A Comparison of Fish Communities in Southwestern Lake Ontario Tributaries From One Century Ago

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A COMPARISON OF FISH COMMUNITIES IN SOUTHWESTERN LAKE ONTARIO TRIBUTARIES FROM ONE CENTURY AGO

By

Ben Carson

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Environmental Science

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Chapter 1 - Was Wright Right?  Fish Assemblages in Lake Ontario Tributaries From Over One Century Ago

Table 1
Abstract

I evaluated a study performed by Albert Hazen Wright between 1902 and 1904, on the Tributaries of Lake Ontario in Monroe County, NY. I extracted data from Wright's original graphical analysis, and analyzed these data with Canonical Correspondence Analysis (CCA), to assess the value of these data for use as historical benchmarks for future studies on the same tributaries. Wright identified 52 species of fish within his distribution diagrams, eight of the species were rare species and were not analyzed with the CCA. The rare species were, Freshwater Drum (*Aplodinotus grunniens*), Iowa Darter (*Etheostoma exile*), Three Spined Stickleback (*Gasterosteus aculeatus*), Bluegill (*Lepomis macrochirus*), Sand Shiner (*Notropis stramineus*), Spotfin Shiner (*Cyprinella spiloptera*), Fathead Minnow (*Pimephales promelas*), and Common Shiner (*Luxilus cornutus*). Of the 44 remaining species analyzed, 37 matched very well between Wright's interpretations of his data, and the results of my analysis. Six species were a partial match, and one, the Tessellated Darter (*Etheostoma olmstedi*), was considered a subspecies and was not interpreted by Wright. Overall, Wright's interpretations matched well with my analysis of his data, and corresponded well with current understandings of the species x species and species x habitat relationships within a stream continuum from more recent studies. Wright's data set and interpretations proved to be accurate, and a valuable historical reference.
Was Wright Right?  Fish Assemblages in Lake Ontario Tributaries from Over One Century Ago

Introduction

Understanding fish communities of the past helps us better understand the communities of today. Historical data helps establish a timeline to aid in understanding how these communities have changed over time. Some important questions to consider include: How has fish species composition changed? Have new fish species found their way into the ecosystem? Have fish species disappeared altogether? Have species-specific habitat associations changed?

Utilizing historical data comes with challenges. Often there are differences in data collection techniques, formats, and data presentation, which may result in data sets that are not comparable with present day research methods and analyses. Some of the earliest records cataloging biodiversity were simple mentions of species presence or absence, jotted down in haphazard recollections of local anecdotes or sightings. Near the turn of the twentieth century, some of the first ecological investigations into freshwater fisheries that go beyond categorical listing of species, began to take place (Shelford, 1911).

My research closely examines one such investigation into the fish communities of the tributaries of Lake Ontario within Monroe County, NY, performed by Albert Hazen Wright from 1902 – 1904 (Wright, 2006). A native of Hamlin, NY, Wright began researching the fishes within the Lake Ontario tributaries near his home, as a student at Cornell University. He earned a Master's degree in 1905 with a thesis entitled The Fishes of Northern Monroe County, NY. Wright then continued on to earn a PhD in 1908, becoming a faculty member at Cornell University and a noted herpetologist (Adler, 1989). What makes Wright’s study worth closer
examination is that Wright was among the first to associate fish species with specific habitat parameters (Daniels, 2006). Wright's research on these tributaries was prepared for publishing in the late 1920s as part of a New York State Museum Bulletin, but never made it into print. Despite the significance of this research for freshwater fish ecology, it went unpublished for over a century (Daniels, 2006). While publication was intended in the late 1920s, the materials were packed away into the archives of the New York State Museum. It wasn't until the archives were being moved that the box containing the manuscript, printing plates, and cover sheets was rediscovered and delivered to the desk of Robert Daniels, a faculty member at the Museum Research and Collections Division, and Curator of Ichthyology. Daniels published the research in 2006 as it had been preserved, adding only a preface and appendices that accounted for differences in fish nomenclature, and making a few minor spelling and organizational changes. Daniels also published a companion article telling the story of finding Wright's research and the significance of this previously unknown data (Daniels 2006; Wright 2006).

Wright’s investigation surveyed fish communities in five tributaries to Lake Ontario in Monroe County, NY; Round Pond Creek, Larkin Creek, Northrup Creek, Buttonwood Creek, and Salmon Creek (Figure 1). Wright also looked at several of the feeder creeks to these main tributaries, including West Tributary of Northrup Creek, West Tributary of Salmon Creek, West Fork of Salmon Creek, East Tributary of West Fork of Salmon Creek, and North Creek.

Wright’s methodology for the collection of fish data included a combination of fishing reports, visual observation, and seine netting. Wright also recorded a number of physical habitat parameters including stream depth, stream width, elevation, stream flow, substrate types, and other unique habitat features from the mouth to the source of each stream. Wright recorded and displayed his data with a novel, but elegant, graphical analysis (Figure 2). While seemingly
complex, it is possible to simultaneously see all of the physical habitat parameters, as well as fish species, at any location along the entire course of a stream. Wright's distribution diagram is laid out from left to right by river mile, with the left side indicating the mouth of the stream and the right side showing the source. Across the top of the diagram, Wright gave descriptions of substrates found along the course of the stream. Down the left column is a species list, as well as headings for river miles, current, miscellaneous data (bridges, culverts, tributaries, etc.), stream width, and a cross-sectional view of the river valley. The horizontal bars following each species name depicts where in the course of the stream Wright recorded the presence of that species. Also in the species field there are two more graphs, the upper showing stream depth
and the lower showing stream elevation, both recorded in feet as indicated down the right column.

Wright's research was groundbreaking in its application. He borrowed the idea of graphical distribution analysis from avian biology, and applied it to fisheries biology (Wright, 1907). He
also included habitat in his distribution analyses, making his study an ecological one. The scientific discipline of ecology was still just being defined at the turn of the twentieth century (Clements, 1905). This is an important step, because while some ecological studies were taking place in marine fisheries, ecological studies had not yet become established in freshwater fisheries. Additionally, because Wright's data includes all of the fish species and all of the habitat parameters he identified at any particular place at the same time, his study begins to break ground into community ecology, a branch of ecology that would not fully begin to take shape until the 1930's (Clements, 1939).

