brook trout biomass is found at Pefferlaw River 104 while low biomass is found at Hawkestone Creek 122 (young of year (YOY) brook trout are found at this site). This is reflected in the IBI scores. Sampling has occurred between the years of 2004 and 2013 at both the Pefferlaw River and the Hawkestone River sites.

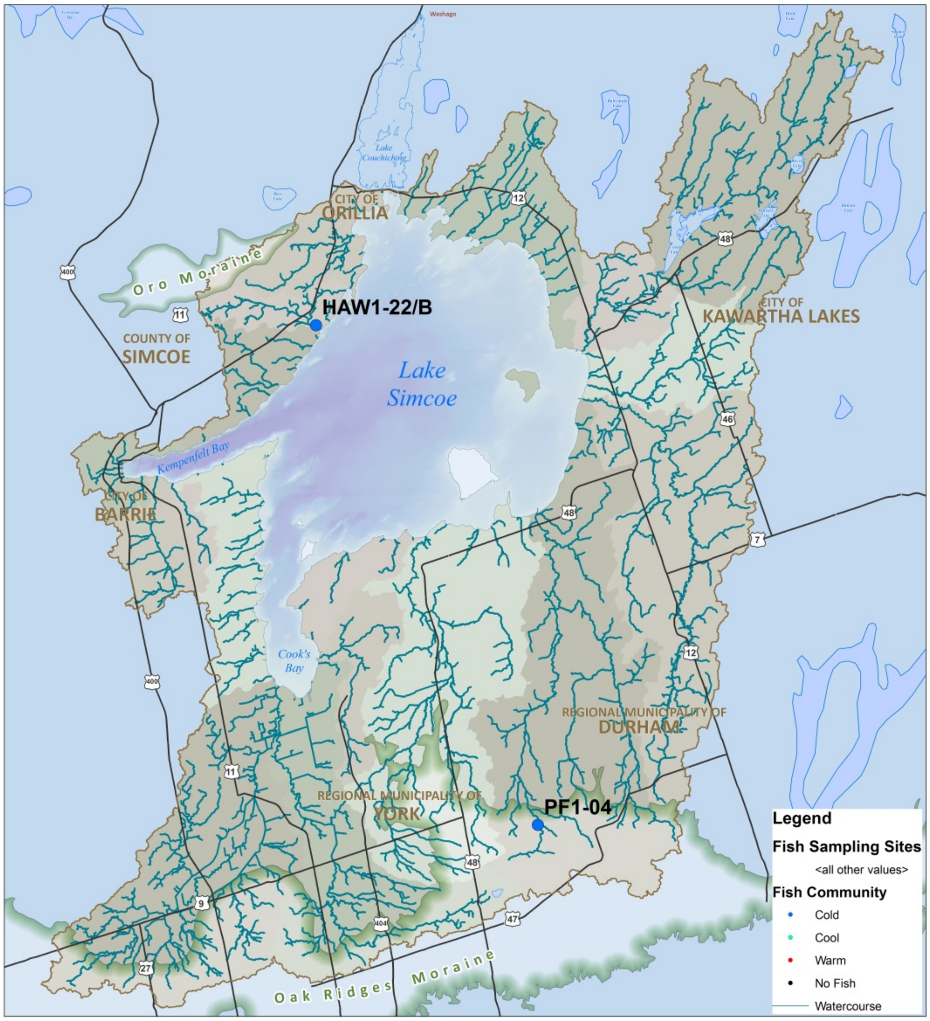

Figure 20: Comparison of two cool water sites in the Lake Simcoe Watershed Hawkestone Creek (HAW1-22) and Pefferlaw River (PF1-04)

4.5.1. Index of Biotic Integrity

For all ten of the routine cool water sites the mean IBI score is showing a slightly decreasing trend with an $r^2 = 0.003$ (Figure 21). The mean IBI score for the cool water sites is 26 (Fair) but annually the IBI fluctuates annually between being fair and good scores (Figure 21). This is very similar to the mean biotic scores for all of the routine monitoring sites of 27 (fair/good). Hawkestone Creek has lower IBI scores on average than Pefferlaw River (Figure 19) with Hawkestone Creek 122 fair (25) staying in the fair range the majority of the time and Pefferlaw River 104 good (28) staying in the good range the majority of the time. The higher IBI score for the Pefferlaw River site is due to brook trout being caught at this site every year.

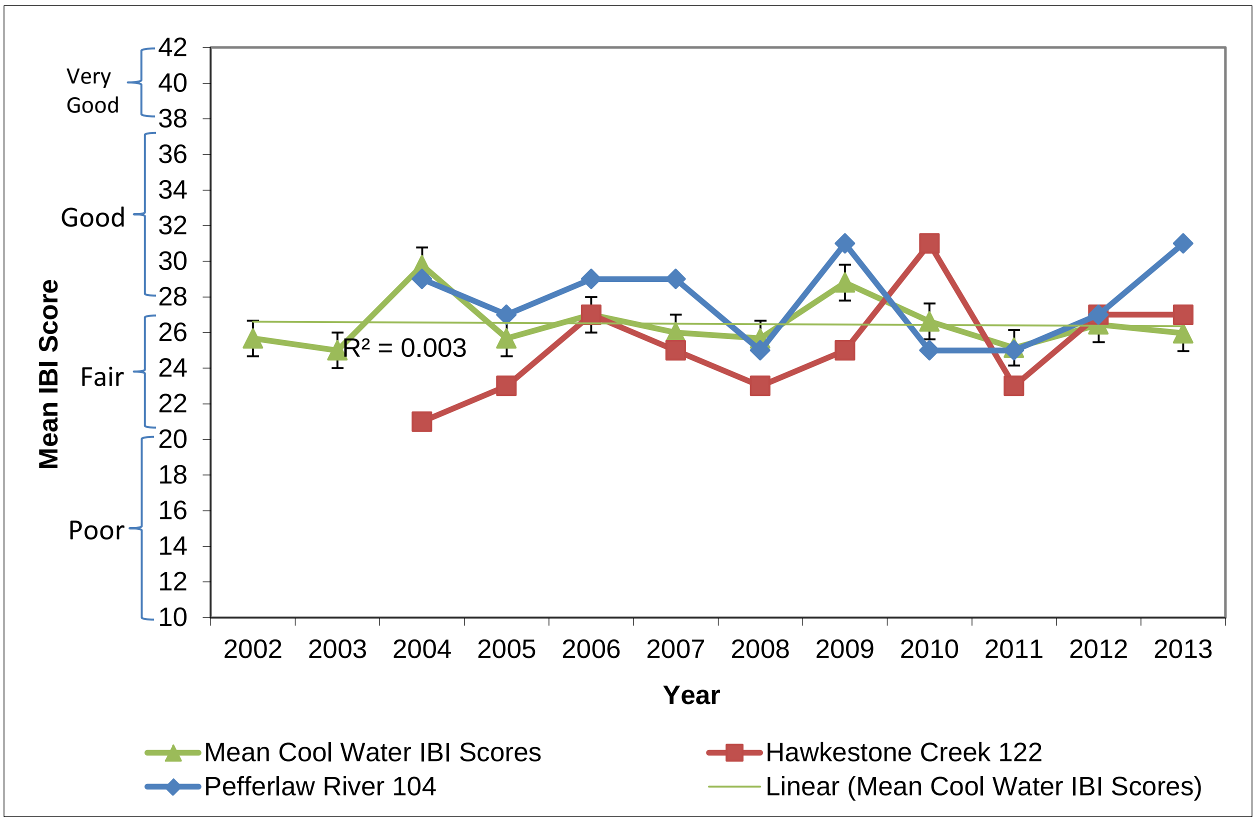

Figure 21: Mean IBI Scores for cool water routine monitoring sites in the Lake Simcoe watershed between 2002 and 2013

