4-2014

Minnow Diversity and Habitat Associations in the West Branch of Sandy Creek, Orleans County, New York

Coral Lenore Reina
The College at Brockport, crei0927@brockport.edu

Minnow Diversity and Habitat Associations in the West Branch of Sandy Creek, Orleans County, New York

By

Coral Lenore Reina

A thesis submitted to the Department of Environmental Science and Biology

of The College at Brockport, State University of New York,

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

April 2014

Minnow Diversity and Habitat Associations in the West Branch of Sandy Creek,

Orleans County, New York

by Coral Lenore Reina

APPROVED BY:

James Haynes, Advisor	Date
Christopher Norment, Reader	Date
James Zollweg, Reader	Date
Joseph Makarewicz, Graduate Coordinator	Date
Christopher Norment, Department Chairman	Date

ACKNOWLEDGEMENTS

I thank Dr. James Haynes (my major advisor) for his unfailing support, time and patience. I thank my thesis committee members Dr. Christopher Norment (Chair, Dept. of Environmental Science & Biology and Dr. James Zollweg (Chair, Dept. of the Earth Sciences) for their enduring assistance and generous encouragement. I also thank Dr. James Zollweg's "Minnows and Stream-Watershed Ecology Team": Renee Allen, Rebecca Bernacki, Adam Durkee, Jennalee Holzschuh and Erin Stockschlader, as well as Lynn Zicari, all of whom assisted with Geographic Information Systems mapping. I am also grateful to my excellent and dedicated field crew members: Nicole Saavedra, Emily McCall, Gretchen Murphy, Cody Smeltzer, Coneie Munio, Erik Long and Ryan Cook. Ross Abbett (U.S. Geological Survey) and Scott Wells (NY Department of Environmental Conservation) provided assistance with fish identification. Daniel Watkins, Lynn Zicari and, and Elaine Enfonde assisted with plant identification for the riparian zone analysis. Finally, I thank my family members who assisted with field and laboratory work: Karmel Robinson and Zachery Robinson as well as my wonderful daughters Lenore and Nicole Reina.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

While often attempted, successfully associating fish species with in-stream and riparian land use habitat variables has been problematic in fisheries literature. To explore such associations in the west branch of Sandy Creek, Orleans County, New York, I sampled 12 in-stream variables in rifle, run and pool habitats, three land use variables along urban, agricultural and forested stream segments, as well as the fish communities associated with the nine in-stream habitat and land use combinations. Cluster analysis yielded cluster grouping patterns and determined which habitat variables and fishes influenced clustering of land uses and in-stream habitats. Creek chub (*Semotilus atromaculatus*), river chub (*Nocomis micropogon*), striped shiner (*Luxilus chrysocephalus*), and white sucker (*Catostomus commersonii*) had statistically significant associations with land use or habitat variables. Additionally, the point-quarter method was used to compare riparian plant community composition at three agricultural and three forested land use sites. I characterized water quality, soil organic content and riparian zone plant cover. Forested sites had greater riparian species evenness and richness, as well as significantly lower amounts of nitrate in steam water, relative to agricultural sites. The determination of habitat requirements is important for species preservation. Finding significant fish species associations with land use and stream habitat variables demonstrates habitat preference.

KEY WORDS

Cyprinidae, stream habitat-fish species/land-use-fish community associations.

INTRODUCTION

Minnows

Minnows are often thought of as any small fish; however, they are technically only those fish in the family Cyprinidae (ITIS 2014). This huge freshwater fish family has a vast distribution, many distinctive physical traits, and important ecological and anthropogenic significance (Smith 1985, Hasse and Stegemann 1992, Thai *et al.* 2007). While many physical characteristics of minnows have been studied, much about their habitat preferences is unknown (Hasse and Stegemann 1992, Wells 2009).

Taxonomy

Cyprinidae is the largest fresh water fish family in the world. Cyprinids are placed in Superclass Osteichthyes: bony fishes, which contain the Class Actinopterygii, the ray-finned fishes. Actinopterygii contains Subclass Neopterygii, modern ray finned fishes, and Infraclass Teleostei: fishes in which a protractile jaw is possible due to adaptations of the maxilla, premaxilla and jaw musculature. The vertebral column terminates at the caudal peduncle, and the caudal fin is homocercal. Minnows are further placed in Superorder Ostariophysi, wherein all species have a series of bones that connect the swim bladder to the inner ear. Together with associated vertebral column adaptations these are called the Weberian apparatus and augment hearing. Ostariophysi contains Order Cypriniformes: cyprins, meuniers, minnows, and suckers. Diagnostic traits include the lack of teeth in the oral cavity, with both the jaws and palate always toothless. Minnows exhibit specialized pharyngeal teeth that arise from the posterior gill arches that oppose a basioccipital process, rather than dorsal pharyngeal elements (Smith 1985, Fishbase 2013). Pharyngeal teeth masticate food against a horny pad formed on the basioccipital process (Page and Burr 2011). The number of teeth and their arrangement are species-specific and useful in identification (Smith 1985, Fishbase 2013). The opercular canal (cephalic lateral line canal on the operculum) is usually present, as are scales on the head; however, an adipose fin is generally absent (Smith 1985, Cypriniform Tree of Life 2013, Fishbase 2013). Order Cypriniformes contains several families, including Cyprinidae, the carps and minnows.

Distribution

Family Cyprinidae has the most widespread distribution of any freshwater fish family and is present on all continents except South America, Australia and Antarctica (Berra 1981, Mecklenburg *et al.* 2002, Page and Burr 2011). Worldwide, Cyprinidae has 318 genera and ~2,900 species (Fishbase 2013, Integrated Taxonomic Information System 2013). North America is home to 261 native species and 10 introduced species (Page and Burr 2011). In New York State, Cyprinidae is by far the largest fish family with ≥ 48 species (Smith 1985; Mecklenburg *et al.* 2002). Several species are exotic, including grass carp (*Ctenopharyngodon idella*), common carp (*Cyprinus carpio*), goldfish (*Carassius auratus*), ide (*Leucis cusidus*), rudd

(*Scardinius erythrophthalmus*), tench (*Tinca tinca*), and bitterling (*Rhodeus sericeus*) (NYSDEC 2013). Due to their ubiquity cyprinids often are important ecologically.

Distinguishing physical characteristics

Several physical traits distinguish cyprinids, including paired pelvic fins on the abdomen, one dorsal fin, cycloid scales on the body, a lateral line (rarely absent), and no true spines (some Asian species have serrated, spine-like hard rays) in the fins (Smith 1985, Fishbase 2013, NYDEC 2014). Most species are small; in North America the average size is 10 cm (NYDEC 2014). The Indonesian cyprinid *Paedocypris progenetica* is the smallest known fish in the world, with females reaching a maximum of 10.3 mm (Fishbase 2013). However cyprinids can be quite large. Common carp reach 1.1 m and 35 kg (USGS 2012). The largest North American cyprinid is the endangered Colorado pike-minnow (*Ptychocheilus lucius*) which historically reached 39 kg and 1.8 m (Colorado Department of Natural Resources 2014). Furthermore creek chub (*Semolitus atromaculatus*), fallfish (*S. corporalis*) and river chub (*Nocomis micropogon*) commonly exceed 30 cm (NYDEC 2014).

<u>Nuptial tubercles</u>

Males of many minnow species develop nuptial tubercles during the breeding season. The tubercles are keratinized structures derived from epidermal cells and develop primarily on the anterior regions of the head (Wiley and Collette 1970, Smith

1985). They occur in a wide variety of predictable patterns that are useful in species identification (Smith 1985). Tubercles may be involved in aggression between males, nest building, and contact between sexes during spawning (Wiley and Collette 1970, Smith 1985). While other families of fish have nuptial tubercles they are particularly well developed in minnows (Smith 1985).

<u>Schreckstoff</u>

Minnows also have dermal alarm cells that release a fright substance (schreckstoff) when ruptured, as in a predator attack (NYDEC 2014). During the breeding season males stop producing schreckstoff because the male’s skin may be broken during nest building or during competition for mates; if the male was still producing schreckstoff any females in the area would initiate predator avoidance behavior (i.e., depart quickly) upon its release (NYDEC 2014). These unusual physical traits highlight this distinctive family of fish and reinforce the conclusion that the Cyprinidae is a fascinating subject of study.

Anthropogenic importance

Minnows have substantial anthropogenic importance. They impact game fish populations, serve as food fish, populate aquariums, and provide scientific specimens. Throughout Eurasia cyprinids are a significant aquaculture food fish and have been raised for this purpose for centuries (NYDEC 2014). Minnows, notably the goldfish, koi (*Cyprinus carpio carpio*), danio (*Danio* spp.) and rasbora (*Rasbora* spp.) are also common aquarium fish, (NYDEC 2014). Additionally danios and goldfish are widely used as model organisms by geneticists, physiologists and developmental biologists (Thai *et al.* 2007).

Minnows also impact the aquatic environments in which they live (Hasse and Stegemann 1992, Mecklenburg *et al.* 2002). They are an important link in the food chain, converting small animals and plants (invertebrates, algae, aquatic macrophytes) into protein that larger piscivorous fish, as well as birds, can access (Smith 1985, NYDEC 2014). Impacts on game fish populations are mixed due to the fact that minnows may predate young of the year and consume eggs. On the other hand minnows can also provide an alternate prey source and relieve predation on small game fish (NYDEC 2014). Human perception of cyprinids is varied, depending on the viewpoint taken. However it is clear that due to their ubiquitous presence cyprinids have environmental importance.