Community ecology is a very complex discipline, with even relatively small systems having multiple environmental variables and species, all with direct and indirect effects on one another. This complexity makes trying to quantify species x species and species x habitat relationships difficult (Palmer, n.d.). A paradox within the study of community ecology is that of defining scales. Finding ecological patterns is an exercise that seems to be the most fruitful at two extremes of scale, the very small and the very large. This search for patterns becomes more difficult at the community level scales in between (Lawton 1999). Some early ecologists used a graphical analysis, as Wright did, to overcome this problem. Graphical analyses allowed the researcher to see all of the desired parameters simultaneously. However, these graphical analyses relied entirely upon the researcher's ability to detect the ecological patterns within the data set and then make accurate interpretations. Nowadays, modern computer based statistical programs aid researchers in looking for ecological patterns and interpreting the data.

For this study, my research question asked, was Wright right about his interpretation of species x habitat associations? I wanted to assess if Wright was able to accurately describe the ecology of the fish communities within these streams from his graphical distribution diagrams. I
also wanted to determine whether Wright's data were usable as an accurate historical benchmark for future studies on the same tributaries. Performing this assessment was necessary to evaluate the use of Wright’s historical data for studying the changes in fish communities in these Lake Ontario streams that has occurred over the last century.

Methods

I first extracted data from Wright's distribution diagrams, and converted them for use in Canonical Correspondence Analysis (CCA). CCA is a multivariate analysis technique that allows for a visual analysis of the species x species and species x habitat relationships from complex data sets (Ter Braak & Verdonschot, 1995). In essence, CCA accomplishes statistically the same aims as Wright's graphical analysis. I used the CCA analysis available in the statistical software PAST, version 3.08 for Windows (Hammer, 2001).

Wright's distribution diagrams contained a combination of continuous and categorical data. I recorded and converted these data into a spreadsheet format using Microsoft Excel. Wright displayed the environmental variables of depth, elevation, and width as continuous line graphs, labeled in feet, within his distribution diagrams. For each of these variables I recorded the maximum values shown for each river mile. Wright recorded flow with a number of different descriptive terms. Because his descriptors for relative flow were all adjectives that could be subject to individual interpretation, I created a new variable called flow rank. I categorized and assigned each of Wright's descriptors a value of 0, 1, 2, or 3, with 0 representing the least flow, and 3 the most flow. The descriptors and their flow rank were: imperceptible = 0, perceptible, sluggish and slow = 1, apparent and noticeable = 2, swift, very pronounced and considerable = 3. Wright recorded nine categories of substrate: clay, mud, sand, gravel, stone, and rock. He also
included weeds, swamp, and dry as substrates. I recorded each of these substrate variables with either a 1 for present or a 0 for absent, for each river mile. Similarly for each fish species, I recorded their presence within each river mile with a 1 for present or a 0 for absent.

After recording all of these data, I removed any species or environmental variables that Wright encountered fewer than three times from the analysis. This was to prevent these rare occurrences from potentially skewing the results of the CCA. I also removed data for river miles in which no fish were recorded because CCA is not able to calculate species x habitat associations for sites where no species occur.

Following the CCA analysis and determination of species x habitat associations, I compared each species with Wright’s original interpretations. Each species was then categorized as good, moderate or poor, based on how well the two interpretations matched (Table 1). Because of the manner in which Wright described each species, there were some

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instances which did not precisely fit my criteria. In those cases I made a determination of good, moderate or poor match based upon other available information.
Results

During the course of his investigation, Wright recorded 52 species of fish on his distribution diagrams. Of these, eight species were categorized as rare, and hence not used in my CCA analyses, because Wright recorded them in fewer than three locations. These rare species are, Freshwater Drum (*Aplodinotus grunniens*), Iowa Darter (*Etheostoma exile*), Three-spined Stickleback (*Gasterosteus aculeatus*), Bluegill (*Lepomis macrochirus*), Sand Shiner (*Notropis stramineus*), Spotfin Shiner (*Cyprinella spiloptera*), Fathead Minnow (*Pimephales promelas*), and Common Shiner (*Luxilus cornutus*).

The ordination diagram (Figure 3) depicts the environmental variables as vectors emerging from the origin of the graph. Species are plotted as points, and are located at the centroid of their habitat associations (Ter Braak 1995). The smaller the angle between two vectors, the greater the correlation is between them (Palmer, n.d.). The length of each vector indicates the relative importance that particular habitat parameter has for explaining species distribution along the axes. Axis 1 and 2 were the two most descriptive axes, having the highest eigenvalues. The eigenvalues are the values used to rank the axes, the higher the eigenvalue the more descriptive that axis is (Palmer, n.d.). Together Axis 1 and 2 described 61.55% of the variation within the data. Along Axis 1 the most important environmental variables were flow rank, mud, and gravel, thus two primary environmental gradients, flow and substrate type. Along Axis 2 the most important environmental variables were max width, max elevation, and max depth, representing the classical stream gradient, where in the course of the stream continuum a fish species is likely to appear (Matthews, 1998).
**Figure 3:** Ordination diagram for Wright’s (2006) data, with environmental variables (in black) as vectors, and species as points. Species that were a good match to Wright's interpretations are shown in blue, a moderate match are shown in orange, a poor match are shown in red. The environmental variables are, FlowRank = Stream Flow, RvMile = River Mile, MaxDepth = Maximum Depth, MaxWidth = Maximum Width, Clay = Clay, Mud = Mud, Sand = Sand, Gravel = Gravel, Stone = Stone, Rock = Rock, Weeds = Weeds, Swamp = Swamp, and Dry = Dry. The species abbreviations are, AmEel = American Eel (Anguilla rostrata), BanKilli = Banded Killifish (Fundulus diaphanus), BkBull = Black Bullhead (Ameiurus melas), BkCrapie = Black Crappie (Pomoxis nigromaculatus), BkDace = Blacknose Dace (Rhinichthys atratulus), BluntMin = Bluntnose Minnow (Pimephales notatus), Bowfin = Bowfin (Amia calva), BrBull = Brown Bullhead (Ameiurus nebulosus), BridShin = Bridle Shiner (Notropis bifrenatus), BrindMad = Brindled Madtom (Noturus midas), BrkStick = Brook Stickelback (Culaea inconstans), BrkTrout = Brook Trout (Salvelinus fontinalis), CCSucker = Creek Chubsucker (Ernmyzon oblongus), CommCarp = Common Carp (Cyprinus carpio), CommShin = Striped Shiner (Lumilus chrysocephalus), CrChub = Creek Chub (Semotilus atromaculatus), EmShiner = Emerald Shiner (Notropis atherinoides), FiDarter = Fantail Darter (Etheostoma flabellare), GoShiner = Golden Shiner (Notemigonus crysoleucas), GrasPick = Grass Pickerel (Esox americanus vermiculatus), GrDarter = Green Sided Darter (Etheostoma blennioides), HogSuck= Northern Hog Sucker (Hypentelium nigricans), HornChub = Hornyhead Chub (Nocomis biguttatus), JoDarter = Johnny Darter (Etheostoma nigrum), LMBass = Largemouth Bass (Micropterus salmoides), LnGar = Longnose Gar (Lepisosteus osseus), Logperch = Logperch (Percina caprodes), MudMin = Mud Minnow (Umbrla limii), Pike = Northern Pike (Esox lucius), PirPerch = Pirate Perch (Aphredoderus sayanus), Pkinseed = Pumpkinseed (Lepomis gibbosus), Redhorse = Shorthead Redhorse (Moxostoma macrolepidotum), RockBass = Rock Bass (Ambloplites rupestris), SeaLamp = Sea Lamprey (Petromyzon marinus), SMBass = Smallmouth Bass (Micropterus dolomieu), SpShiner = Spottail Shiner (Notropis hudsonius), Stonecat = Stonerel (Noturus flavus), StoneR = Central Stoneroller (Campostoma anomalous), TatMad = Tadpole Madtom (Noturus griseum), TeDarter = Tessellated Darter (Etheostoma olmstedti), Walleye = Walleye (Sander vitreus), WhSucker = White Sucker (Catostomus commersonii), YeBull = Yellow Bullhead (Ameiurus natalis), YePerch = Yellow Perch (Perca flavescens).