4.5.2. Brook trout

The trend of the mean brook trout biomass and density for all ten of the routine cool water sites are decreasing slightly with $r^2 = 0.001$ (Figure 22) and $r^2 = 0.04$ (Figure 23) respectively. The density and biomass of brook trout is higher at the Pefferlaw River site than the Hawkestone Creek site. Pefferlaw River 104 has a mean biomass of 5 g/m², and is above the 2 g/m² average for cool water sites. The mean biomass for Hawkestone Creek 122 is 0.04 g/m² which is below both the average and Pefferlaw River 104. In the 10 years of sampling data, brook trout have only been captured in all of the Hawkestone Creek subwatershed during three sampling events. Only one adult sized brook trout was captured and the rest were young of the year. The habitat at this site is not conducive to brook trout. The site is a long cobble filled riffle without undercuts and log jams. There is good flow and one large deep pool but the temperatures are not stable enough for brook trout to stay within the site. The instances of brook trout capture are likely migrant fish.

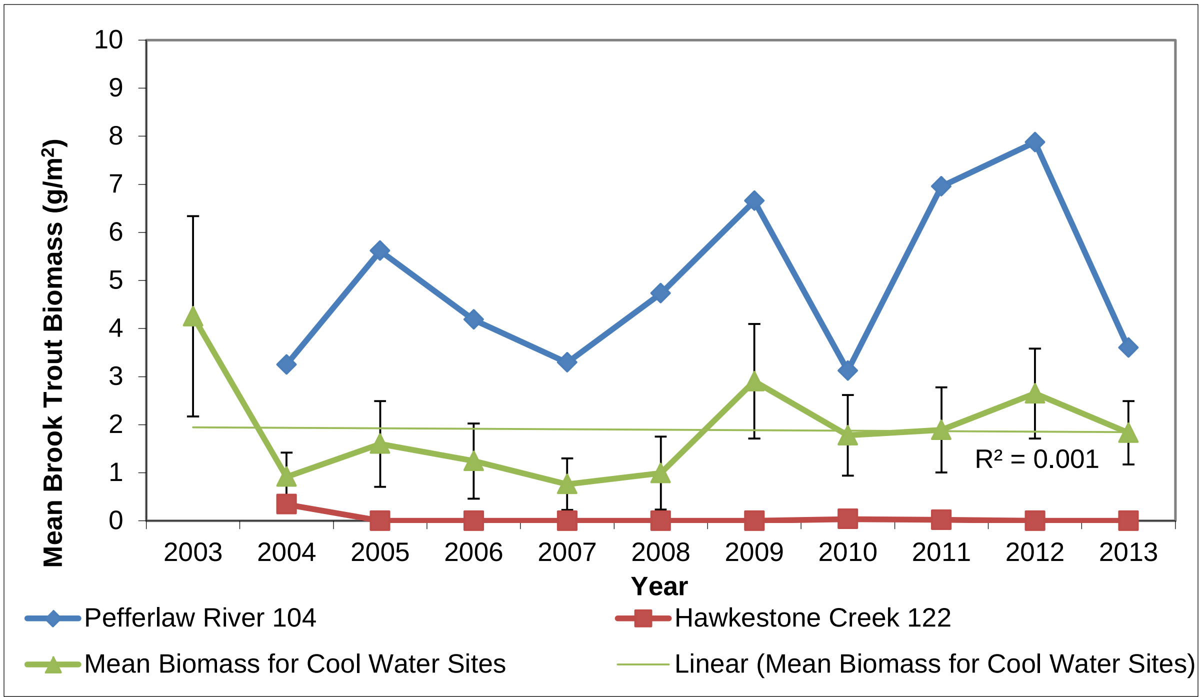

Figure 22: Mean brook trout biomass for cool water routine monitoring sites in Lake Simcoe watershed between 2003 and 2013

The Pefferlaw River site has great habitat for brook trout and the biomass results show this. There are many undercut banks, small pools, cold water upwellings and log jams. To improve the habitat directly upstream of this site the Mill Run Golf & Country Club created 500m of stream to bypass one of their online ponds in the summer of 2011. This opened up approximately 10km of linear stream habitat that was previously blocked by the barrier and online pond. Not only did this project extend the range of the brook trout population in this watershed it lowered the temperature of the downstream waters significantly.

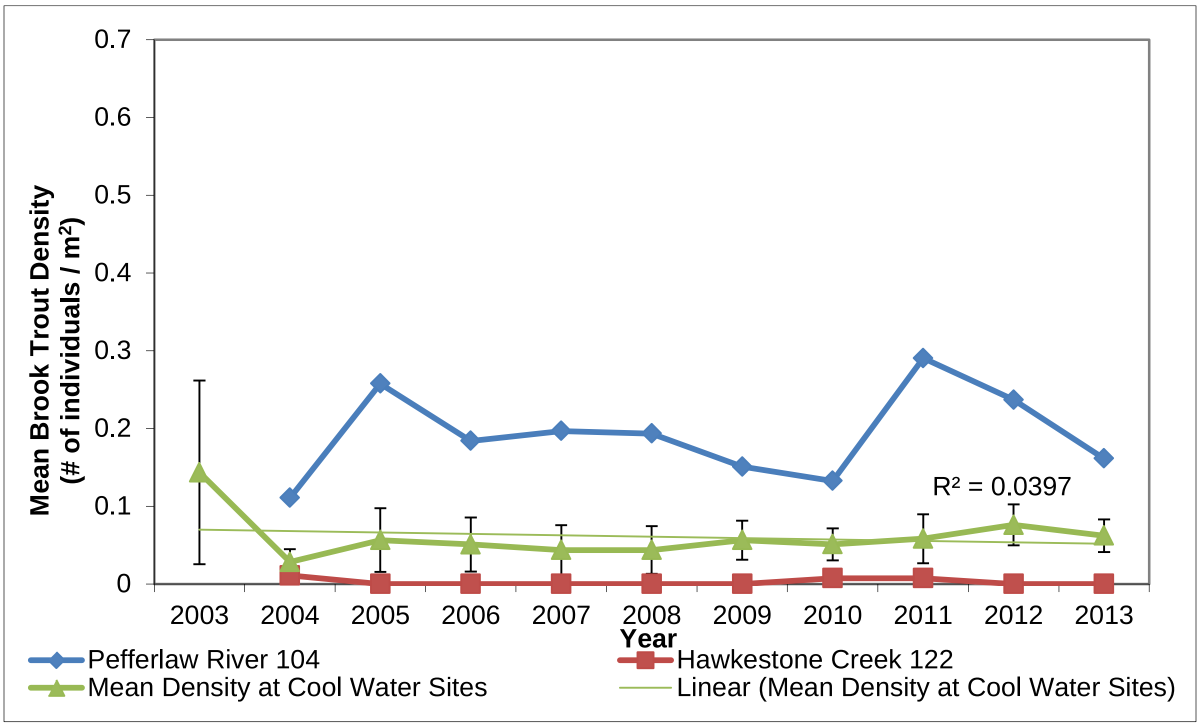

Figure 23: Mean brook trout density for cool water routine monitoring sites in Lake Simcoe watershed between 2003 and 2013

4.5.3. Temperature

For all ten of the routine cool water sites mean water temperature showed a slight increasing trend with an $r^2 = 0.08$ (Figure 24). The mean daily maximum water temperature during the summer months for the Hawkestone Creek site (2007-2013) was 21ºC and the mean temperature for the Pefferlaw River site was 19ºC (2005-2013). On average the Pefferlaw River site was colder by 2ºC than the Hawkestone Creek site (Figure 24). Again the Hawkestone Creek 122 was marginal habitat for brook trout as the temperature was within the “tolerate” range meaning that brook trout will only stay in these habitats for brief periods of time. Pefferlaw River 104 was colder but was still at the upper range of the optimal temperature for brook trout until 2012 at which point the bypass channel was constructed. The daily maximum temperature dropped from almost 20ºC to just over 15ºC between 2011 and 2012 (Figure 24). The dam bypass put the temperatures back into the lower end of optimal temperature range for brook trout. After the restoration was completed the water temperatures have remained consistently cold and the site has now been reclassified as a cold water site.