The riparian zone

The riparian zone is the interface between terrestrial and aquatic habitats. Aquatic environments are connected to upland areas through subsurface water and overland flows that pass through the riparian zone. Hydrophilic plants and hydric soils generally characterize these areas (Gregory *et al*. 1991). Ecosystem benefits provided by canopy cover from riparian zones include shading that result in decreased water temperatures and consequently increased dissolved oxygen. Many important game fish, notably salmonines, benefit from these conditions (Abbett 2010). The riparian zone is a source for in-stream wood that provides habitat for benthic macroinverebrates and fish. Additionally the riparian flora provides stream bank stabilization from roots as well as increased carbon cycling (Gerlak *et al.* 2009, Mouton *et al.* 2009, Sparks 2010).

Land use influences

Pollution sources as well as historical land use influence stream water quality (McLaren and Singer 2007). Increases in turbidity and sediment load are often found in streams adjoining agricultural land (Gerlak *et al.* 2009; Sparks 2010), and narrow riparian zones are often linked to decreased water quality. Thus, the ecological status of aquatic systems is beneficially impacted by natural bank restoration (Mouton *et al.* 2009). Conversely, agricultural landowners are often concerned that riparian zones will provide weed seed dispersal and habitat for pests. Furthermore millions of dollars have been spent on the removal of invasive riparian zone plants like the salt-cedar (*Tamarix*), considered a "water waster" (Stromberg *et al.* 2009). However the importance of riparian zones for maintaining stream water quality is widely recognized, regardless of the worth attributed to these interface systems (Gregory *et al*. 1991, Lee *et al.* 2003, Smiley *et al*. 2011).

Water quality impacts of the riparian zone

Riparian zones are used worldwide to decrease the discharge of point and non-point source pollutants into streams, primarily those transported by surface run-off

(Jankauskas and Jankauskiene 2003, Lee *et al.* 2003, McLaren and Singer 2007, Smiley *et al*. 2011). Riparian zones have the potential to convert or sequester up to 75% of nitrogen and 70% of phosphorous from non-point runoff (Lee *et al.* 2003) and they reduce pesticide, nutrient, and sediment loading of streams (Gregory *et al*. 1991, Lee *et al.* 2003, Smiley *et al*. 2011). Decreasing overland speed of runoff water by riparian buffers can reduce sediment loads by 50-80% (McLaren and Singer 2007).

Study objectives

Many minnows are morphologically similar and little studied (Hasse and Stegemann 1992, Mecklenburg *et al.* 2002, NYDEC 2014). While a number of species of minnows are used as bait fish and several are caught by anglers, “the vast majority of minnows never even receive a passing glance from most humans” (Hasse and Stegemann 1992). Accordingly, there is a need for additional information on species associations in stream communities and habitat preference of cyprinids (Wells 2009). The principal objective of my study was to explore potential relationships between land use (urban, agricultural, forested), stream habitat (riffle, run, pool), other stream habitat parameters (e.g., substrate composition, depth, width, turbidity), and species-specific cyprinid habitat requirements. I also examined potential effects of anthropogenic disturbance and the resulting riparian plant community composition on selected aspects of soil composition and water quality parameters.

Study area

My study stream was the west branch of Sandy Creek (Figure 1). Sandy Creek in western New York has several minor tributaries and two main branches that combine to form the principal creek which flows into Lake Ontario. The west branch flows north from headwaters in Barre, NY into the Village of Albion (Orleans County), NY. In Albion it passes under the Erie Canal, thereafter flowing in a north-easterly direction. Both of the west and east branches receive water, fish, and sediment from the Erie Canal, except during the winter when the canal is drained. West of Route 237 and south of Ridge Road (Route 104) in Murray (Orleans County), NY the west branch joins the east branch. After this confluence the main creek continues in a northeasterly direction through the Towns of Kendall and Hamlin to a drowned river mouth at its confluence with Lake Ontario.

METHODS

Sampling site selection

From 30 May 2010 to 6 July 2010 I surveyed the west branch of Sandy Creek from where the creek passes under Erie Canal in the village of Albion (Orleans County) to its confluence with the east branch just south of Ridge Road (Route 104) in Murray (Monroe County). During the surveying process the locations of three aquatic habitat types (riffle, run, and pool) were recorded with a Garmin Etrex

Legend handheld Global Positioning System (GPS) receiver. Subsequently I identified three land use categories (urban, agricultural, and forested) in the study area using a combination of Geographic Information System (GIS) maps and field observations (Figure 2). GIS data sources included the New York State Geographic Information System Clearinghouse (2007) and Orthoimagery of New York State. The GIS maps contained stream bank conditions as indicated in the maps created by Dr. James Zollweg's "Minnows and Stream-Watershed Ecology Team". I added the GIS data regarding location of the aquatic habitats to these maps for use in analysis and re-location of the waypoints (Figure 3). Next, using random numbers generated by Excel, and a stratified random selection process, I determined the waypoints to be sampled. Within each of the land types, three of each of the aquatic habitat types (riffle, run, and pool) were selected randomly for sampling. Thus the sampling design was three land-use types by three stream habitats by three replicates, or 27 randomly chosen, independent sampling locations in the west branch of Sandy Creek (Table 1).

Fish survey protocol

Using the GPS way points determined in May-June 2010 the 27 sampling sites were relocated and sampled from 8 July 2010 to 19 August 2010 and 31 May 2011 to 31 July 2011. Each habitat selected was sampled with a beach seine (6.4 x 1.2 m, 0.63 mm mesh, no bag) and backpack electro-fisher (Halltech HT 2000). I seined perpendicular and parallel to the shore until the desired effort was attained. Three effective seine hauls (about 30 min total time) constituted part of one unit of effort. An effective haul was one that was not spoiled by debris and caught fish. When necessary the seine path was cleared of loose in-stream wood or rocks to facilitate effective hauls and reduce fish loss, as recommended by Angermeier and Schlosser (1989). Fifteen minutes (power on) of electrofishing per sampling section constituted the remaining portion of one unit of effort. I used both sampling techniques along 100 m of stream at each sampling site. I identified fish to species in the field and counted them, or I preserved (in 10% formalin) a representative sample of unidentified minnows in the field, brought the samples back to the laboratory and identified the fish using an American Optical Corporation forty power microscope and the key of Smith (1985).

Habitat variables survey protocol

I assessed physical and chemical attributes of the sampling sites following methods recommended by Murphy and Willis (1996). I collected data on cloud cover, air and water temperature, dissolved oxygen, turbidity, pH, depth, stream velocity, stream width and substrate composition, as well as the in-stream wood, aquatic vegetation, canopy cover, riparian zone width and nearby land uses.

At each field site I determined water temperature (^{o}C) and dissolved oxygen (mg/L) using a handheld YSI 55 dissolved oxygen meter. I recorded depth and velocity every 60 cm across the span of the creek and averaged the data for each sampling site. I measured depth with a meter stick from water surface to substrate. I measured velocity (m/s) with a pigmy Gurley meter with readings taken 5 cm above the substrate. I calculated the average velocity and depth (Appendix I-A). I measured creek width with a 50 m retractable tape measure. I estimated substrate particle size composition in two ways: 1) picking up and measuring all rocks (where possible) along a 1m transect at each sampling site and 2) visually estimating percent area of large immobile rocks, sand, gravel and silt. Each particle size class was assigned a number, using the Wentworth classification (Appendix I-B) and a weighted average was computed (Appendix I-C) to provide one number as an overall index of substrate composition for each site. I used visual estimation of the percent bottom covered in a 50 m reach of the creek at each sampling site to determine the percent of in-stream wood and percent in-stream aquatic vegetation. I estimated canopy cover by looking 25 m upstream and 25 m downstream from the center of the sampling site and estimating the percent area of the creek with overhanging canopy. I estimated riparian zone width (meters inland from shore) for both sides of the stream using visual observation and GIS maps. Water analysis was done in the Water Quality Laboratory at the College at Brockport. I recorded the pH of water samples before the end of the day in which they were obtained with a Beckman ϕ 45 pH Meter and analyzed the turbidity (NTU) of water samples with a Micro 100 Turbidimeter.

Riparian zone plant community and soil survey protocol

I used field assessments of fish sampling sites and GIS maps to determine an appropriate subset of sites for riparian vegetation, soil and water quality analyses. I used the Excel random number generator function to choose six sites for sampling riparian vegetation and soils at forested (N=3) and agricultural sites (N=3). At each sampling site the forested or agricultural riparian zone classification was continuous for at least 200 m upstream on both sides of the creek. I determined the riparian zone classification (agricultural or forested) with field observations and GIS maps that show stream bank erosion classification and land use. GIS data sources included the New York State Geographic Information System Clearinghouse (2014). Urban sites were not examined for riparian plant community due to time constraints.

Primary field work for the riparian zone examination was done on 8 and 9 October 2010. Fifty m transects perpendicular to water's edge on the left bank (facing downstream) of the creek were used to sample sites. Using Excel's random number generator five points along each transect were sampled. The point quarter method (Kent and Coker 1992) was used to record small trees <10cm diameter at breast height (DBH, 1.37m above ground) and large trees ≥10cm DBH. Four large and four small trees were recorded for each center point, one each in each quarter. The distance of the nearest small and large tree in each quarter to the center point was recorded, the DBH to the nearest 0.1cm of each tree was recorded with a measuring tape, and all sampled trees were identified to species. A densiometer was used at the center points of each sample site to determine amount of canopy cover. Additionally, at each site, I flagged a 1x1 m square and estimated cover of the understory vegetation (<1.37 m tall). Plants were categorized as woody plants (trees and shrubs), graminoid (grasses, sedges, and rushes), and forbs (herbaceous [annual] plants that are not a graminoid, including ferns) using the classes (0) none, (1) 1-5%, (2) 5-25%, (3) 25-

25%, (4) 50-75%, and (5) 75-100%. Dominant or notable species were recorded as well. Riparian tree species diversity was determined using the Shannon-Wiener index (H' = - Σ p_i ln p_i, where p_i = the proportion of individuals of species *i*). I determined density and dominance (density for a species x the average basal area for a species) of riparian tree species following the procedures of Mueller-Dombois and Ellenberg (1974).