The orientation of the environmental variables should, and did, show a logical alignment of environmental gradients. In this case, maximum elevation is opposite maximum width and maximum depth; as a stream runs its course, elevation will decrease and the stream will generally become wider and deeper. Additionally, mud and flow rank are opposite one another, and again this makes sense because faster upstream currents will carry the smaller sediments farther downstream. This logical orientation of environmental variables to one another adds credibility to the validity of Wright's data and the ability to extract quality data from Wright's distribution diagrams. Additionally, a randomization test of 999 permutations, yielded a p-value of 0.001, indicating that the relationships within these data are not random.

Species plotted close to one another are often found together, and represent communities of fish. My CCA analyses revealed 4 primary communities, one upper course, one middle course and two lower course communities (Figure 4). The two large lower course communities are
separated by flow and substrate. The species located near the middle of the diagram are not well explained by the CCA, but tend to be cosmopolitan species. For example, a species like Creek Chub (*Semotilus atromaculatus*), which is a very common stream fish and is tolerant of a wide variety of environmental conditions, is likely to be found in a variety of locations (Smith 1985). Species nearer to the margins of the diagram tend to be associated with one or more specific environmental variables. For example, Mud Minnow (*Umbrla limi*), is a small minnow usually inhabiting waters with little flow and soft muddy bottoms (Smith, 1985).

**Figure 4:** CCA analysis of Wright's 1902 - 1904 survey with communities circled in red, environmental variables (in black) as vectors, and species as points. Species that were a good match to Wright's interpretations are shown in blue, a moderate match are shown in orange, a poor match are shown in red.
37 of the 44 species I analyzed were a good match to the description Wright gives in his annotated species list. For example, Wright described the Bowfin (*Amia calva*), as being common in the ponds along the lakeshore and in the lower courses of several streams, and as preferring “muddy bottoms and a sluggish current”. The CCA plotted the Bowfin to the far right of the lower right quadrant near Axis 1. This plot indicates a lower course fish, with a positive association with mud substrate and a negative association with flow. Both of these analyses correlate with current understanding of the relationship of the Bowfin to its environment (Smith, 1985).

Six of the 44 species I analyzed were a moderate match, four of these were fish that Wright listed in his species list but gives little description of habitat for. These are American Eel (*Anguilla rostrata*), Brook Trout (*Salvelinus fontinalis*), Common Carp (*Cyprinus carpio*), and Spottail Shiner (*Notropis hudsonius*). The remaining two species that were a moderate match are fish that Wright described more completely. However, they did not match the CCA analysis either for course or substrate. These fish were the Grass Pickerel (*Esox americanus vermiculatus*), and Bluntnose Minnow (*Pimephales notatus*).

Only one of the 44 species I analyzed was a poor match, the Tessellated Darter. This is because Wright considered the Tessellated Darter to be a subspecies of the Johnny Darter (*Etheostoma nigrum*) which is presently described as a separate species (Smith, 1985), and gave no independent description of the Tessellated Darter in his species list, or elsewhere within the text of his manuscript.
Discussion

With 84% of the fish analyzed by CCA being a good match to Wright's descriptions, the CCA results supported the majority of conclusions drawn by Wright from his distribution diagrams. I compared the results of my CCA analysis to Wright's interpretations of species x habitat relationships from his graphical analysis species by species. I focused on the three main environmental gradients described by Axes 1 and 2 of the CCA, which were river mile, substrate, and flow rank. There were seven species that did not match on all three of these main environmental gradients with the conclusions made by Wright, six of them were a moderate match and just one a poor match.

Of the six species that were a moderate match, four of them (American Eel, Brook Trout, Common Carp, Spottail Shiner) were so because Wright did not describe a course or substrate component, making it difficult to classify them as a good match. However, for each of these four fish, their plot on the CCA makes sense with current understanding of their habitat associations (Smith, 1985). The two fish that Wright gives a description of course and substrate for, yet still are not a good match, are the Grass Pickerel and Bluntnose Minnow. The Grass Pickerel does not match on substrate. Wright describes it as being most commonly associated with weedy, heavily vegetated areas. The CCA plots the Grass Pickerel as being strongly associated with mud. I believe this difference has to do with the inconsistent manor of Wright’s description of habitat type, resulting in both the environmental variables of weeds and swamp not being strong descriptors in this CCA.