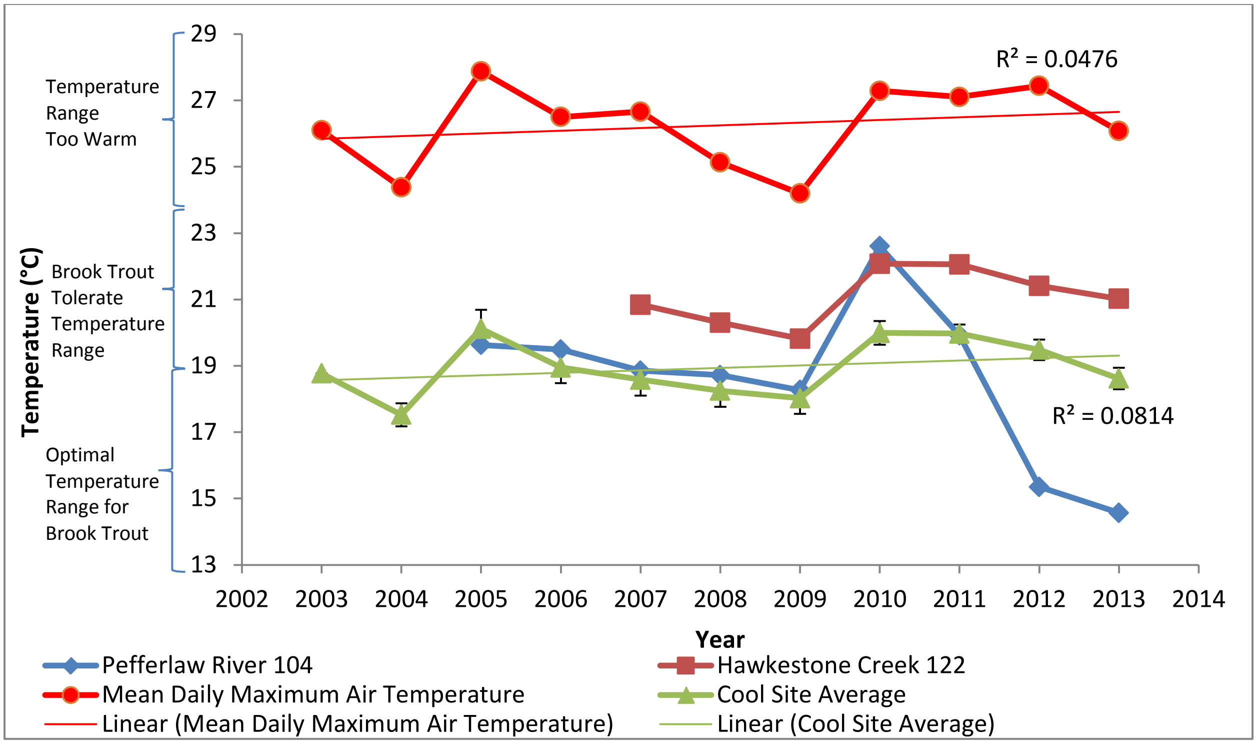

Figure 24: Mean daily maximum air and water temperatures for cool water routine monitoring sites in the Lake Simcoe watershed between 2003 and 2013

The Pefferlaw River site is a great example of how stewardship initiative can improve habitat. Not only was a barrier to fish migration removed but the thermal impacts and fluvial processes were also mitigated. The bypass for will allow brook trout, white sucker and other species access to approximately ten kilometers of new fish habitat and dropped the daily maximum water temperature by about 5 ºC. This is very beneficial to the brook trout population and there should be improvements in the biomass over the next few years.

There are fish migration barriers upstream and downstream of the Hawkestone Creek site. These dams no longer have large impoundments so removing the barriers would not improve the thermal regime of the site or in the creek. The removal of barriers would however open up the creek to fish migration for trout and other migratory species such as white sucker, and provide access to diverse habitat. Priority should be given to barrier removal, diversity of accessible habitat, and identifying any thermal impacts along the stream for future mitigation. The goal of mitigating the impacts from barriers to fish habitat could allow brook trout to utilize the lower reaches of Hawestone Creek. Further study is required to identify the reason(s) that brook trout are currently not supported in the lower sections.

4.6. Warm Water Site Conditions

The warm water sites in the Lake Simcoe watershed are predominantly in the lower sections of the subwatersheds. Brook trout are not captured at these sites on a regular basis but instead several species of the sunfish family are captured at them. The two sites characterized in this section have been selected due to their long term data set and that several species of sunfish are captured at these sites each year. Black River 22 is a routine monitoring site situated at the mouth of the Black River subwatershed in the residential and commercial area of the Town of Sutton (Figure 25). This site has a large catchment of 317 km^2 with a large dam and impoundment directly upstream of the site. Upstream land uses are predominantly natural heritage (50%) features and agriculture (40%). The substrate at the site is a mix of large cobble/rubble with some course gravel. The flows are consistent throughout the year with the exception of high flows that coincide with heavy rain events and melting snow. Sampling has occurred at this site every year between 2003 and 2013.

The routine monitoring site, Pefferlaw River 101 is at the mouth of the Pefferlaw River subwatershed in the town of Pefferlaw (Figure 25). The upstream catchment for this site is also quite large (410 km^2) and has a large impoundment less than one kilometer upstream. Upstream land uses are made up of mostly natural heritage features (44%) and agriculture (45%). The substrate at this site is mostly cobble with some sand and gravel. Sampling has occurred at this site in 2003-2007, 2009-2013. Flows are relatively consistent with the exception of high flows during storm events.

These two sites have the largest catchments of the rest of the watershed with the exception of the site at the mouth of the Talbot River. They are large riverine systems with warm water and good flow regimes. We would expect to find warm water fish and fish that migrate upstream from the lake. Round goby have taken up residence at both of these sites and their effect on the native fish populations has not yet been fully assessed. Continued monitoring of these sites is required to assess the interactions of the gobies and the native populations. The dams upstream of each of these sites are preventing the round gobies from moving upstream, but may also be negatively affecting the native fish community. These dams should stay in place until there is sufficient evidence that the round gobies will not have a negative effect on the native species.