I determined turbidity of water samples collected on 8-9 October 2010 with a Micro 100 Turbidimeter. In addition soluble reactive phosphorous (SRP), total phosphorus (TP), total nitrogen (TN) and nitrate (NO_3^-) were analyzed with a Bran Leubbe Technicon Autoanalyzer II in the Water Quality Laboratory at the College at Brockport. I collected soil samples 2 m from the water's edge at each sampling site to a depth of 20cm, and then I sieved the soil to remove roots, rocks and woody fragments. Soil samples were then dried in a Fisher Scientific Isotemp Oven for 48 h at 105° C to constant mass. To ascertain soil organic composition by Loss on Ignition (LOI) I weighed two sub-samples of soil for each location with an AGN 100 professional analytical balance, combusted them in a Mettler Toledo oven for 2 h at 360° C and re-weighed the samples to determine the difference in weight.

Statistical analysis

Several assumptions and factors influenced the design of the study and statistical analysis of the data. First, a representative sample of the fish assemblage was obtained through the use of two sampling techniques at each site. Second, the stratified random selection of the fish sampling sites also provided random sampling of habitat data. Third, the relatively stable water temperatures and dissolved oxygen levels throughout the sampling area negated thermal advantages for fish movement, which minimized intra-stream fish movement. Fourth, only fish species found at ≥4 sites were used in analysis because species found at only a few sites would not contribute to understanding species and community relationships to stream habitat and land use categories. Fifth, data transformations did not successfully normalize my data, which constrained the multivariate and univariate statistical tests that could be used to analyze the data collected.

Multivariate analysis of fish communities

I entered all data into Microsoft Excel spreadsheets divided into two matrices (minnows and non-minnows) of 27 rows (27 sampling sites) and 30-40 columns, including land use (forested, agricultural, urban) and stream habitat (riffle, run, pool), environmental variables (cloud cover and air temperature; stream width, depth, dissolved oxygen, turbidity, pH, velocity and substrate composition; in-stream wood and aquatic vegetation; and canopy cover and riparian zone width), and species (11 for minnows, 21 for non-minnows). I computed the proportional representation of each species in the minnow and non-minnow community separately for each sampling site. Habitat variables were entered as observed. To facilitate data analysis some data were then converted to a code that represented the type of land use, aquatic habitat, or the percent observed for five habitat variables (Appendix I-D).

Next I used IBM® SPSS® Statistics with agglomerative hierarchical cluster analysis because it is a multivariate technique that does not require sample data with normal distributions or equal variances (Personal communication, Dr. Jacques Rinchard, Department of Environmental Science and Biology, SUNY Brockport.). I used separate cluster analyses for minnows and non-minnows which occurred at $\geq$4 sampling sites to determine which species and habitat variables influenced clustering relationships among sampling sites. To establish the important variables for each analysis, habitat variables were removed until removing one changed the clustering relationship followed by removing species until removing one changed the clustering relationship.

Univariate analysis of fish communities

After important species and habitat variables were determined by cluster analysis, I determined if land use (urban, agricultural, forested) or steam habitat (riffle, run, pool) variables were significantly related to individual species distributions using the Wilcoxon Rank Sum Test. This test was used due to its acceptance of non-parametric data; however, it can only accommodate two treatments; therefore some variables were combined. For land use, urban and agricultural sites were combined (both have high anthropogenic disturbance) compared to forested sites with lower disturbance. For stream habitat riffles and runs were combined and compared with pools, additionally runs and pools were combined and compared with riffles because runs have features both in common with and different from riffles and pools. Analyses were done for both minnow and non-minnow species found at four or more sampling sites. With the multiple tests the chance of a Type 2 statistical error (error of false significance) was higher; therefore, I used a modified Bonferroni-corrected alpha (α/number of significant results) to determine statistical significance.

Riparian zone plant, water quality and soil analyses

I tested null hypotheses that there would be no statistically significant differences in water quality parameters and riparian plant community composition for different land use types (agricultural vs. forested) using goodness-of- fit and two sample T- tests in Excel.

RESULTS

During two summers of sampling (2010 and 2011) 11 minnow and 21 non-minnow species were captured and identified at the 27 sampling sites (Table 2). The most commonly encountered native cyprinids in the study area were creek chub, central stoneroller (*Campostoma anomalum*), sand shiner (*Notropi stramineus*) and river chub (Table 3). The most commonly encountered non-minnow species included rainbow darter (*Etheostoma caeruleum*), round goby (*Neogobius melanostomus*), tessellated darter (*Etheostoma olmstedi*), and white sucker (*Catostomus commersonii)* (Table 4).

Clustering of sampling sites based on fish species and habitat variables

Among the 14 measured habitat variables only stream depth, stream width, substrate composition and turbidity influenced relationships among sampling sites for both minnows and non-minnows. Percent aquatic vegetation, percent woody debris; physical and chemical conditions (percent cloud cover, air and water temperature, dissolved oxygen, pH), percent canopy cover and width of riparian zone did not influence clustering of the 27 sampling sites and were not considered further.

Once the four meaningful habitat variables were determined, a separate cluster analysis using only those variables was done for minnows found at more than four sites to explore associations with the 27 sampling sites. Minnows not included in this cluster analysis because they were captured at four or fewer sites were fathead minnow (*Pimephales promelas*), eastern silvery minnow (*Hybognathus regius*) and common shiner (*Luxilus cornutus*). The spotfin shiner (*Cyprinella spiloptera*), which occurred at more than four sites, had no effect on clustering and was also removed from the analysis. Minnows finally included in the analysis were creek chub, striped shiner (*Luxilus chrysocephalus*), hornyhead chub (*Nocomis biguttatus*), river chub, central stoneroller, sand shiner and bluntnose minnow (*Pimephales notatus*). Removal of any of these species caused clustering to change. The cluster dendrogram that was the same as the initial cluster dendrogram (after eliminating both habitat variables and species that did not affect clustering) was retained for interpretation (Figure 4).

An additional cluster analysis was done with non-minnows. For non-minnows the johnny darter (*Etheostoma nigrum*), which occurred at more than four of the 27 sampling sites, had no effect on clustering and was removed from further analysis. Non-minnows not included in this cluster analysis because they were captured four or fewer sites were central mudminnow (*Umbra limi*), mottled sculpin (*Cottus bairdi*), northern pike (*Esox lucius*), green sunfish (*Lepomis cyanellus*), black crappie (*Pomoxis nigromaculatus*), gizzard shad (*Dorosoma cepedianum*), smallmouth bass (*Micropterus dolomieu*), largemouth bass (*Micropterus salmoides*), yellow perch (*Perca flavescens*), and brown trout (*Salmo trutta*). Non-minnows included in the analysis were white sucker, rainbow darter, round goby, northern hog sucker (*Hypentelium nigricans*), tessellated darter, stonecat (*Noturus flavus*), fantail darter (*Etheostoma flabellare*), rock bass (*Ambloplites rupestris*), pumpkinseed (*Lepomis gibbosus*) and bluegill (*Lepomis macrochirus*). Removal of any of these species caused the clustering to change. The cluster dendrogram that was the same as the initial cluster dendrogram (after eliminating both habitat variables and species that did not affect clustering) was retained for interpretation (Figure 5).

The final cluster analysis used the four cluster-affecting habitat variables and the cluster-affecting minnow and non-minnow species (Figure 6). Associations that were found in all analyses were considered consistent. Agricultural land use had five consistent land use/habitat associations, forested had four and urban had two. Sampling sites that consistently clustered together were agricultural run sites 9 and 10 and agricultural pool sites 11, 12 and 13; forested run sites 8 and 18 and forested pool sites 26 and 27; and urban pool sites 3 and 5. The greatest number of consistent clustering associations was for agricultural land use and pools: 100%, or three out of three possible matches. Forested runs, forested pools, agricultural runs, and urban pools were associated 67% of the time (2/3 of possible matches) in all cluster analyses.

Associations of fish species with land use and stream habitat variables

Three minnows had significant P-values before and after applying the Bonferroni-corrected alpha (0.05/3 tests = 0.0167) to the Wilcoxon Rank Sum Test results. The river chub ($P = 0.0048$) and striped shiner ($P = 0.0162$) preferred habitat adjacent to urban and agricultural land uses rather than forested land use sites, and the creek chub preferred riffle habitat rather than run/pool habitat ($P = 0.0035$) (Table 5).

Before applying the Bonferroni-corrected alpha four non-minnows had P-values <0.05: white sucker, riffle/run over pool habitat ($P = 0.0076$); stonecat, pool/run over riffle habitat ($P = 0.0415$); rock bass, forested over agricultural/urban land use ($P = 0.0237$); and rainbow darter, pool over riffle/run habitat ($P = 0.0182$) and run/pool over riffle habitat ($P = 0.0224$). After applying the Bonferroni-corrected alpha (0.05/5 tests = 0.01), only the white sucker association with riffle/run over pool habitat remained statistically significant (Table 6).