It is also common for weedy areas of streams to also have a muddy substrate. The Bluntnose Minnow differs in course. Wright describes this fish as an upper course fish with the only exception being Larkin Creek, where it was common throughout the entire course. However, in his distribution diagrams Wright records the presence of this fish
in the mid to lower courses of all but Buttonwood Creek, Northrup Creek and the West Tributary of Main Fork of Salmon Creek. I believe the discrepancy here is likely one of abundance, from Wright’s distribution diagrams I can only draw species presence or absence. In his descriptions Wright discusses the commonality of the Bluntnose Minnow, a factor that could not be taken into account by the CCA in this case.

The only fish that is a poor match, the Tessellated Darter, is such because Wright gave no independent description of this fish at all, despite plotting it separately from the Johnny Darter in his distribution diagrams. The Tessellated Darter at the time of Wright’s investigation was considered a subspecies of the Johnny Darter. Today the Johnny Darter and Tessellated Darter have been split into two separate species (Stone, 1947; Smith, 1985; Heckman 2009). The two species are morphologically very similar, making identification difficult (Scott, 1973; Heckman, 2009). However, they are known to show a difference in habitat preference, with the Tessellated Darter typically showing up slightly further downstream and over more sandy substrates, as opposed to more rocky substrates. This difference in habitat preference is apparent in the CCA analysis, where the Johnny Darter is plotted as an upper course fish, and the Tessellated Darter has been plotted as a mid course fish. In this instance the CCA analysis was able to show differences in habitat associations between two species that were not described by Wright.

Another instance where the CCA was able to show details not presented by Wright, and could be difficult to isolate from his graphical analyses alone, is that of the Spottail Shiner, which I determined to be a moderate match to Wright’s conclusions about this species. Wright did not give a detailed description of the Spottail Shiner in his species list, but did mention it in the text of his stream descriptions. He believed it to be a lake species that found its way into the
upper courses of several streams via the Erie Canal. My analysis plotted the Spottail Shiner in the lower left quadrant of the CCA diagram (Figure 4), showing it to be a mid to upper course fish associated with strong to moderate current, over sandy substrate. The Spottail Shiner’s location within the course of the stream as depicted by the CCA supports Wright's assertion that it gained access via the Erie Canal. Wright’s hypothesis is further supported by the Spottail Shiner’s reported occurrence in the Erie Canal in the State of New York Conservation Department Biological Survey of the Lake Ontario Watershed in 1939 (Greely, 1939). The Spottail Shiner is often thought of as a fish of lakes and large rivers (Seghers, 1981; Hartman, 1992). However, they are known to occur in smaller streams and tributaries, over sandy and rocky substrates (Smith, 1985; Page 1997). Whether in large lakes and rivers, or small ponds and streams, the common link was an affiliation with sand, a correlation that is clearly depicted in the CCA.

The difficulty in describing the ecology of a fish or group of fishes lies in the complex nature of the systems and animals being worked with. There are many environmental parameters that might influence the distribution of fish species, in addition to the ones such as substrate, flow, and river mile, that were the important parameters for comparison in my study. Additionally, there may be seasonal and even diurnal variations in habitat use (Clough, 1997) that might influence patterns of species x habitat associations.

In this study, the Stonecat (Noturus flavus), exemplifies this complexity, because it utilizes multiple habitats and makes seasonal and diurnal migrations (Brewer, 2008). Wright's interpretation of the Stonecat stated, “This species frequents the swift, shallow portions of the larger creeks, being found especially under stones, not infrequently taken under rubbish. Noturus flavus is often found in deeper (yet swift) water, not being confined to the shallows.”
Wright accurately described the use of multiple habitats by the Stonecat. The CCA indicates this species to be a mid/lower course fish of wide, swifter waters with gravel and rock substrate, and is a good match because it accurately associates the Stonecat, with substrate, flow, and course.

Based upon my evaluation, Wright appeared to accurately describe what he had displayed in his distribution diagrams. Additionally, my CCA analysis elucidated additional details about fish species x habitat associations and fish communities in Lake Ontario tributaries from over one century ago. Therefore, I conclude that these data are a valuable historical benchmark and a solid basis of comparison for future investigations of the fish communities of Lake Ontario tributaries.

**Literature Cited**


A Comparison of Fish Assemblages in Lake Ontario Tributaries
from Over One Century Ago to Today

Abstract

This study examined five tributaries of Lake Ontario, in Monroe County, NY, that were surveyed by Albert Hazen Wright from 1902 to 1904. I surveyed a total of 50 sites for fish, using a point-transect methodology, and a combination of haul seine and dip nets to sample each macro-habitat (pool, riffle, run) present at each site. I found a total of 34 species of fish, three fewer than Wright's 37 species, within the same segments of these streams. Of the 34 species I found, eight were species Wright did not find. These were, Bluegill (*Lepomis macrochirus*), Brown Trout (*Salmo trutta*), Chinook Salmon (*Oncorhynchus tshawytscha*), Fathead Minnow (*Pimephales promelas*), Green Sunfish (*Lepomis cyanellus*), Longnose Dace (*Rhinichthys cataractae*), Rainbow Darter (*Etheostoma caeruleum*), and Round Goby (*Neogobius melanostomus*). Of the 37 species Wright described, 11 were species I did not encounter. These were the American Eel (*Anguilla rostrata*), Banded Killifish (*Fundulus diaphanus*), Black Bullhead (*Ameiurus melas*), Black Crappie (*Pomoxis nigromaculatus*), Bowfin (*Amia calva*), Brook Trout (*Salvelinus fontinalis*), Brown Bullhead (*Ameiurus nebulosus*), Grass Pickerel (*Esso americanus vermiculatus*), Pirate Perch (*Aphredoderus sayanus*), Tadpole Madtom (*Noturus gyrinus*), and Yellow Bullhead (*Ameiurus natalis*). Introductions of native and non-native invasive species appeared to greatly influence the habitat associations of some species. I found that the habitat parameters river mile, depth, width and vegetation, had the greatest influence on fish distribution.
Introduction

Prior to the 1900s we understood little about the ecological relationships of fishes to each other and to their habitats (Mathews, 2012). We now know that fish show definite ties to specific habitats, and that these associations often produce predictable communities of fish (Schlosser, 1982). These communities show natural variance over time as environmental factors fluctuate. These environmental fluctuations stress some species more than others, resulting in changes in relative abundance (Strange, 1993). The effects of anthropogenic influences on aquatic environments may also result in more drastic and lasting effects on fish communities. Due to a combination of natural and anthropogenic changes to aquatic habitats, many fish communities are experiencing changes in composition and habitat utilization (Fitzgerald, 1997).