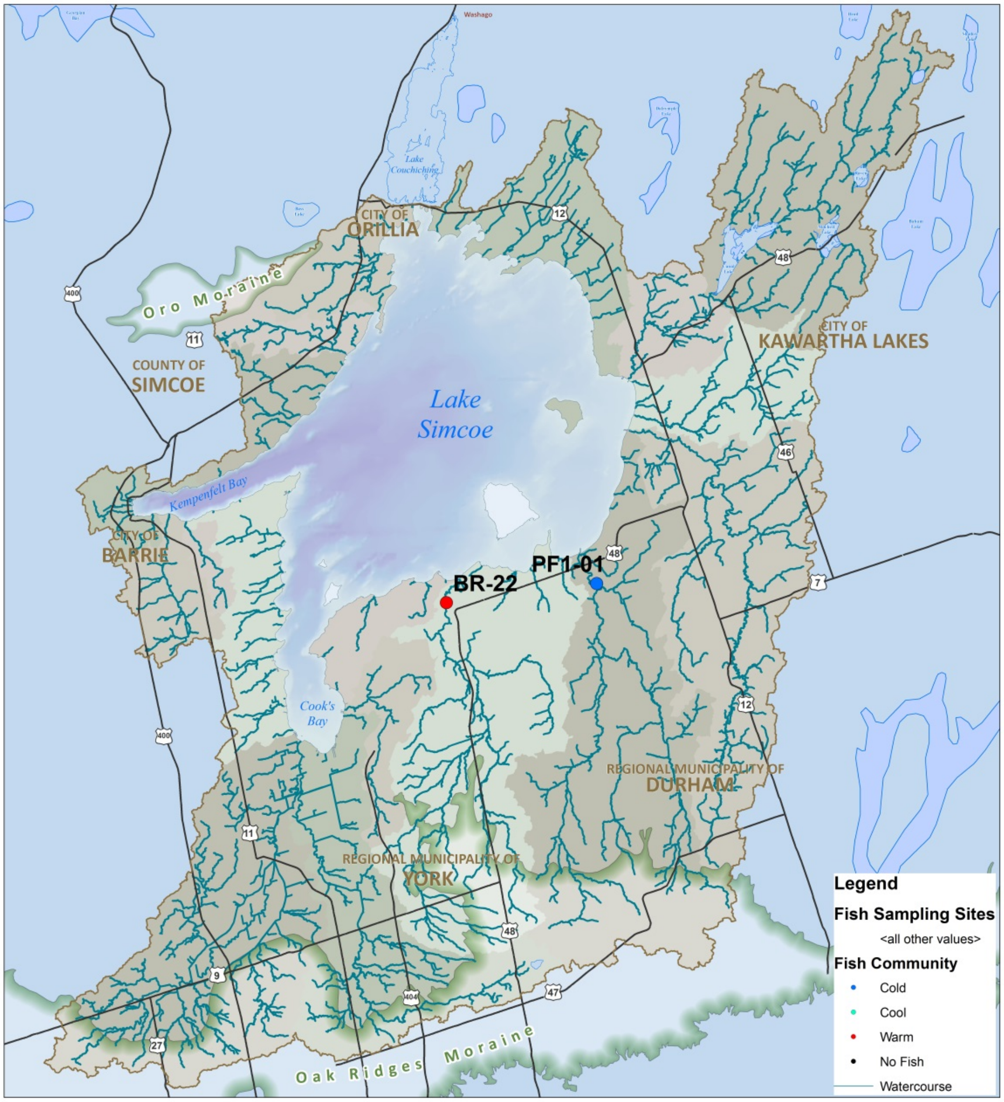

Figure 25: Comparison of two warm water sites in the Lake Simcoe Watershed Black River (BR-22) and Pefferlaw River (PF1-01)

4.6.1. Index of Biotic Integrity

For all 25 of the routine warm water sites the mean IBI score is showing a slightly declining trend with an $r^2 = 0.10$ (Figure 26). Of these 25 sites there are two sites of interest: Black River 22, the site at the mouth of the Black River, and Pefferlaw River 101 at the mouth of the Pefferlaw River. The IBI scores for both of these sites fluctuated quite a bit compared to the relative stability of warm water average (Figure 26). At the Black River site (Black River 22) the IBI fluctuated from a low of 20 (Poor) in 2007 to a high of 32 (Good) in 2008. There were only seven species of fish captured in 2007 vs the 14 species of fish captured in 2008. The number of species of sunfish, suckers and catfish were higher in 2008 than in 2007. This combination of factors provided the highest and lowest IBI scores in consecutive years. There does seem to be a trend towards a declining IBI scores at this site but it is too early to tell.

At the Pefferlaw River site (Pefferlaw River 101) the IBI fluctuated from a high of 34 (Good) in 2004/05 to a low of 27 (Fair) in 2010/11. There was a reduction in the number of catfish and sucker species from 2004/05 to 2010/11. The species diversity also dropped from 21 in 2004 to 13 in 2011. The combination of reduced numbers of catfish and sucker species and lower diversity lowered the IBI scores for 2010 and 2011. There is also a trend of declining IBI scores starting to emerge from the Pefferlaw site that is similar to the Black River site and the overall average of all warm water sites in the watershed.

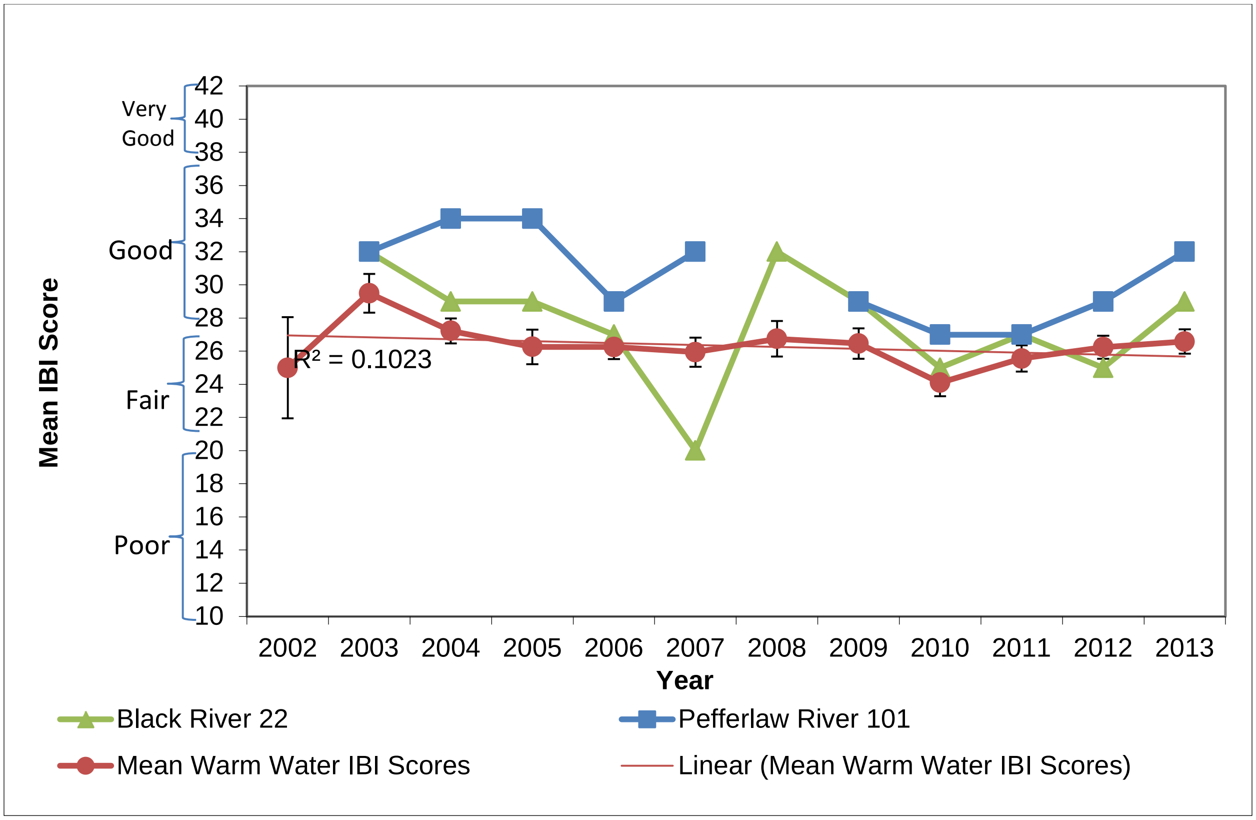

Figure 26: Mean IBI Scores for 25 warm water routine monitoring sites in the Lake Simcoe watershed between 2002 and 2013