Riparian zone analysis

Average graminoid ground cover was greater at the agricultural sites (75- 100 %) than at the forested sites (0%). Forested sites (vs. agricultural) had greater average woody (1-5 % vs. 0%) and forb cover (5-25% vs.1-5%) (Appendix II-A). Average large and small woody debris was greater at forested (7 and 6 pieces of debris respectively) than at agricultural sites (0 and 0 respectively). Canopy cover was greater at forested (73.3%) than at agricultural (6.6%) sites (Appendix II-B).

The wooded sites were second growth forest dominated by American beech (*Fagus grandifolia)* and white ash (*Fraximus americana*). Two of the agricultural sites were corn fields (*Zea maize*) and one was an apple (*Malus domestica*) orchard. The density of large trees (≥10cm DBH) was greater in the apple orchard (659.2 trees/ha) than in the forested sites (622.4 trees/ha). Additionally, the density of small trees (<10cm DBH) was greater in the apple orchard (835.3 trees/ha) than in the forested sites (648.0 trees/ha) (Appendix II-C).The two tree species with greatest relative density in forested sites for ≥10cm DBH were white ash followed by American beech; for <10cm DBH they were American beech followed by shagbark hickory (*Carya ovata*). The two tree species ≥10cm DBH in wooded sites with the highest relative dominance (relative basal area) score were white ash followed by red oak (*Quercus rubra*); for trees <10cm DBH they were shagbark hickory, and American Elm (*Ulmus americana*). In the agricultural areas with corn fields, the scarcity of trees prevented calculation of relative density and dominance. In the agricultural apple orchard site the tree species with the greatest relative density for ≥10cm DBH were apple and white ash; for trees <10cm DBH they were apple, white ash, and dogwood (*Cornus* spp.). Trees with highest relative dominance scores ≥10cm DBH were apple and white ash; for trees <10cm DBH they were apple, white ash, and dogwood (Table 7).

The agricultural sites had lower species richness and evenness (Shannon-Wiener Diversity Index: H'=0.50 for trees ≥10cm DBH and H'=0.61for trees <10cm DBH) than forested sites (H'=1.81 for trees ≥10cm DBH, and H'=1.87 for trees <10cm DBH). Species richness for wooded sites (N=11) was significantly higher than for agricultural sites (N=5) sites (X^2 Goodness of fit=4.57143, *df* =1, *P* 0.033).

Using the Two sample T – test I found that the stream water nitrate was significantly higher at agricultural sites than at wooded sites (T=4.90, *df* =2, P=0.039) (Table 8). Total phosphorus (T=3.28, *df* =2, P = 0.082), loss on ignition (T=-1.06, *df* =2, P=0.401), total nitrogen (T=2.58, *df* =2, P=0.123), total suspended solids (T=0.33, *df* =3, P=0.761), and soluble reactive phosphorous (T=-0.23, *df* =3, P=0.831) were not significantly different between these land use areas. Although turbidity (T=-1.06, *df*=2, P=0.401) was not significantly correlated with land use there were greater turbidity values for all agricultural sites as opposed to forested (Table 9).

DISCUSSION

Clustering of sampling sites

The strong clustering of fish species (minnow and non-minnow) in relation to agricultural pools and less strongly for agricultural runs may have been influenced by water quality (Smith 1985, Angermeier and Schlosser 1989, Berra 2008, Page and Burr 2011). As expected (Jankauskas and Jankauskiene 2003, McLaren and Singer 2007, Smiley *et al.* 2011) the agricultural sites (highly disturbed) yielded data suggesting higher levels of total phosphorous, total suspended solids, total nitrogen and turbidity, as well as significantly higher levels for nitrate than for forested sites. This may be due to run-off from ongoing agricultural use of fields adjacent to the creek. Additionally, forested sites (minimally disturbed) had higher soil organic matter than agricultural land use sites presumably due to increased deposition of litter and decreased erosion (Smiley *et al.* 2011, Lee *et al.* 2003). This was predicted due to decreased overland water velocity and increased deposition as a result of relatively higher numbers of physical impediments (e.g. riparian flora) (Jankauskas and Jankauskiene 2003, McLaren and Singer 2007, Gerlak *et al.* 2009, Smiley *et al.* 2011). These differences between agricultural/urban and forested areas have been attributed to removal of natural land cover, fertilization and run-off (Gregory *et al*. 1991, Lee *et al.* 2003, Mouton *et al.* 2009). At some agricultural land use sampling sites fields were planted to within a meter of the creek's edge and in one agricultural area the entire riparian area was bulldozed and adult trees growing in the creek were taken down. This extremely high level of disturbance removed all stream bank stabilization (Smiley *et al.* 2011). A likely consequence of this was that creek beds in agricultural areas often consisted of deep (≥0.5 m) mud and silt. However, graminoid cover at agricultural sites was greater than at wooded sites. This was most likely due to best agricultural practices that advise the use of grass cover in orchards (one of the three agricultural sites sampled was an orchard) to reduce soil erosion (Mueller-Dombois and Ellenberg 1974, Jankauskas and Jankauskiene 2002).

Forested runs and pools had less anthropogenic disturbance than agricultural and urban stream habitats, and also some consistent clustering. A contributing factor may have been that some fish species prefer cooler shaded water (Scott and Crossman 1973, Smith 1985, Page and Burr 2011) and densitometer readings in the riparian zone were higher in the wooded sites than in the agricultural sites. The fruit trees in the agricultural sites were pruned and undersized, supposedly for ease of picking, and did not provide much stream canopy cover. However, the sampling area was not pristine and occasionally I came across a mowed lawn bordering the creek in what appeared to be an otherwise undisturbed area. This disturbance may have contributed to fewer clustering associations for forested sites vs. agricultural sites.

The only consistent urban land use/ stream habitat association indicated by cluster analysis was for riffles. The urban creek substrate was generally rocky and the water appeared to have low turbidity. However, there were occurrences of human refuse (from construction supplies and bicycles to an entire toilet) and frequent anthropogenic disturbance, including a riparian zone that was generally mowed, appeared sprayed with herbicide (there were clearly delineated areas where all the plants were dead or brown), or appeared deliberately planted for aesthetic purposes. In some areas the stream bank soil was dug up or dumped in piles, and stream bank stabilization had been attempted by use of wire mesh and stone. These impacts may have contributed to a weak cluster analysis result for this land use.

Significant associations of fish species with land use and stream habitat variables

Creek chub – habitat associations The significant association with riffle habitat for this habitat generalist (Smith 1985, Wells 2009, Hasse and Stegemann

1992) fits well with knowledge of its life history. Creek chub prefer shallow water (Scott and Crossman 1973, Smith 1985, Mecklenburg *et al.* 2002) with a preference for pools and pool-riffles with bank and weed cover (Wells 2009), and they spawn in shallow water over gravel in riffles (Smith 1985).

River chub – land use associations The significant association with urban/agricultural land use as opposed to forested is not in complete agreement with other studies which indicate that the river chub has a preference for large gravel-bottomed or rocky rivers and requires clean clear water (Scott and Crossman 1973, Smith 1985, Hasse and Stegemann 1992). However all of Sandy Creek is usually quite turbid and I did not find a significant difference in turbidity between agricultural and wooded land use sites. Also, Wells (2009) did not find an association between the river chub and habitat variables in the nearby Tonawanda and Johnson Creek watersheds.

Striped shiner land use associations The significant association with urban/agriculture land use areas as opposed to forested may have occurred because two of the three forested sites sampled were downstream from the urban/agriculture sites, and therefore were in a higher order stream with faster current and deeper pools relative to lower order streams. Therefore agreement was found with Wells (2009), who stated that the striped shiner is a habitat generalist in streams and is often found close to but not in main currents. Additionally, Smith (1985) and Wells (2009) both indicated that striped shiners tolerate moderate flows but avoid extremes such as deep torpid pools with soft bottoms or fast water in riffles.

White sucker- habitat associations The significant association for this fish with riffle/run as opposed to pool is supported by the majority of studies. White suckers are adaptable generalists commonly found in shallow water (Smith 1985, Wells 2009). Although adult white suckers are known to congregate in pools with moderate current during the winter, they prefer to spawn in riffle habitat <60cm deep over clean gravel or sand substrate (Smith 1985).

Riparian zone analysis

Several aspects of the riparian analysis confirmed that forested sites are less disturbed and more dynamic ecologically than agricultural sites. In the apple orchard the highest relative dominance and relative density was for apple trees for both ≥10cm DBH and <10cm DBH trees, indicating a lack of community composition change in the near future. This is in contrast to the wooded sites with a predicted shift, based on highest relative dominance and relative density, in future community composition from American elm (≥10cm DBH) and red oak (<10cm DBH) to American beech (for both ≥10cm DBH and <10 cm DBH). The predicted shift could be due to an advance in succession from two intermediate shade tolerant tree species to a shade tolerant one. Additionally the overall diversity of the riparian zone was higher in the forested sites as opposed to agricultural ones. The increase in species richness may be due in part to dispersal potential, niche heterogeneity, and competition found in natural settings (Gregory *et al.* 1991, Bestelmeyer *et al*. 2011). This conclusion is supported by Shannon-Wiener Diversity Index data, which showed greater values for both the trees ≥ 10 cm DBH, and for trees < 10 cm DBH in the wooded sites, than in the agricultural sites. Also the forested sites had a greater amount of total woody debris in the large and small categories, as well as greater woody and forb cover, than the agricultural sites.