In the early 1900s, Albert Hazen Wright performed one of the first ecological studies of freshwater fishes, on the tributaries of Southern Lake Ontario in western Monroe County, NY (Daniels, 2006). This research was prepared for publication in the 1920s as part of a New York State Museum Bulletin, but never made it into print. Robert Daniels of the New York State Museum rediscovered Wright's manuscript and published it for the first time in 2006 (Daniels, 2006). The rediscovery of this research gives us a rare glimpse of these fish communities and their habitats at the turn of the twentieth century.

In this study I examined fish communities within five of the tributaries of Lake Ontario studied by Wright. These tributaries are part of the Lake Ontario Minor Tributaries watershed (NYSDEC, 2015) (Figure 1). Lake Ontario comprises a portion of the border between the United States and Canada, and its watershed contains a number of large cities including Buffalo,
Toronto, and Rochester. Within New York State, there are five main watersheds that feed Lake Ontario. From west to east these are: the Niagara River, the Genesee River, the Oswego River, the Black River, and a collection of smaller tributaries, including the streams of northern Monroe County, which comprise most of the immediate shoreline of Lake Ontario (NYSDEC, 2007). These smaller tributaries include 5,891 miles of streams, draining 2,460 square miles of land, and comprise nearly 17% of Lake Ontario's watershed within the United States (NYSDEC, 2007). The tributaries in Monroe County are an excellent microcosm of this watershed.

The 1800s were a time of rapid development for this region, when it changed from mostly wilderness to an area split between urban/suburban development in the east, and heavy
agricultural activities in the west by 1900 (Turner 1852). Now in the early 2000s, this pattern remains, though urban/suburban sprawl is pushing further west. As a result, many of these tributaries now flow through a wide variety of land uses, and this has led to significant alterations to the course and structure of these streams. For example, since 1904 the number of bridges crossing Larkin Creek nearly doubled from 10 to 18. At present, Larkin Creek flows north from its source, through agricultural lands, under the Erie Canal via a culvert, meanders through a patchwork of residential, commercial and industrial areas, through the Braddock Bay Fish & Wildlife Management Area, and finally into Lake Ontario.

Prior to the arrival of the European settlers, the fishes of Lake Ontario and its tributaries were an important food source for the Seneca, the indigenous peoples of the region (Wright 2006). The late 1800s marked the beginning of fisheries management in New York with the formation of the New York Commissioners of Fisheries in 1868, which later became part of the New York State Department of Environmental Conservation (NYSDEC - History of DEC, n.d.). In 1885, the newly formed U.S. Commission of Fish and Fisheries, a forerunner of the U.S. Fish and Wildlife Service, began investigation into the New York waters of the Great Lakes (Wright, 2006). These organizations, as well as fisheries research, were focused on commercial fisheries and the cataloging of species, making Wright among the first to look at these fisheries from an ecological standpoint.

The formation and attention of the various fisheries management agencies on Lake Ontario and its tributaries coincided with the growing anthropogenic effects on the region and its waterways. By the 1870s, many of the streams were reported to be half the size they were when the first European settlers arrived. Beaver dams and ponds were falling into disrepair and drying up due to over-harvest of beaver, the abundant wetlands were being drained for
agriculture, and the rivers of the area were being adapted to provide power for various milling operations (Thomas 1871). Also during this time there were numerous incursions of native and non-native invasive species. Some of these introductions were done purposefully, such as the stocking of nonnative trout and salmon by the New York State Dept. of Environmental Conservation, while others were accidental, such as the stocking of native pickerel from Lake Ontario into Conesus Lake during the early 1800s (Turner 1852).

The increase in commercial activity created a demand for more efficient and safer transportation of goods and people. This demand led to the construction of the Erie Canal. Originally completed in 1825, the Erie Canal connected the waters and potentially aquatic organisms of Lake Erie to the Hudson River for the first time, and the canal also crossed many of the waterways flowing into Lake Ontario. The Erie Canal was later expanded and modified two more times, the final expansion being finished in 1918, near the time of Wright's investigations (Canal Corp, n.d.). The Erie Canal is now connected to the Champlain, Oswego and Cayuga-Seneca canals, that together make up the New York State Barge Canal System, and also connect the waters of the Mohawk, Oswego, Seneca, Clyde, and Oneida Rivers. Oneida Lake, Onondaga Lake, and Cross Lake now also connect directly to the canal system (Canal Corp, n.d.). This interconnecting system potentially gives fish the ability to move from one watershed to another in a way never before possible.

Two species that are thought to have possibly entered the Lake Ontario basin through the canal are, Alewife (*Alosa pseudoharengus*), and Sea Lamprey (*Petromyzon marinus*). Both of these invasive species have had significant effects on the ecology of Lake Ontario and its tributaries (Rahel, 2002). Alewives were first recorded in Lake Ontario in 1873, and while the timing is right to make entry via the Erie Canal plausible, there is some debate as to exactly how
and when Alewife first entered the Lake Ontario system (Daniels, 2001).

As with Alewife, there is a fair amount of debate as to how Sea Lamprey found their way into the Lake Ontario basin, regarding whether they found their own way via the St Lawrence Seaway, the Erie Canal, or even accidental stocking by fishermen using the ammocoetes (juvenile lampreys) as bait (Daniels, 2001). They were first reported in Lake Ontario in the early 1900's, with one of, if not the first, official records being made by Wright during his 1903 survey of Salmon Creek in Hilton, NY.

The arrival of new species into Lake Ontario continues today with other aquatic species like the Zebra Mussel (Dreissena polymorpha) first recorded in Lake Ontario in 1989, Quagga Mussel (Dreissena rostriformis) in 1991, and Round Goby (Neogobius melanostomus) in 1998 (Stewart, 2012). These invasive species are not only competing for food with native species, but also potentially altering physical habitats. Zebra Mussels are capable of significantly increasing water clarity (Caraco, 1997), and growing in dense colonies (5,000-6,000 individuals per square meter), smothering benthic habitat, and out-competing native mussels (Schloesser, 1996). Along with Round Goby, they act as vectors for diseases such as botulism, accumulating toxins and passing them higher up the food chain (Getchell, 2006).