4.6.2. Sunfish

For the warm water sites brook trout cannot be used as an indicator of overall health of the fish population as they are cold water fish. A suitable surrogate is the number of sunfish found at a sampling site. The number of sunfish found at a site is used as one of the indicators for the IBI score calculations. Biomass and density of sunfish species has been calculated for the all of the routine warm water monitoring sites. For these 25 routine sites the mean sunfish biomass and density are showing a decreasing trend with $r^2 = 0.30$ (Figure 27) and $r^2 = 0.34$ (Figure 28), respectively. The leading causes of declines in sunfish and other freshwater fishes are habitat loss and habitat fragmentation. This is caused by dams, weirs, roads and degradation of the riparian zone. Non-native aquatic species, overfishing, pollution and climate change, are also linked to declining populations of freshwater fishes (Biodiversity Canada, 2015). The initial trend for sunfish species at Pefferlaw River 101 is an increase in both biomass and density. The Pefferlaw River site was the first site where round gobies were captured in the watershed. In 2005 Rotenone®, a piscicide, was applied through this site to prevent round gobies from becoming established in the Lake Simcoe basin along with a large scale, temporary, native fish removal effort. This resulted in a reduction in biomass in 2006 with an increase in density. The data show that there were fewer larger fish but more recruitment of younger fish at the site. Conversely, an increase in sunfish biomass and density after gobies were found at the Black River site in 2009. There wasn't any Rotenone® applied at this site and the gobies could provide more forage fish for the sunfish explaining the increases in biomass and density in 2010 and 2011. The trend emerging for sunfish at Black River 22 is a declining population in both biomass and density but it is still early. Continued monitoring of these sites is required to see the effects that round goby will have on the population dynamics. The top level predators, like sunfish species, may thrive but other forage fish population may be affected negatively by increases in goby populations.

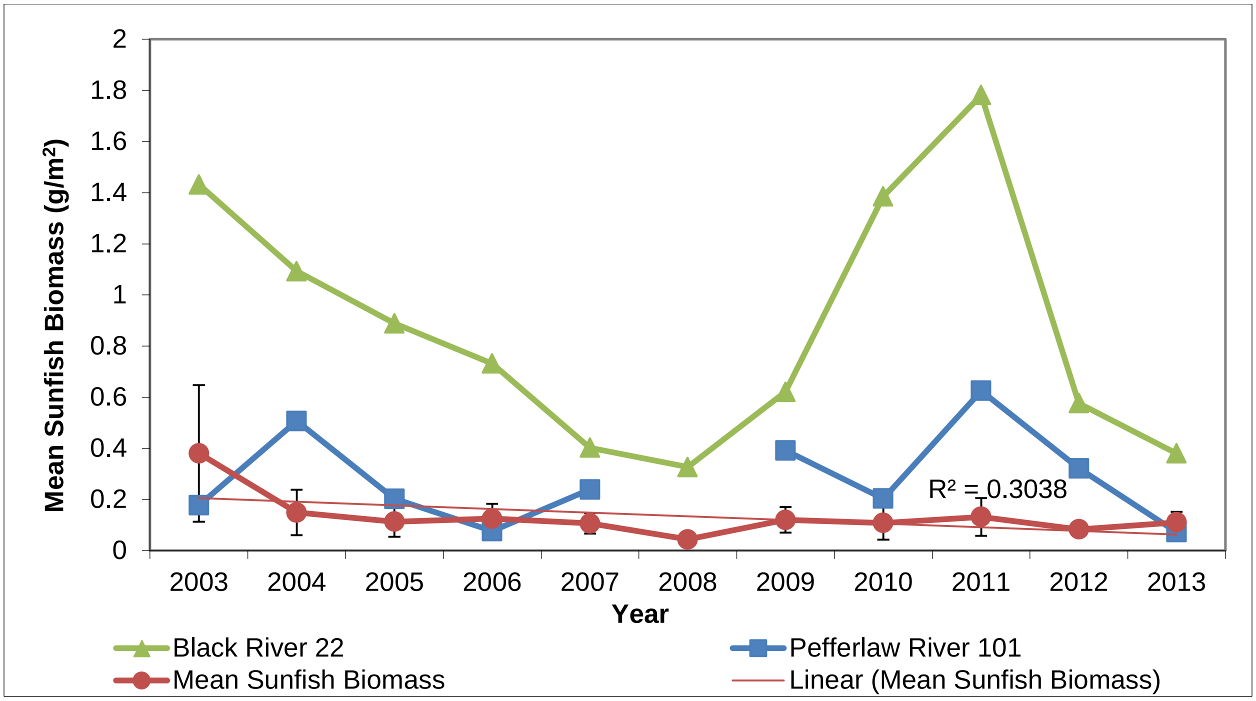

Figure 27: Mean sunfish biomass for 25 warm water routine monitoring sites in the Lake Simcoe watershed between 2003 and 2013