CONCLUSIONS

Although many factors influence the habitat where a species may be found, four stream habitat variables (stream depth, width, substrate composition, turbidity) influenced clustering association for the fish communities I sampled at 27 sites in the west branch of Sandy Creek. These sites varied by land use (forested, agricultural, urban) and habitat (riffle, run, pool). Four species (creek chub, river chub striped shiner, white sucker) had statistically significant associations with a stream habitat-land use condition. The associations found reinforce the conclusion that some fish species have specific associations with habitat variables. On the other hand many stream fishes are habitat generalists and are therefore found in a variety of habitats, as was the case in my study.

Significant differences in nitrate were found in stream water at forested as opposed to agricultural sites. The riparian plant community diverged between forested and agricultural land use areas. I forecast that this difference will persist because the young tree species <10cm DBH are different in the two land use regimes. Furthermore this is in agreemnet with other studies that have found that there is a greater percent of woody and forb cover in forested land use areas as opposed to agricultural land use areas (Smiley *et al.* 2011, Lee *et al.* 2003). Wider natural riparian buffers, including more herbaceous and woody cover, would augment water quality.

Reduced overland runoff would lower soil erosion rates and increase retention of organic matter in forest soils as well as fertilizers applied to agricultural fields.

RECOMMENDATIONS FOR FUTURE STUDIES

Research – Future studies might include validation of habitat requirements for habitat-specific minnow species, perhaps allowing these fishes to be used for habitat quality assessments. Continued research will enable tracking of possible shifts in species distributions as global change impacts our current and future environment. Species distribution changes can have wide ranging impacts (NYDEC 2014) beyond the trophic level of the specific species as evidenced by the widely recognized impacts of invasive species (Fausch and White 1986).

Methodology – Future stream sampling should include initial placement of blocking seines that span the width of the stream at the upper and lower reaches of sampling sites. This recommendation is because I did not catch many large fish. Furthermore, I observed adult common carp when I was mapping the creek but did not capture any when sampling. I believe they simply left the area when we started sampling, which implies that other large fish may have done the same to avoid capture. Also, nets encompassing the sampling site would prevent released specimens from reentering. While I released all captured fish downstream from the sampling site as recommended by Wells 2009, this is not guaranteed to be 100% effective. Finally, I strongly recommend duplication of all data collected on multiple media, specifically not relying solely on data storage in portable electronic devices.

LITERATURE CITED

Abbett, R. 2010. An Investigation of Salmonine Reproduction and Factors Limiting their Production in Sandy Creek, Monroe County, New York. M.S. thesis. The College at Brockport, State University of New York, Brockport, NY.

Angermeier, P. L., and I. J. Schlosser. 1989. Species-area relationships for stream fish. Ecology 70: 1450-1462.

Berra, T. M. 2008. Freshwater Fish Distribution. University of Chicago Press, Chicago, Illinois.

Bestelmeyer, B. T., J. R. Miller, and J. A. Wiens. 2003. Applying species diversity theory to land management. Ecological Applications 13: 1750-1761.

Colorado Department of Natural Resources. 2014. Colorado pikeminnow (*Ptychocheilus lucius*). [Online.] Colorado Water Conservation Board. Denver, Colorado. Available at: http://www.coloradoriverrecovery.org/general-information/the-fish/colorado-pikeminnow.html

Fausch, K. D., and R. J. White. 1986. Competition among juveniles of coho salmon, brook trout, and brown trout in a laboratory stream, and implications for Great Lakes tributaries. Transactions of the American Fisheries Society 115: 363-381.

Fishbase. 2014. Family Cyprinidae - minnows or carps. [On line.] Fishbase.org. Penang, Malaysia. Available at: http://www.fishbase.org/Summary/FamilySummary.php?ID=122

Gerlak, A. K., S. Eden, S. Megdal, K. M. Lacroix, and A. Schwarz. 2009. Restoration and river management in the arid southwestern USA: exploring project design trends and features. Water Policy 11: 461-480.

Gregory, S. V., F. J. Swanson, W. A. McKee, and K. W. Cummings. 1991. An ecosystem perspective of riparian zones. BioScience. 41: 540- 610.

Hasse, J. J., and E. C. Stegemann. 1992. Fresh water fishes of New York. [Online.] Department of Environmental Conservation, New York. Available at: http://www.dec.ny.gov/animals/7040.html.

Integrated Taxonomic Information System (ITIS). 2014. Cyprinidae. [Online.] IT IS. Available at: http://www.itis.gov.

Jankauskas, B., and G. Jankauskiene. 2003. Erosion-preventive crop rotations for landscape ecological stability in upland regions of Lithuania. Agriculture, Ecosystems and Environment 95: 129-142.

Kent, M. and P. Coker. 1994. Vegetation Description and Analysis: A Practical Approach. John Wiley and Sons Ltd., West Sussex, England.

Lee, K. H., T. M. Isenhart, and R. C. Schultz. 2003. Sediment and nutrient removal in an established multi-species riparian buffer. Journal of Soil and Water Conservation 58: 1-8.

McLaren, P., and J. Singer. 2007. Sediment transport and contaminant behavior in the Buffalo River, New York: Implication for river management. Journal of Coastal Research 24: 954-968.

Mecklenburg, C. W., T. A. Mecklenburg, and L. K. Thorsteinson. 2002. Fishes of Alaska. American Fisheries Society, Bethesda, Maryland.

Mouton, A. M., B. De Baets, and P. L. M. Goethals. 2009. Knowledge-based versus data-driven fuzzy habitat suitability models for river management. Environmental Modeling and Software 24: 982-993.

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. John Wiley and Sons, New York, New York.

Murphy, B. R. and D. W. Willis. 1996. Fisheries Techniques. Second Edition. American Fisheries Society, Bethesda, Maryland.

New York State Department of Environmental Conservation (NYDEC). 2014. Freshwater fishes of New York series. [Online.] NYSDEC, Albany, NY. Available at: http://www.dec.ny.gov/animals/84775.html.

New York State Geographic Information Systems (NYSGIS) Clearinghouse. 2014. [Online.] NYSGIS Clearinghouse, New York. Available at: http://www.nysgis.state.ny.us/

Page, L. M., and B. M. Burr. 2011. Peterson field guide to freshwater fishes of North America north of Mexico. Third Edition. Houghton Mifflin Harcourt, Boston, New York.

Schofield, P. J., J. D. Williams, L. G. Nico, P. Fuller, and M. R. Thomas. 2005. Foreign Nonindigenous Carps and Minnows (Cyprinidae) in the United States - A guide to their Identification, Distribution, and Biology. [Online.] United States Geological Society (USGS), Reston, Virginia. Available at: http://fl.biology.usgs.gov/Carp_ID/html/contents.html.

Scott, W. B. and E. J. Crossman. 1973. Freshwater Fishes of Canada. Fisheries Research Board of Canada, Ottawa, Canada.

Smiley, Jr., P. C., K. W. King, and N. R. Fausey. 2011. Influence of herbaceous riparian buffers on physical habitat, water chemistry, and stream communities within channelized agricultural headwater streams. Ecological Engineering 37: 1314-1323.

Smith, C. L. 1985. The Inland Fishes of New York State. New York State Department of Environmental Conservation, Albany, NY.

Sparks, R. E. 2010. Forty years of science and management on the Upper Mississippi River: an analysis of the past and a view of the future. Hydrobiologia 640: 3-15.

Stromberg, J. C., M. K. Chew, P. L. Nagler, and E. P. Glenn. 2009. Changing perception of change: The role of scientists in *Tamarix* and river management. Restoration Ecology 17: 177-186.

Thai, B. T., V. N. Si, P. D. Phan, and C. M. Austin. 2007. Phylogenetic evaluation of subfamily classification of the Cyprinidae focusing on Vietnamese species. Aquatic Living Resources 20:143-153.

United States Geological Society (USGS). 2014. USGS. Reston, Virginia. Available at: http://www.usgs.gov/.

Wells, S. M. 2009. Habitat Associations of Fish Species and their Assemblages in the Tonawanda and Johnson Creek Watersheds of Northwestern New York State. M.S. thesis, The College at Brockport, State University of New York, Brockport, NY.

Wiley, M. L. and B. B. Collette. 1970. Breeding tubercles and contact organs in fishes: their occurrence, structure, and significance. Bulletin of the American Museum of Natural History 143: 143-216.

TABLES

Table 1. Sample site locations. WP = way point and Site = date the waypoint was sampled from first to last. The sampling sites were all on the west branch of Sandy Creek, Orleans County, NY. Sites sampled on 8 July 2010 - 19 August 2010 and 31 May 2011 - 31 July 2011.

Site	WP	latitude	longitude	land use	habitat
1	111	N43˚15.860	W078 ˚ 06.556	wooded	run
2	68	N43˚16.419	W078 ˚ 03.766	wooded	riffle
3	52	N43˚15.040	W078 ˚ 10. 710	urban	riffle
4	50	N43˚15.013	W078 ˚ 10. 770	urban	riffle
5	244	N43˚15.216	W078 ˚ 10. 327	urban	riffle
6	81	N43˚16.503	W078 ˚ 03.427	urban	pool
7	79	N43˚16.507	W078 ˚ 03.465	urban	run
8	75	N43˚16.561	W078 ˚ 03.623	wooded	run
9	213	N43˚15.664	W078 ˚ 07.145	agricultural	run
10	215	N43˚15.629	W078 ˚ 07.208	agricultural	run
11	169	N43˚15.976	W078 ˚ 08.976	agricultural	pool
12	204	N43˚15.902	W078 ˚ 07.149	agricultural	pool
13	43	N43˚16.202	W078 ˚ 04.375	agricultural	pool
14	174	N43˚15.653	W078 ˚ 08.869	agricultural	riffle
15	238	N43˚15.183	W078 ˚ 10.393	wooded	pool
16	243	N43˚15.229	W078 ˚ 10.350	urban	pool

17	108	N43˚15.826	W078 ˚ 06.650	agricultural	run
18	272	N43˚15.765	W078 ˚ 05.997	wooded	run
19	85	N43˚16.471	W078 ˚ 03.289	urban	run
20	71	N43˚16.443	W078 ˚ 03.685	wooded	riffle
21	93	N43˚16.414	W078 ˚ 03.189	wooded	riffle
22	231	N43˚15.131	W078 ˚ 10.471	urban	run
23	209	N43˚15.125	W078 ˚ 06.981	agricultural	riffle
24	256	N43˚15.125	W078 ˚ 06.981	urban	pool
25	152	N43˚15.381	W078 ˚ 09.106	agricultural	riffle
26	10	N43˚15.845	W078 ˚ 05.272	wooded	pool
27	70	N43˚16.420	W078 ˚ 04.697	wooded	pool

Table 2. Fish species identified during sampling. All sites on the west branch of Sandy Creek, Orleans County, NY and sampled on 8 July 2010- 19 August 2010 and 31 May 2011 - 31 July 2011.