My goal for this research was to examine the current fish communities and habitats of some of these tributaries, and compare them to what was present at the turn of the twentieth century. For a basis of comparison I used Albert Hazen Wright’s 1902 – 1904 survey of these same streams.

Wright's survey looked at the relationships of fish to one another, and to particular habitat types; I studied how these communities have changed in the last 100 years, and how species x habitat associations have changed. I also sought to determine where there have been incursions
of native and/or non-native invasive species. Additionally, I studied some of the possible impacts of the Erie Canal on present fish communities and their habitats. By reexamining the same tributaries that Wright surveyed over 100 years ago, I hope to further our understanding of the role of native and non-native invasive species, habitat alterations, and their effects on the fish communities of these Lake Ontario tributaries. I predicted that land use changes, influences by the Erie Canal, and incursions by both native and non-native invasive species over the past 100 years have caused substantial changes in the fish communities of these tributaries to Lake Ontario.

**Methods**

I examined five of the tributaries to Lake Ontario that were examined in Wright's 1902-1904 survey (Figure 2). These tributaries are located in Monroe County, NY, west of the City of Rochester, NY, and the Genesee River. The tributaries I assessed were Round Pond Creek, Larkin Creek, Northrup Creek, Buttonwood Creek, and Salmon Creek (Figures 2 & 3). These tributaries were the five main branches of the stream systems surveyed by Wright. Round Pond Creek was the tributary closest to Rochester, and likely most impacted by urban development. The two tributaries farthest from Rochester, (Salmon Creek and Buttonwood Creek) were likely most impacted by agricultural activity. The two tributaries in the middle were likely most impacted by sub-urban development (Northrup Creek and Larkin Creek). All of these creeks now cross the under Erie Canal via a series of culverts. During Wright's investigation only Round Pond Creek, Northrup Creek and Salmon Creek were reported to cross the canal. Larkin Creek and Buttonwood Creek both originated North of the Erie Canal. All of the tributaries flow into a series of embayments of Lake Ontario. These embayments are Round Pond (43° 16'
8” N, 77° 38' 44” W), Buck Pond (43° 16’ 53” N, 77° 39’ 59” W), Long Pond (43° 17’ 24” N, 77° 41’ 27” W), and Braddock Bay (43° 18’ 43” N, 77° 42’ 53” W).

I selected my sample sites by river mile, beginning at the mouth of each tributary (Figure 3). I used Google Earth for this process because of the ability to later access and revise the maps in the field via a smartphone. I then examined each of these sites in person, and if necessary shifted them slightly upstream or downstream for the purposes of stream access, or to avoid the direct influence of a man made structure, such as a bridge abutment or culvert. At each selected sample site I recorded river mile, max stream width, max stream depth, and max stream flow.
used a point transect method of sampling (Marques, 2010), and recorded all macro habitat types (pools, riffles, runs) for 50 meters upstream and downstream of the selected points. I then surveyed for fish, and recorded data for substrate types and aquatic vegetation.

I collected fish by dip net and seine net, keeping with Wright’s method of fish collection to ensure data comparability. The dip nets I used had 0.25 in. mesh bags, with net openings of 1 x 1.5 ft and 4 ft handles. Dip netting was typically done from shore where I could reach across and sweep back through the water. The seine nets were 10, 25 or 50 ft in length, 4 ft deep and had 0.25 in. mesh. The technique for seine netting depended upon the stream conditions at each site, in most cases one net was stretched across the stream as a blocker net, while another was used to push fish downstream into the blocker net. In other cases, such as shallow riffles, I used a blocker net downstream and chased fish into the blocker by kicking from just upstream. In some situations where a natural barrier was present, like a waterfall or a sharp bend, one long net could be used as a haul seine more efficiently to surround the fish and draw them in. At most sites, each of these habitats were sampled twice, either with two pulls directly over the same patch of riffle or run, or two pulls of the seine nets over two sections of riffle, run, or pool. I took care to ensure that sampling was performed clear of the influence of artificial alterations to the stream, such as bridges or culverts.

All of the fish I collected were identified and a representative individual was photographed before being returned to the water. I tallied fish by species, recorded the habitat type (pool, riffle, or run), the substrate type, and the gear used for every fish collection. I visually identified all substrate types present and recorded each, by presence or absence, as one of the following: mud, clay, sand, silt, gravel, rock, boulder, bedrock, or vegetation. I treated aquatic vegetation as a single substrate type. This included both emergent and submerged plant life.
Sections of the stream that were dry were not used for data analysis.

For stream width and depth, I recorded the maximum width and the maximum depth for each site in meters. Similarly, I measured water flow at the maximum velocity points for each site, with an NTech USA Flowatch Flowmeter Station, measuring in meters per second.

I created a variable called “Flow Rank”, as was done with Wright’s data (Carson, 2015), where I coded a value of 0, 1, 2, or 3 to a range of flow meter velocities. The Flow Rank categories are 0 – 0.1 m/s = 0, 0.2 – 0.4 m/s = 1, 0.5 – 0.7 m/s = 2, and > 0.7 m/s = 3.

I used PAST Statistics Version 3.08 for Windows, Canonical Correspondence Analysis (CCA) to compare my data to Wright’s 1902-1904 investigation (Hammer, 2001). CCA is an
analysis technique that shows the relationships of species to each other and habitat parameters (Ter Braak & Verdonschot, 1995). In a previous study (Carson, 2015), I digitized Wright's data into a spreadsheet format that was compatible with the CCA software to determine the validity of his interpretation of species x habitat associations. Using these data, I then compared the results of my study to Wright’s own interpretations of his data.

To conduct my comparison, I had to ensure that Wright’s data set and the variables were as similar as possible. The habitat parameters I extracted from Wright’s data included river mile, elevation, max width, max depth, flow rank, and substrate type (clay, mud, sand, gravel, stone, rock, vegetation, swamp and dry). My habitat parameters matched Wright’s, with one exception. I included the substrate type bedrock. Wright did not identify bedrock in any of the streams during his survey. I identified bedrock in several streams, and decided to include this important substrate type under the assumption that Wright would have recorded bedrock had he found it in any of the streams he surveyed. I then removed any fish species that were collected fewer than three times for both Wright's investigation and my own. This was to prevent these rare occurrences from biasing the results of the CCA. I also removed any sites where no fish were caught, because CCA does not compute species x species and species x habitat associations for sites with zero.