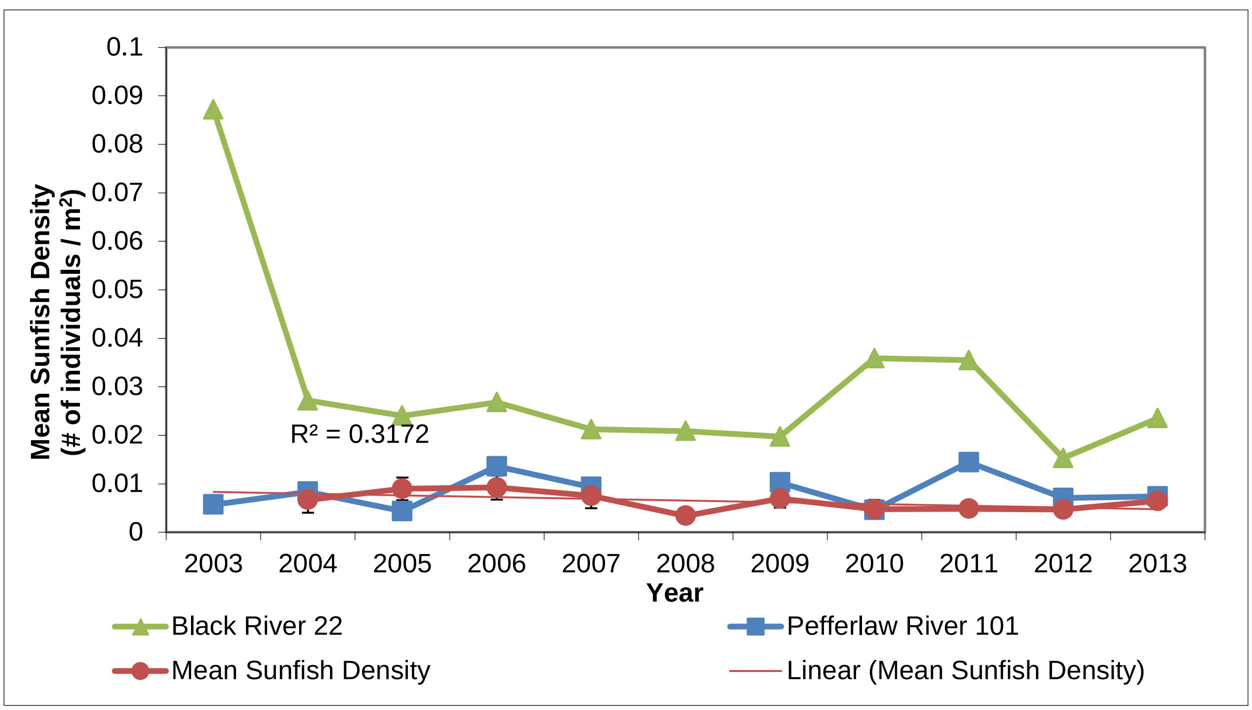

Figure 28: Mean sunfish density for 25 warm water routine monitoring sites in the Lake Simcoe watershed between 2003 and 2013

4.6.3. Temperature

The trend of the mean water temperature for all the routine warm water sites is increasing slightly with an $r^2 = 0.01$ (Figure 29). The water temperatures for Black River 22 are consistently warm over the 10 years of monitoring using the Stoneman and Jones method for thermal stability (Stoneman and Jones 1996). The mean daily maximum temperature over the sampling period was 24.6ºC. The temperatures at Pefferlaw River 101 were also consistently warm over the 11 years of monitoring. The mean daily maximum temperature over this sampling period is 23.8ºC. This puts the average temperatures for both of these sites above the tolerance levels for brook trout but this is ideal for species in the sunfish family. Both of these sites are above the mean for all warm water sites (23.2ºC).

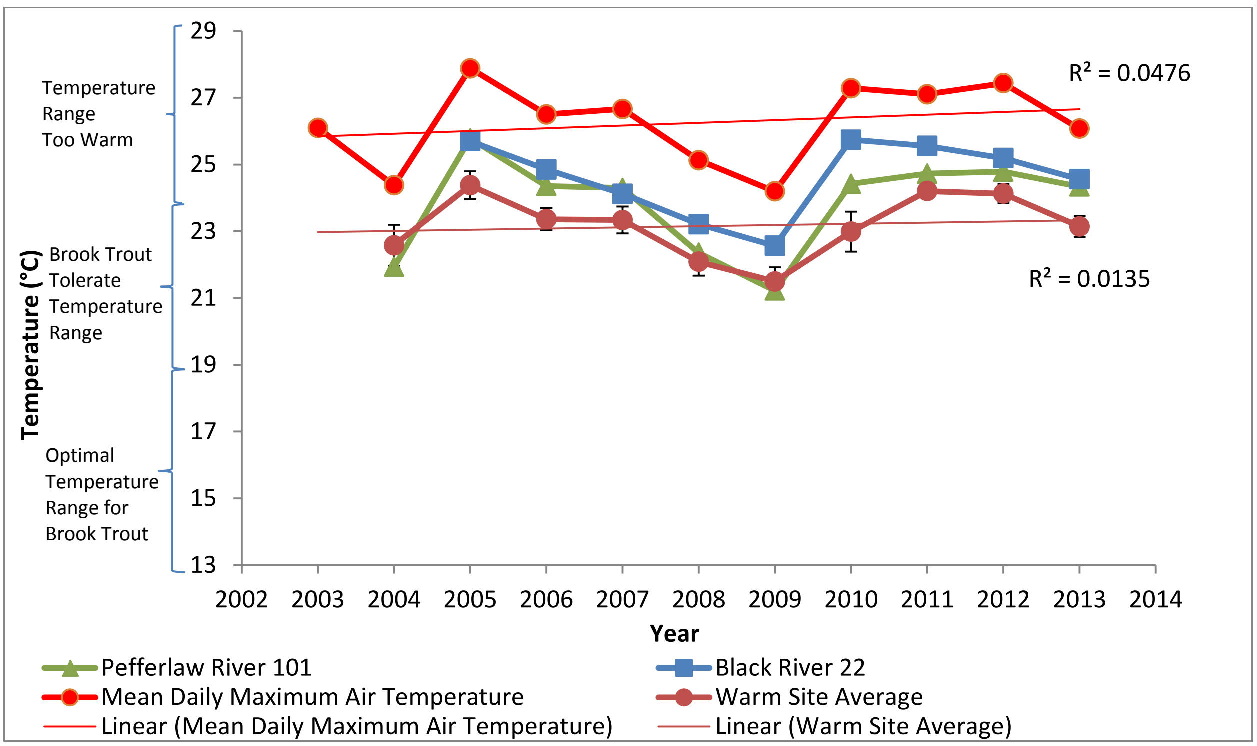

Figure 29: Mean daily maximum water temperatures for 25 warm water routine monitoring sites in the Lake Simcoe watershed between 2004 and 2013

5.0. Invasive Species

While there are several non-native species such as black crappie (*Pomoxis nigromaculatus) and common carp (Cyprinus carpio)* in the Lake Simcoe watershed that are naturalized and not considered to be invasive. The round goby (*Neogobius melanostomus*) is an invasive species in both the Lake Simcoe watershed and Great Lakes Region as a whole. Round gobies are native to the Ponto-Caspian region of Europe and likely arrived in the Great Lakes in the ballast water from ocean-going ships. They are an aggressive species that reproduce quickly, thereby out-competing native species, such as the mottled sculpin (*Cottus biardi*), or other benthic species of fish (e.g. darters) for space and food. Lake Simcoe goby populations were most likely transported from the Great Lakes via baitfish transfers.