[1]Abbreviation	Common Name	Scientific Name
Caan	central stoneroller	*Campostoma anomalum*
Seat	creek chub	*Semotilus atromaculatus*
Nomi	river chub	*Nocomis micropogon*
Luch	striped shiner	*Luxilus chrysocephalus*
Nobi	hornyhead chub	*Nocomis biguttatus*
Hyre	eastern silvery minnow	*Hybognathus regis*
Nost	sand shiner	*Notropis stramineus*
Cysp	spotfin shiner	*Cyprinella spiloptera*
Pino	bluntnose minnow	*Pimephales notatus*
Pipr	fathead minnow	*Pimephales promelas*
Luco	common shiner	*Luxilus cornutus*
Caco	white sucker	*Catostomus commersonii*
Etca	rainbow darter	*Etheostoma caeruleum*
Neme	round goby	*Neogobius melanostomus*
Hyni	northern hog sucker	*Hypentelium nigricans*
Etol	tessellated darter	*Etheostoma olmstedi*
Umli	central mudminnow	*Umbra limi*
Nofl	stonecat	*Noturus flavus*
Etfl	fantail dater	*Etheostoma flabellare*

Etni	johnny darter	*Etheostoma nigrum*
Coba	mottled sculpin	*Cottus bairdii*
Eslu	northern pike	*Esox lucius*
Amru	rock bass	*Ambloplites rupestris*
Lecy	green sunfish	*Lepomis cyanellus*
Poni	black crappie	*Pomoxis nigromaculatus*
Doce	gizzard shad	*Dorosoma cepedianum*
Mido	smallmouth bass	*Micropterus dolomieu*
Mi sa	largemouth bass	*Micropterus salmoides*
Legi	pumpkinseed	*Lepomis gibbosus*
Lema	bluegill	*Lepomis macrochirus*
Pefl	yellow perch	*Perca flavescens*
Satr	brown trout	*Salmo trutta*

[1]Fish species are listed by common and Latin name (first two letters of genus/species) in accordance with Wells (2009).

Table 3. Percent minnow capture data by site. Fish are reported as the proportion of all minnows found at that waypoint. For the full fish name (scientific and common) see Table 2. For the location of the waypoint see Table 1. The sampling sites were all on the west branch of Sandy Creek, Orleans County, NY on 8 July 2010 - 19 August 2010 and 31 May 2011 - 31 July 2011.

WP	[1]land use	[2]habitat	*Caan*	*Seat*	*Nomi*	*Luch*	*Nobi*	*Hyre*	*Nost*	*Cysp*
52	1	1	5.9	0.0	0.0	0.0	94.1	0.0	0.0	0.0
50	1	1	7.0	14.0	0.0	0.0	14.0	15.8	47.4	1.8
244	1	1	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
81	1	3	12.5	37.5	0.0	0.0	37.5	0.0	12.5	0.0
79	1	2	0.0	46.7	0.0	6.7	13.3	0.0	20.0	0.0
243	1	3	28.0	52.0	0.0	0.0	0.0	0.0	8.0	0.0
85	1	2	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
231	1	2	18.9	18.9	5.4	0.0	0.0	0.0	0.0	0.0
256	1	3	0.0	15.0	15.0	0.0	0.0	0.0	0.0	0.0
213	2	2	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
215	2	2	0.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0
169	2	3	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
204	2	3	0.0	44.4	0.0	3.7	0.0	0.0	51.9	0.0
43	2	3	10.3	85.9	0.0	0.0	0.0	0.0	3.8	0.0
174	2	1	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
108	2	2	60.0	40.0	0.0	0.0	0.0	0.0	0.0	0.0
209	2	1	14.3	28.6	0.0	14.3	0.0	0.0	42.9	0.0
152	2	1	0.0	12.5	87.5	0.0	0.0	0.0	0.0	0.0
111	3	2	10.0	70.0	5.0	15.0	0.0	0.0	0.0	0.0

68	3	1	0.0	0.0	75.0	25.0	0.0	0.0	0.0	0.0
75	3	2	4.5	72.7	0.0	0.0	0.0	0.0	22.7	0.0
238	3	3	11.1	77.8	11.1	0.0	0.0	0.0	0.0	0.0
272	3	2	20.8	62.5	2.1	4.2	0.0	0.0	0.0	0.0
71	3	1	0.0	0.0	50.0	25.0	0.0	0.0	25.0	0.0
93	3	1	10.0	13.3	76.7	0.0	0.0	0.0	0.0	0.0
10	3	3	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
70	3	3	13.0	13.0	26.1	21.7	0.0	0.0	26.1	0.0

[1]Codes for land use: urban =1, agricultural =2, wooded =3.

[2]Codes for stream habitat: riffle =1, run =2, pool =3.

Table 3. Percent minnow capture data by site continued.

WP	Pino	Pipr	Luco
52	0.0	0.0	0.0
50	0.0	0.0	0.0
244	0.0	0.0	0.0
81	0.0	0.0	0.0
79	6.7	6.7	0.0
243	12.0	0.0	0.0
85	0.0	0.0	0.0
231	56.8	0.0	0.0
256	0.0	70.0	0.0
213	0.0	0.0	50.0
215	50.0	0.0	0.0
169	0.0	0.0	0.0

204	0.0	0.0	0.0
43	0.0	0.0	0.0
174	0.0	0.0	0.0
108	0.0	0.0	0.0
209	0.0	0.0	0.0
152	0.0	0.0	0.0
111	0.0	0.0	0.0
68	0.0	0.0	0.0
75	0.0	0.0	0.0
238	0.0	0.0	0.0
272	10.4	0.0	0.0
71	0.0	0.0	0.0
93	0.0	0.0	0.0
10	0.0	0.0	0.0
70	0.0	0.0	0.0

Table 4. Percent non-minnow capture data by site. Fish are reported as the proportion of all non-minnows found at that waypoint. For the full fish name (scientific and common) see Table1. WP = way point, see Table 1. The sampling sites were all on the west branch of Sandy Creek, Orleans County, NY, sampled on 8 July 2010 - 19 August 2010 and 31 May 2011 - 31 July 2011.

WP	[1]land use	[2]habitat	Caco	Etca	Neme	Hyni	Etol	Umli	Nofl	Etfl	Etni
52	1	1	0.0	21.4	0.0	7.1	71.4	0.0	0.0	0.0	0.0
50	1	1	7.4	48.1	0.0	0.0	33.3	3.7	3.7	3.7	0.0
244	1	1	0.0	9.1	0.0	0.0	86.4	0.0	4.5	0.0	0.0
81	1	3	9.1	27.3	36.4	0.0	9.1	0.0	0.0	0.0	9.1
79	1	2	0.0	0.0	55.6	0.0	33.3	0.0	0.0	0.0	11.1
243	1	3	6.7	6.7	20.0	0.0	0.0	0.0	0.0	0.0	6.7
85	1	2	0.0	60.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0
231	1	2	0.0	65.0	5.0	0.0	0.0	0.0	0.0	27.5	0.0
256	1	3	0.0	0.0	0.0	0.0	0.0	14.3	0.0	0.0	0.0
213	2	2	0.0	0.0	16.7	0.0	0.0	0.0	16.7	0.0	8.3
215	2	2	0.0	0.0	36.4	0.0	0.0	0.0	9.1	9.1	0.0
169	2	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
204	2	3	10.0	20.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0
43	2	3	54.0	0.0	41.3	0.0	0.0	0.0	0.0	0.0	0.0
174	2	1	0.0	40.0	26.7	0.0	0.0	0.0	26.7	0.0	0.0
108	2	2	0.0	88.9	7.4	0.0	0.0	0.0	0.0	0.0	0.0
209	2	1	0.0	79.1	16.3	0.0	0.0	0.0	0.0	2.3	0.0
152	2	1	0.0	50.0	25.0	0.0	0.0	0.0	25.0	0.0	0.0
111	3	2	5.6	72.2	22.2	0.0	0.0	0.0	0.0	0.0	0.0
68	3	1	0.0	95.3	4.7	0.0	0.0	0.0	0.0	0.0	0.0
75	3	2	0.0	35.3	17.6	0.0	41.2	0.0	0.0	0.0	0.0

238	3	3	0.0	25.0	25.0	0.0	0.0	0.0	12.5	37.5	0.0
272	3	2	0.0	9.1	36.4	9.1	0.0	0.0	0.0	9.1	0.0
71	3	1	0.0	90.9	9.1	0.0	0.0	0.0	0.0	0.0	0.0
93	3	1	0.0	41.7	12.5	0.0	0.0	0.0	16.7	25.0	0.0
10	3	3	0.0	0.0	11.1	11.1	0.0	0.0	0.0	0.0	0.0
70	3	3	11.1	44.4	11.1	22.2	0.0	0.0	0.0	0.0	11.1

[1]Codes for land use: urban =1, agricultural =2, wooded =3.