I also combined the Johnny Darter (Etheostoma nigrum) and the Tessellated Darter (Etheostoma olmsted) into a single fish category, labeled “JTDarter” for both data sets. The two species are so closely related that there has been uncertainty as to whether they are separate species, and are found in very similar habitats (Stone, 1947; Smith, 1985; Heckman, 2009). Additionally, there seems to be a significant amount of variation in the commonly described morphological diagnostics of the species such as, scale coverage of the breast, nape or cheeks,
number of soft dorsal fin rays, size and shape of pectoral fins, length of the snout, number of lateral line scales, and infraorbital canals, making distinguishing the two species difficult (Scott, 1973; Heckman, 2009). Along the southern shore of Lake Ontario where the two populations overlap and are speculated to hybridize, differentiating the two species becomes even more challenging (Scott, 1973; Heckman, 2009). The combination of morphological similarity and possible hybridization make field and even laboratory identifications very difficult. It is for these reasons that I made the decision to combine the two species into one taxonomic category.

**Results**

I caught a total of 34 species of fish during my investigation. Wright caught a total of 37 species of fish in the same stretches of these streams. After removing the rare species, I was left with 22 species, and Wright had 33 species for CCA analysis (Figure 4 and 5).

The results for the CCA are depicted in an ordination diagram, showing the environmental variables as vectors emerging from the center of the graph. Species are plotted as points, and are located at the centroid of their habitat associations (Ter Braak & Verdonschot, 1995). The smaller the angle between two parameters, the greater the correlation is between them (Palmer, n.d.). The length of each vector indicates the relative strength that particular habitat parameter has in explaining species distribution along the axis shown. The longer the vector, the more descriptive that habitat parameter is for the axes. Parameters such as river mile and max width showed the greatest correlation in describing species distribution in both diagrams.

Fish located near the center of the ordination diagram (Figures 4 and 5) tend to be the more cosmopolitan species. For example, Creek Chub, a very common stream fish both then and now, is tolerant of a wide variety of environmental factors. While it is likely to be found in a
variety of locations, in the ordination diagram, it has a single point depicting the centroid of its distribution with regards to its associations with habitat and other fish. This resulted in a point near the center of the ordination diagram. On the other hand, the Blacknose Dace was located near the edge, and is positively associated with just a few habitat parameters, river mile, and stone/rock. Blacknose Dace is also therefore negatively associated with max width and max depth. Additionally, the 999 permutations test indicated that the habitat and species association of my CCA analyses were significant with p values of 0.001 for both data sets (Figures 4 and 5).

Wright recorded a total of 37 species within the same stretches of streams I investigated. There were 11 species I did not encounter (Figure 6). These species were the American Eel
(Anguilla rostrata), Banded Killifish (Fundulus diaphanus), Black Bullhead (Ameiurus melas), Black Crappie (Pomoxis nigromaculatus), Bowfin (Amia calva), Brook Trout (Salvelinus fontinalis), Brown Bullhead (Ameiurus nebulosus), Grass Pickerel (Esox americanus vermiculatus), Pirate Perch (Aphredoderus sayanus), Tadpole Madtom (Noturus gyris), and Yellow Bullhead (Ameiurus natalis). In addition to the 26 species still present, I encountered 8 species Wright did not. These were the Bluegill (Lepomis macrochirus), Brown Trout (Salmo Trutta) Chinook Salmon (Oncorhynchus tshawytscha), Fathead Minnow (Pimephales promelas),
Green Sunfish (*Lepomis cyanellus*), Longnose Dace (*Rhinichthys cataractae*), Rainbow Darter (*Etheostoma caeruleum*), and Round Goby (*Neogobius melanostomus*).

![Venn diagram](image)

**Figure 6:** Venn diagram showing species only encountered during Wright’s 1902-1904 survey, fish species only encountered during my 2012-2014 study, and fish species found in both surveys.

**Discussion**

Human induced changes have most likely disrupted the stream continuums over the course of the last 100 years in these tributaries. Streams should show regular and predictable changes of environmental variables along with the various biological communities found within (Vannote 1980). These changes included the loss of wetlands, changes in length and course, and alteration of the physical habitats within these streams. Many of these have been brought about by an increase in intensity of agricultural and industrial activity, as well as urban/suburban sprawl.

I found all but Northrup Creek and Salmon Creek to be significantly longer than they were
when described by Wright. Wright described two streams, Buttonwood Creek and Larkin Creek, as originating north of the Erie Canal, both of which now originate south of the canal and in both cases I caught fish in these new stretches of stream. There are several possible reasons for these differences in stream length. These include new mapping technologies such as aerial and satellite imagery, the continued influence of the Erie Canal, changes in land use, and the loss of wetlands.

Wright measured Larkin Creek to be 7.5 miles long, whereas I measured Larkin Creek to be 14 miles long. Similarly, Wright described Buttonwood Creek as being between 10 and 11 miles long, and I measured it to be between 15 and 16 miles long. Wright likely used USGS maps to measure out river miles. The USGS Quadrangles of the time were 15 minute maps with a scale of 1:62,500 (today's Quadrangles are 7.5 minute maps with a 1:24,000 scale). I used Google Earth’s aerial imagery maps to measure out river miles, which could often be zoomed to a 1:600 scale. This finer scale allowed me to follow more of the streams’ meanders, resulting in a longer measurement over the same stretch of streams. To test this possibility I adjusted the scale of the map I was using to match that of the maps Wright used, and measured the stretch of the stream Wright described. With this test, my measurements were much closer to Wright’s. This still however does not describe the entirety of the difference in length of these streams between then and now.