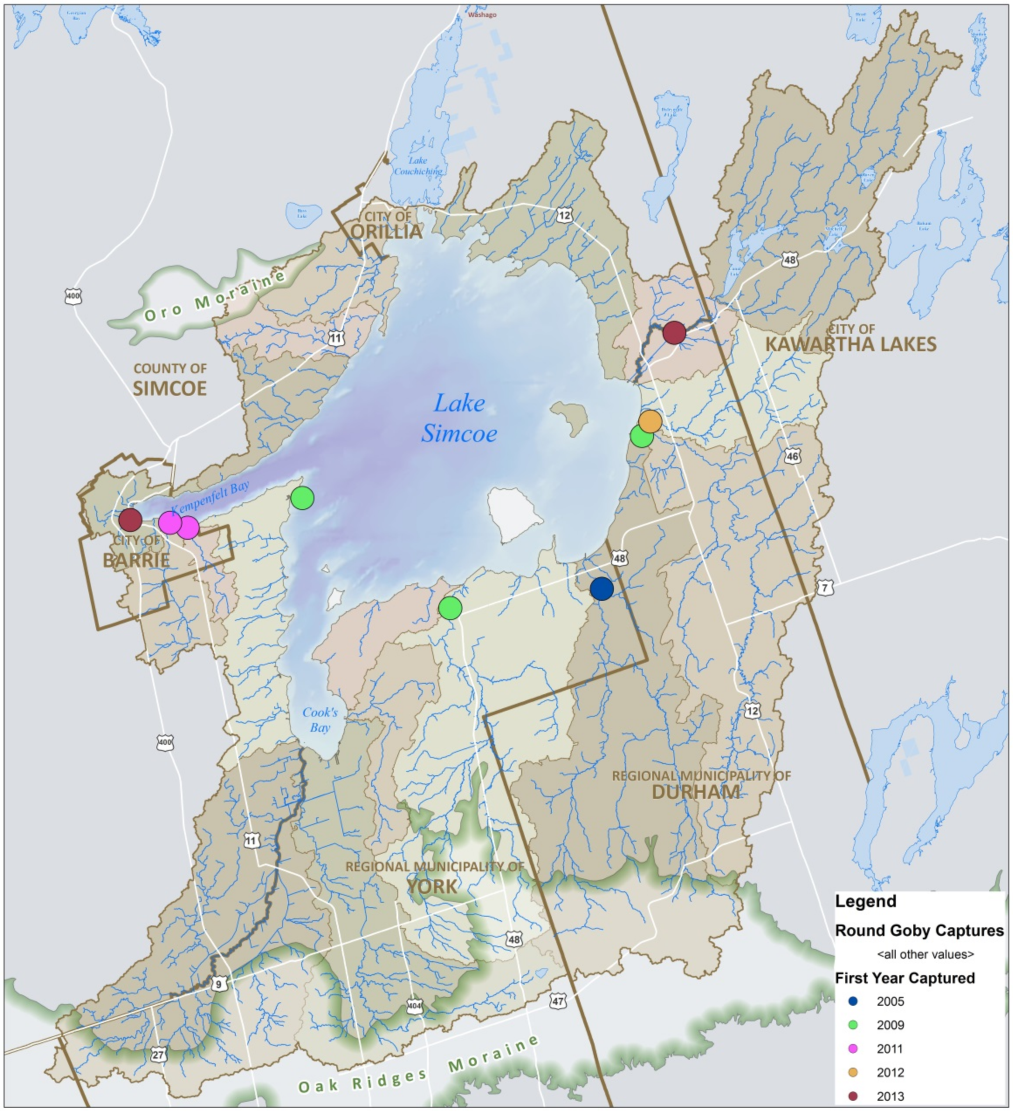

Figure 30: Round goby captures in the tributaries of Lake Simcoe between 2002 and 2013

Round goby Photo Credit: Gary Blight

The round goby was first discovered in the Lake Simcoe watershed in the Pefferlaw River in 2004 by an angler, and their presence was confirmed in June 2005 by LSRCA and the Ontario Ministry of Natural Resources (OMNR). In October 2005, efforts were made to eradicate the gobies by the application of a piscicide (Rotenone®). Unfortunately, some gobies survived and their population has since rebounded and spread to Lake Simcoe. Both near shore and angling surveys by OMNR show that round goby was captured in all areas of the lake in 2010 and 2011 (Trumpickas et al. 2012). LSRCA and OMNR will continue to monitor the spread of this species.

The map (Figure 30) shows where round gobies have been captured by our tributary monitoring. The failure to eradicate round gobies in our watershed illustrates the importance of following proper procedures to prevent the spread of invasive species. Once an invader arrives in a new area, it is nearly impossible to remove it. Continued sampling at our routine sites will help to detect new invasive species if and when they arrive and potentially allow for control measures to be employed.

6.0. Species of Interest

Redside dace Photo Credit: LSRCA

One of the aquatic species of concern in the Lake Simcoe watershed, monitored by the LSRCA, is the redside dace (*Clinostomus elongatus*). Most populations of this species have been recorded in the headwater streams on the western side of Lake Ontario but they have also been recorded in a number of Lake Simcoe tributaries. The species is generally found in smaller streams, with cool, clear-flowing water, pool-riffle sequences, and shaded habitat from overhanging riparian vegetation. Unlike other minnow species, the redside dace leaps out of the water to capture flying insects and, as visual predators, are greatly affected by changes in water clarity such as excessive erosion that increases turbidity. Populations have declined in almost every watershed where they are found and in April 2007, the Committee on the Status of Endangered Wildlife in Canada listed the redside dace as endangered. The primary threat to the redside dace populations is urban development, which is occurring at an increasing rate in much of southern Ontario. By continuing to monitor the distribution and abundance of current fish populations and the health of the tributary habitats within the watershed we can assess shifts within the population. The LSRCA, along with our partner agencies, are working to protect existing habitats and rehabilitate areas identified for re-introduction of this species.

Further details on how this will be accomplished can be found in the full Recovery Strategy (MNR, 2010).

7.0. CONCLUSIONS

Spatially, the Lake Simcoe Region Conservation Authority's sampling program is comprehensive with most subwatersheds having 2-3 routine sampling sites as well as additional sites to characterize each subwatershed. The spatial distribution show that the majority of brook trout and other cold water species are found in the tributary headwaters of the Lake Simcoe watershed, with most captures coinciding with, or located downstream of, the Oak Ridges and Oro moraines. The warm water predators are predominantly found in the downstream areas of the watershed where the rivers and streams are larger and have warmer water. The areas where brook trout and sunfish are found have some of the highest IBI scores.

Our routine dataset has 51 sites across the watershed between the years of 2002 and 2013. There are 12 years of fish monitoring data (2002-2013) and 11 years of temperature data (2003-2013). Long term ecological data sets tend to be measured in decades rather than years so this dataset is relatively short and will be more useful with continued monitoring. Over the entire watershed the preliminary trends show slight declines in IBI numbers. The trends for brook trout and sunfish populations are also showing slight declines in biomass and density. Slight increases were observed in water temperature across all thermal regimes across the watershed.

The most significant impacts are being observed in the tributaries where top level predator fish are found, as these species are more sensitive to changes in temperature and habitat. The cold and cool water sites are showing declines in brook trout density and biomass, while the warm water sites are showing declines in sunfish density and biomass. Sites outside the Lake Simcoe Watershed near Lake Ontario in the Credit Valley (CVC 2013) and Ganaraska Region Conservation Authorities are also reporting declines in brook trout populations (GRCA Pers. Comm.).

The mean water temperatures for each thermal regime are showing slight increases over the entire watershed over the 11 year term of data collection. The water temperatures are related to the air temperature which is showing a similar trend. All of the classifications of water temperature (cold, cool and warm) are showing similar warming trends over time even in this short data set. Long term climate models are showing trends that agree with our short term data. The combined land and ocean surface temperature of the world is showing a warming trend and temperatures have increased by 0.85ºC between 1880 and 2012 (IPPC 2013). There is not a direct correlation between cold water sites and air temperature, which is expected as the cold groundwater feeding these streams buffers them from the effects of air temperature. The mean yearly warm and cool water temperatures are correlated with air temperature. All three of the thermal regimes are showing a trend of warming temperatures between 2003 and 2013 but it is a weak trend starting to emerge at the cold water sites (all with $r^2<0.1$). The increases in water temperature within the Lake Simcoe watershed at the cool and warm water sites are directly related to increases in air temperatures. If the climate change models are correct and the air temperature continues to rise we will see a corresponding increase in water temperatures in the streams (Ficke, et al 2005). If these trends continue this will put stress on the cool, cold and warm water fish populations of Lake Simcoe tributaries.