[2]Codes for stream habitat: riffle =1, run =2, pool =3.

Table 4. Percent non-minnow capture data by waypoint continued.

WP	Coba	Eslu	Amru	Lecy	Poni	Doce	Mido	Misa	Legi	Lema	Pefl	Satr
52	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
244	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
81	9.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
243	0.0	0.0	40.0	13.3	0.0	0.0	0.0	0.0	6.7	0.0	0.0	0.0
85	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0
231	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
256	0.0	0.0	25.7	0.0	0.0	0.0	0.0	0.0	28.6	31.4	0.0	0.0
213	0.0	16.7	8.3	8.3	25.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
215	0.0	0.0	9.1	0.0	0.0	9.1	18.2	9.1	0.0	0.0	0.0	0.0
169	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
204	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43	0.0	0.0	0.0	0.0	0.0	4.8	0.0	0.0	0.0	0.0	0.0	0.0
174	0.0	0.0	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

108	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	0.0	0.0
209	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0
152	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
111	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
68	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
75	5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
238	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
272	0.0	0.0	0.0	27.3	0.0	0.0	0.0	0.0	0.0	0.0	9.1	0.0
71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
93	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	44.4	33.3	0.0	0.0
70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5. Wilcoxon Rank Sum Test for minnows. Two-tailed P-value for normal approximation. Land use: forested (minimally disturbed) as opposed to urban and agricultural combined (substantial disturbance). Habitat 2: pool as opposed to riffle and run combined. Habitat 3: riffle as opposed to run and pool combined. P-values that were significant before applying the Bonferroni-corrected alpha ($P = 0.05/3$ tests $= 0.0167$) continue to be significant after applying the Bonferroni-corrected alpha. Boldface indicates statistically significant values.

Species	Land Use	Habitat 2	Habitat 3
bluntnose	0.4710	0.5189	0.0950
central stoneroller	0.5614	0.5793	0.8950
creek chub	0.9584	0.1119	**0.0035**[a]
hornyhead chub	0.5189	0.7044	0.7044
river chub	**0.0048**[b]	0.7441	0.2237
sand shiner	0.2989	0.8820	0.9763
striped shiner	**0.0162**[c]	0.9290	0.8354

[a]riffle > run/pool

[b]forested < urban/agricultural

[c]forested < urban/agricultural

Table 6. Wilcoxon Rank Sum Test for non-minnows. Two-tailed P-value for normal approximation. Land use: forested (minimally disturbed) as opposed to urban and agricultural combined (substantial disturbance). Habitat 2: pool as opposed to riffle and run combined. Habitat 3: riffle as opposed to run and pool combined. After applying the Bonferroni-corrected alpha (P = 0.05/5 tests = 0.010) only one value continues to be significant. Bold indicates statistically significant values and italic indicates suggestive values.

Species	Land use	Habitat 2	Habitat 3
bluegill	0.8352	0.3823	0.6472
fantail darter	0.4231	0.3331	0.7639
johnny darter	0.5952	0.1969	0.0949
northern hog sucker	0.0506	0.3823	0.6472
pumpkin seed	0.8352	0.0612	0.1454
rainbow darter	0.1773	*0.0182*[a]	*0.0224*[b]
rockbass	*0.0237*[c]	0.4638	0.1186
round goby	0.9382	0.5876	0.0667
stonecat	0.6103	0.1517	0.0415
tessellated darter	0.3770	0.2733	0.2581
whitesucker	0.7386	**0.0076**[d]	0.2047

[a]riffle/run < pool

[b]riffle < run/pool

[c]forested > urban/agricultural

[d]riffle/run > pool

Table 7. Relative density and dominance of riparian trees. All sites sampled at waypoints along the west branch of Sandy Creek, for agricultural sites with apple orchards and for wooded sites. As well as H' = Shannon-Wiener Diversity Index. Orleans County, New York, 8 -9 October 2010.

Wooded - not recently disturbed		
Tree Species	Relative Density	Relative Dominance
Trees ≥10 cm DBH		**H' = 1.81**
Fraxinus americana	40.0	40.47
Ulmus americana	11.67	3.14
Fagus grandifolia	18.33	8.17
Quercus rubra	10.0	31.6
Prunus serotina	1.67	2.36
Salix nigra	1.67	0.36
Tilia americana	5.0	9.07
Carya ovata	5.0	1.27
Acer negundo	1.67	2.57
Carpinus caroliniana	5.0	1.27
Trees < 10 cm DBH		**H' = 1.87**
Fraxinus americana	8.33	10.25

Ulmus americana	20.0	19.9
Fagus grandifolia	23.33	15.11
Salix nigra	3.33	5.89
Carya ovata	23.33	21.78
Acer negundo	6.67	10.08
Carpinus caroliniana	11.67	15.68
Acer saccharum	3.33	1.31

Agricultural-heavily disturbed, data only for apple orchard site

Tree Species	Relative Density	Relative Dominance
Trees ≥10 cm DBH		**H' = 0.05**
Fraxinus americana	20.0	33.64
Malus domestica	80.0	66.36
Trees < 10 cm DBH		**H' = 0.61**
Fraxinus americana	15.0	8.23
Cornus sp	5.0	2.12
Malus domestica	80.0	89.64

Table 8. Water quality parameters. The bottom row gives results for two sample T - test, comparing these values for the high - disturbance agricultural area to the low-disturbance wooded area. Significant P - values are indicated in red. Turbidity is reported in Nephelometric Turbidity Units (NTU). TP = total phosphorous, SRP = soluble reactive phosphorous, TSS = total suspended solids, TN = total nitrogen. Samples are from the west branch of Sandy Creek, Orleans County, New York, 8-9 November 2011.

Sites	Turbidity	TP (mg/L)	SRP (mg/L)	Nitrate (mg/L)	TSS (mg/L)	TN (mg/L)
Agricultural 317	5.71	0.13	0.07	3.60	8.00	4.62
Agricultural 315	2.63	0.12	0.10	3.40	2.70	4.16
Agricultural 316	1.47	0.11	0.07	2.90	1.30	3.45
Average Agricultural	**3.27**	**0.12**	**0.08**	**3.30**	**4.00**	**4.08**
Wooded 318	1.26	0.11	0.08	2.30	5.20	3.20
Wooded 320	0.98	0.10	0.07	2.20	1.50	3.30
Wooded 319	0.99	0.10	0.09	2.30	3.00	3.02
Average Wooded	**1.08**	**0.10**	**0.08**	**2.27**	**3.23**	**3.17**
P-Value =	0.226	0.082	0.831	**0.039**	0.761	0.123

Table 9. Loss on ignition for riparian soil. This indicates the percent organic matter in the soil. Data from 8-9 November 2011, soil samples from the riparian zone adjacent to the west branch of Sandy Creek, Orleans County, New York.

Location	Loss on ignition (g/kg)	Loss on ignition (%)
Agricultural 315	57.5	5.8
Agricultural 316	55.0	5.5
Agricultural 317	51.9	5.2
Average		**54.8**
Wooded 318	63.5	6.4
Wooded 319	131.4	13.1
Wooded 321	49.8	5.0
Average		**81.6**