Wright clearly stated the sources of Larkin Creek and Buttonwood Creek as being north of the Erie Canal. Now, the sources of each of these streams are clearly south of the Erie Canal. According to the New York State Canal Corporation (NYSCC) the culverts through which Larkin and Buttonwood Creeks flow are along an original stretch of the Erie Canal that was initially completed 1825. These culverts would have been installed during the original
construction of the canal in the 1820s and would only have been lengthened and modified as needed, with the last being an Erie Canal Contract to Extend Existing Culverts (Contract 60 – 1908) completed in 1913 (NYSCC, Personal Communication, April 16, 2015). The NYSCC records of the installation of these culverts lacked explicit reasons for why culverts were placed where they were. However, the NYSCC Engineer with whom I spoke informed me that culverts would have only been installed in locations with existing water. Yet, the only named stream in the records was Salmon Creek. It stands to reason that with this region having been historically rich with wetlands (Thomas 1871), that the construction of the Erie Canal could have cut off some of these wetlands. These culverts, installed to prevent water from damming up and jeopardizing the integrity of the south wall of the canal, could create an area of concentrated flow (USDA, NRCS, 2012). This new concentrated flow could erode new stream channels, thus extending the existing Larkin and Buttonwood Creeks (Knapen, 2007).

Additionally, the draining of the once plentiful wetlands for agricultural, industrial, and urban/suburban development could also have affected the length of these streams. The presence of wetlands play a big role in regulating surface water flow and maintain a consistent flow of water in the surrounding waterways (Johnston, 1990; Demissie, 1993). The sources of many of these streams were located within areas of wetland (Wright, 2006). The draining of these wetlands could have increased surface water flow, creating new streambed in areas that were previously flooded. These kinds of large scale changes to flow regime have significant impacts on the habitats available to fish.

Wright described streams that were far more constant in nature in 1902-1904 than they are now. Following the theory of a stream continuum, they had regular and predictable changes of the various environmental variables from the source to the mouth of each stream (Vannote 1980).
There were only three environmental variables that remained as important now, in determining fish distribution within the streams I studied as they did 100 years ago. They were river mile, max width and max depth (Figure 5). During Wright's investigations, the other important variables were flow rank, mud, gravel and stone. Presently, I found the greatest determinants of fish distribution, outside of river mile, max depth and max width, to be vegetation, followed distantly by gravel, flow rank and rock. These changes to the continuums of these streams are visible in the CCA analyses (Figures 4 & 5) with the variables of flow rank, mud, gravel and stone being far less descriptive of fish distribution in 2012-2014, than they were in 1902-1904. The variable of flow rank best shows this loss of continuity. Wright described uniform flow patterns for all of these streams from source to mouth. Presently this uniformity has been lost, with all of these streams having variable flow patterns.

Additionally, the environmental variable of vegetation, which was not very descriptive of fish distribution during Wright’s study is now a major factor. One possible reason for this, for which there is evidence within the CCA, is the role of invasive species. The introduction of native invasive species, such as Largemouth Bass and Blugill, appear to have had an effect on the habitat selection of species like Brook Stickleback and Central Mudminnow (Figure 7 and 8). Largemouth Bass were plotted as a lower course fish most closely associated with max depth. Brook Stickleback was plotted as an upper course fish most closely associated with river mile. Central Mudminnow was also plotted as an upper course fish, but was most closely associated with mud. In my study, the Largemouth Bass plotted much further upstream and was more closely associated with vegetation (Figure 8). Concurrently, both Brook Stickleback and Central Mudminnow plotted much further downstream, and were most closely associated with vegetation. This would appear to be a predator avoidance response, with both Brook
Stickelback and Central Mudminnow being most closely associated with an environmental variable (vegetation) that can provide cover from predatory fish like Largemouth Bass.

Figure 7: CCA Ordination Diagram of Wright 1902-1904 data from stream sections matching Carson 2012-2014. Species in red are species that were either missing or too rare to be included in the Carson 2012-2014 analysis.

The Erie Canal likely had a role in the introduction of several native invasive species such as Largemouth Bass and Bluegill into Northrup Creek and Salmon Creek. Water control structures on Northrup Creek and Salmon Creek give the fish that are native to the lower courses of these streams and in the Erie Canal the opportunity to access the upper courses. Wright mentioned several times in his manuscript, the presence of lower course fishes in the upper courses of the streams where there is influence from the canal.

The Erie Canal however, is not the only means by which these lower course fish could have accessed the upper courses of these streams. During my surveys I encountered several
occasions where landowners had man-made ponds stocked with Largemouth Bass and Bluegill, that were tied directly into the streams. Similarly, during the construction of State Route 531, several retention ponds were constructed alongside the highway. The residents of Larkin Creek informed me that the ponds, which are situated just above the source of the stream, will flood and spill over into the stream during especially wet periods, and indeed I caught Blugill in the upper most stretches of Larkin Creek. Northrup Creek, the pond just south of the highway, presently serves as the primary source of the stream for much of the year. The three to four miles of stream above the pond now run dry most of the year. Here I caught Blugill as well as Largemouth Bass in the upper course of Northrup Creek.

Interestingly the effect of the non-native invasive species on the fishes within these
tributaries appeared to be minimal. I did not encounter any Lamprey or Alwife. I did catch Round Goby in every stream I surveyed, however when plotted on the CCA, they appeared to occupy a habitat niche that was previously not utilized in Wright’s survey. Laboratory experiments have shown Round Goby to be highly competitive with several native Great Lakes fishes, including one that is present in these streams both in 1902-1904 and in 2012-2014, the Logperch (Kornis 2012). However, in this case it appears that changes in habitat association of the Logperch in these tributaries are more likely a result of habitat change than of competition from the Round Goby.

The CCA analysis of Wright’s investigation showed four primary communities of fish, one upper course, one mid course, and two lower course communities that appear separated by flow rank. This arrangement of the communities is consistent with the stream continuum theory in that there is a progressive increase in diversity as you move downstream. In the CCA analysis of fish communities in my survey, I found only three fish communities. There is evidence of a disrupted stream continuum, with a very small upper course community, a large mid course community separated by the presence or absence of vegetation, and one small lower course community. Thus, my study revealed the loss of an entire fish community since the time of Wright’s survey (2006).

Over the last 100 years, changes in human activity have had a significant impact on a variety of ecosystems worldwide (Vitousek, 1997). The tributaries of the southern shore of Lake Ontario have been no different. Increased agricultural and industrial activity, urban/suburban sprawl, draining of wetlands, alterations to the physical habitat, and the appearance of native and non-native invasive species, have all had an effect on the fishes and the habitats of these tributaries.
Literature Cited


Kornis, M. S., Mercado-Silva, N., & Vander Zanden, M. J. (2012). Twenty years of invasion: a