Despite increased pressures from urban development, invasive species such as round goby, and increasing water temperature, the diversity of the fish population has remained stable. The Index of Biotic Integrity (IBI) scores are showing fairly stable numbers with a very small decreasing trend across the watershed. Examination of the data by thermal regimes shows some differences. The cold and cool water systems are showing IBI scores that are relatively stable but the warm water sites are showing a slight decline in IBI scores. The declines in IBI scores are likely due to the introduction of the invasive species, round goby. The majority of warm water sites are in the lower sections of the subwatersheds where these invasive species have access from Lake Simcoe. With these sites being near the outlet of their respective subwatersheds they have the most impacts from loss of habitat, overfishing and pollution as these types of effects are cumulative. Continued sampling of the routine sites is needed to monitor the spread of invasive species that are currently in the watershed as well as new species. This would include watching sensitive brook trout habitats like Hewitt's Creek where there aren't any barriers between the lake and the brook trout populations upstream.

Monitoring of redside dace needs to continue to provide data for the recovery strategy. This data could be used for focused efforts on site specific habitat rehabilitation and species recovery efforts.

When the land use changes to a more urbanized setting the impervious land cover increases. Impervious land cover includes roof tops, roads, and parking areas. These areas do not allow rain water to percolate back into the soil. Instead it flows over the hard surfaces quickly and ends up in streams and river very quickly. This runoff not only increases the flashiness of the stream but it increases the water temperatures as well. Sensitive cold water fish assemblages are not typically found in streams where their catchments exceed 10% impervious cover (Stanfield 2006). Continued protection and enhancement of these habitats is necessary to mitigate the effects of urbanization and climate change.

To build in resilience in the tributaries and mitigate the impact of increasing air temperatures, increasing urban development, and invasive species, work needs to be done around the watershed to protect cold water habitats and enhance cool and warm water habitats. Stewardship initiatives such as planting riparian buffers, treating storm water runoff at the site level and removing or bypassing ponds would work to mitigate some of the pressures on the fish populations. Protecting areas where there are significant groundwater inputs into the streams and known brook trout spawning areas should also be a priority. The Lake Simcoe Region Conservation Authority is working to identify and protect these Environmentally Significant Ground Water Recharge Areas (ESGRA) through the Lake Simcoe Protection Plan (LSPP) and Source Water Protection initiatives. Works should be prioritized where there is a large amount of habitat improved for the least amount of money (“biggest bang for the buck”). These sites have been selected by the LSRCA using a prioritization tool to select sites from a database of stewardship opportunities within the watershed. Projects like the dam bypass at Mill Run Golf and Country Club on the Pefferlaw River in Siloam were very successful because they improved habitat quality by reducing water temperatures and allowed fish access to a large amount of habitat upstream that they weren’t able to move into historically.

7.1. RECOMMENDATIONS

- Continued monitoring of the long term sites is recommended to document significant changes to the fish populations, along with integrating fisheries monitoring to other monitoring activities and disciplines. The expansion of urban development in the Lake Simcoe Watershed along with the continued trend of warming air temperatures, and the introduction of new invasive species pose a direct threat to the fish communities of the watershed.
- Improvements to the fisheries monitoring program should be undertaken to create a more robust data set for further studies.
  - This should include adding more sites to the routine monitoring program to offer better coverage in a few subwatersheds. Additional sites should be investigated in the Talbot River, White's Creek and Ramara Creeks subwatersheds. These catchments only have one routine monitoring site each, while other subwatersheds have 2-3 sites. The majority of the subwatersheds have good coverage for long term data sets.
  - Targeted sampling in the Hawkestone Creek subwatershed needs to be undertaken to better understand why brook trout are not being captured more regularly. This could help inform where stewardship works would take place to help the fish community.
  - The collections of individual lengths and weights of warm water piscivorous fish would improve the data set and make it more robust. Currently only individual lengths and weights are collected on the cold water piscivores and warm water fish are bulk weighed. Including data for individual fish for warm water species will improve the quality of the index of biotic integrity (IBI).
  - Inclusion of nearshore Lake Simcoe fish community data

8.0. ACKNOWLEDGEMENTS

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10.0. Appendix 1: Species captured by program between 2002-2013

Species	Scientific Name	Native to Watershed	Global Rank	Srank
Bowfin	*Amia calva*	Yes		
Coho Salmon	*Oncorhynchus kisutch*	No		
Rainbow Trout	*Oncorhynchus mykiss*	No		
Brown Trout	*Salmo trutta*	No		
Brook Trout	*Salvelinus fontinalis*	Yes		
Northern Pike	*Esox lucius*	Unknown		
Muskellunge	*Esox masquinongy*	Yes		
Central Mudminnow	*Umbra limi*	Yes		
White Sucker	*Catostomus commersoni*	Yes		
Northern Hog Sucker	*Hypentelium nigricans*	Yes		
Goldfish	*Carassius auratus*	No		
Northern Redbelly Dace	*Phoxinus eos*	Yes		
Finescale Dace	*Phoxinus neogaeus*	Yes		
Redside Dace	*Clinostomus elongatus*	Yes	G3G4	S2
Common Carp	*Cyprinus carpio*	No		
Brassy Minnow	*Hybognathus hankinsoni*	Yes		
Hornyhead Chub	*Nocomis biguttatus*	Yes		
River Chub	*Nocomis micropogon*	Yes		
Golden Shiner	*Notemigonus crysoleucas*	Yes		
Emerald Shiner	*Notropis atherinoides*	Yes		

Common Shiner	*Luxilus cornutus*	Yes
Blackchin Shiner	*Notropis heterodon*	Yes
Blacknose Shiner	*Notropis heterolepis*	Yes
Spottail Shiner	*Notropis hudsonius*	Yes
Rosyface Shiner	*Notropis rubellus*	Yes
Spotfin Shiner	*Cyprinella spiloptera*	Yes
Sand Shiner	*Notropis stramineus*	Yes
Mimic Shiner	*Notropis volucellus*	Yes
Bluntnose Minnow	*Pimephales notatus*	Yes
Fathead Minnow	*Pimephales promelas*	Yes
Blacknose Dace	*Rhinichthys atratulus*	Yes
Longnose Dace	*Rhinichthys cataractae*	Yes
Creek Chub	*Semotilus atromaculatus*	Yes
Pearl Dace	*Margariseus margarita*	Yes
Central Stoneroller	*Campostoma anomalum*	No
Yellow Bullhead	*Ameiurus natalis*	Yes
Brown Bullhead	*Ameiurus nebulosus*	Yes
Stonecat	*Noturus flavus*	No
Banded Killifish	*Fundulus diaphanus*	Yes
Brook Stickleback	*Culaea inconstans*	Yes
Rock Bass	*Ambloplites rupestris*	Yes
Green Sunfish	*Lepomis cyanellus*	No
Pumpkinseed	*Lepomis gibbosus*	Yes
Bluegill	*Lepomis macrochirus*	Yes
Smallmouth Bass	*Micropterus dolomieu*	Yes

Largemouth Bass	*Micropterus salmoides*	Yes
Black Crappie	*Pomoxis nigromaculatus*	No
Yellow Perch	*Perca flavescens*	Yes
Greenside Darter	*Etheostoma blennioides*	No
Rainbow Darter	*Etheostoma caeruleum*	Yes
Iowa Darter	*Etheostoma exile*	Yes
Johnny Darter	*Etheostoma nigrum*	Yes
Logperch	*Percina caprodes*	Yes
Blackside Darter	*Percina maculata*	No
Round Goby	*Neogobius melanostomus*	No
Mottled Sculpin	*Cottus bairdi*	Yes
Slimy Sculpin	*Cottus cognatus*	Yes
Lepomis hybrids	*Lepomis hybrids*	No
Number of Species Reported		58