FIGURES

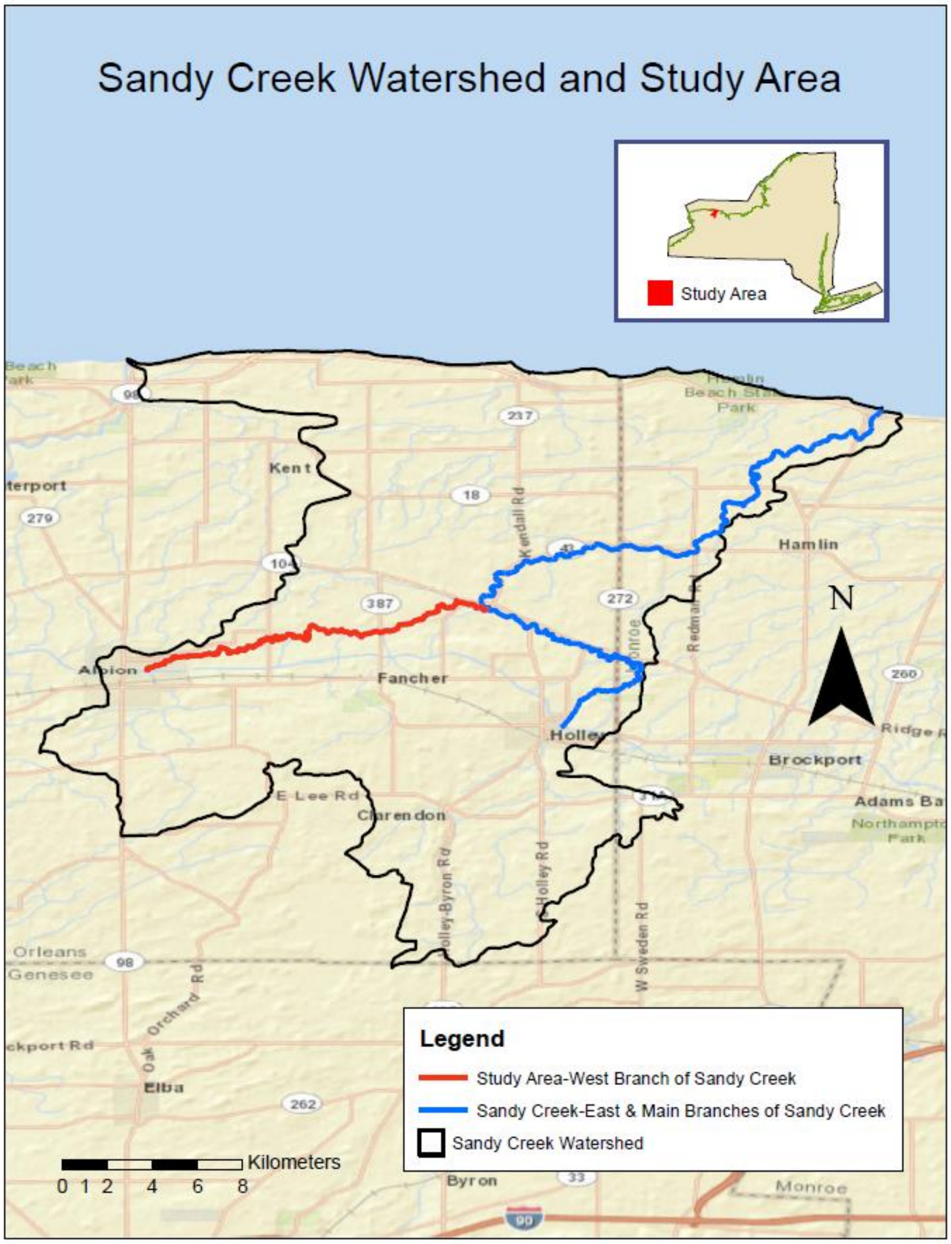

Figure1. Thesis study area map. The west branch of Sandy Creek with thesis study area indicated in red. The Sandy Creek watershed is indicated by the black outline. The locator map shows New York State boundaries, shorelines (in green), and the study area (in red).

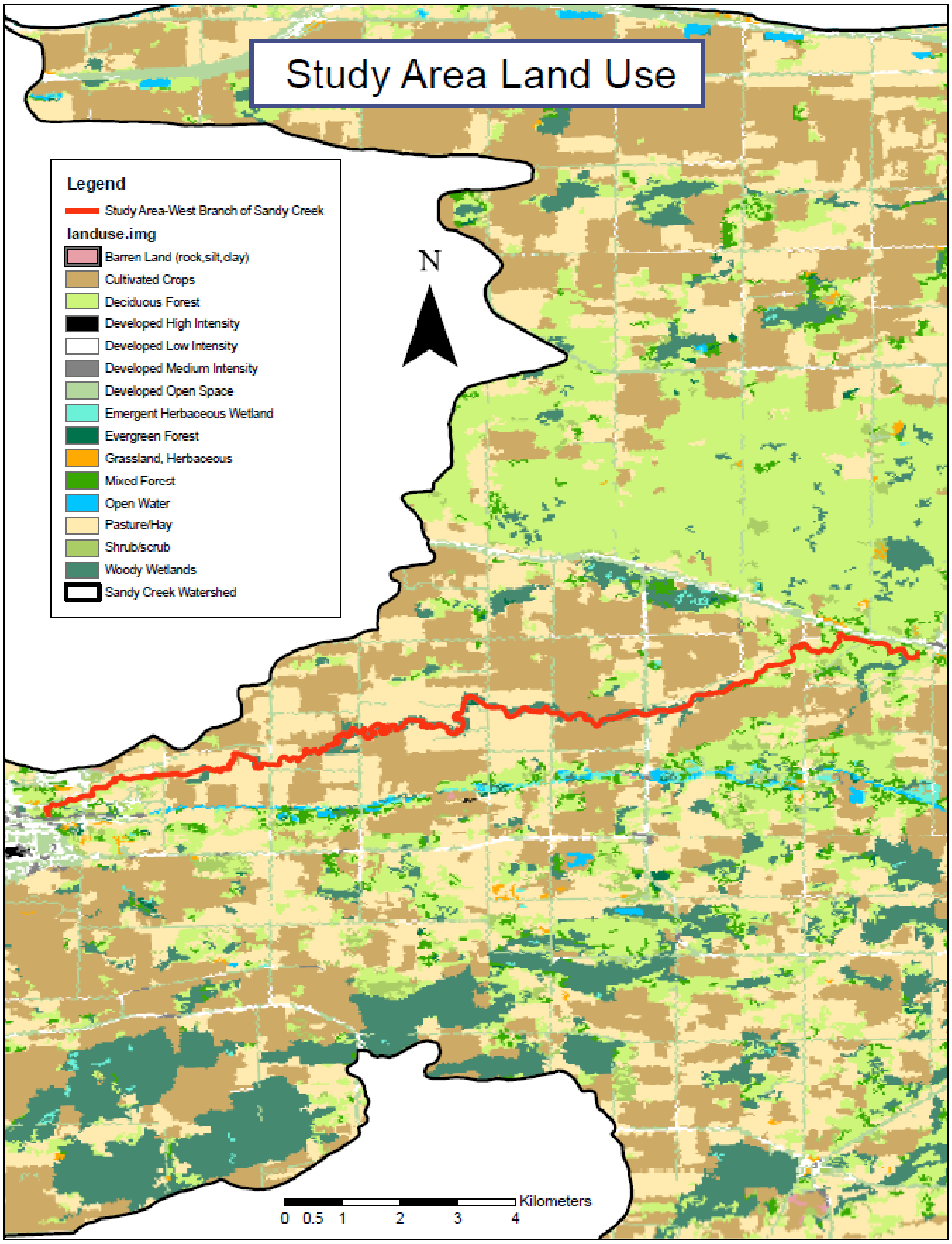

Figure 2. Thesis study area land use map. The west branch of Sandy Creek with thesis study area indicated in red. The Sandy Creek watershed is indicated by the black outline. Land use is indicated in the legend. Sources: ESRI, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, ESRI Japan, METI, ESRI China (Hong Kong), ESRI (Thailand), TOMTOM, 2013.

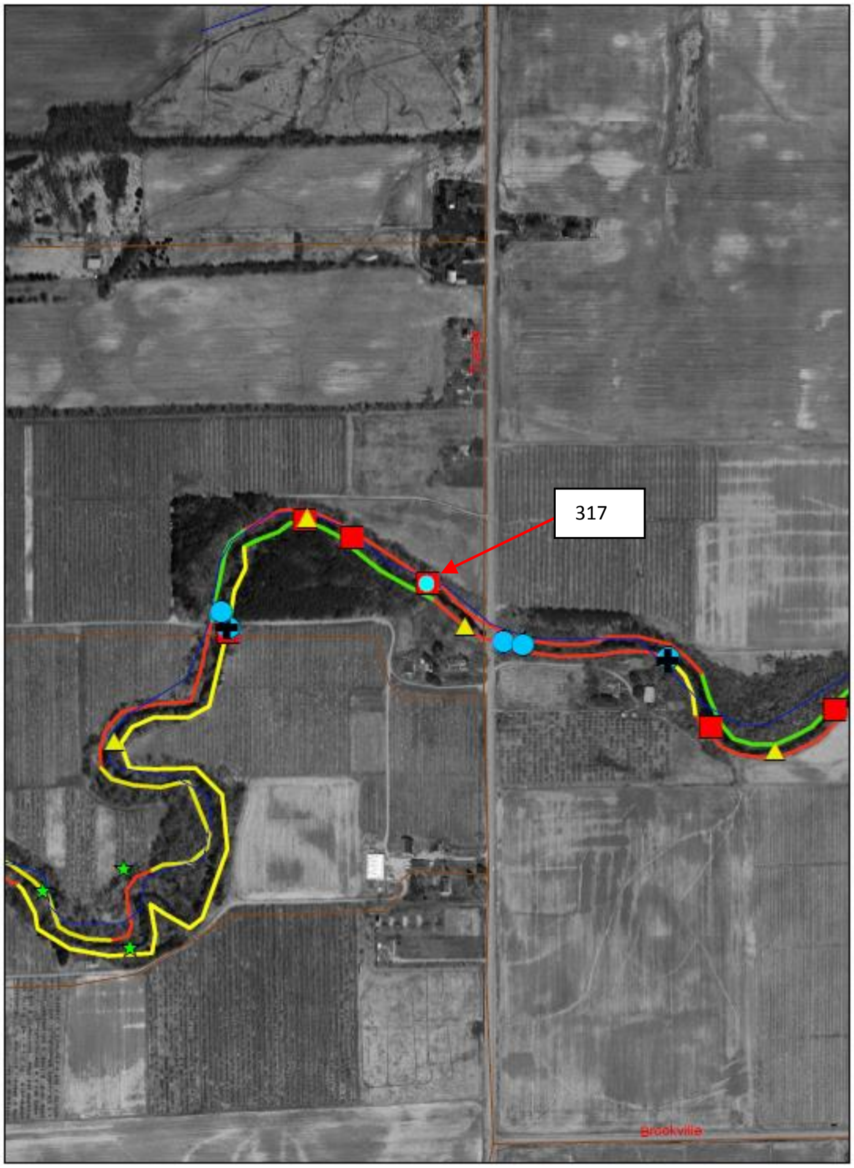

Figure 3. GIS map of sampling site 317 with stream bank conditions. Red creek borders indicate degraded banks, orange is somewhat degraded, and green is not degraded. Water flow is from left to right. Way point indicated with arrow. Blue circles are pools, red squares are riffles, and yellow triangles are runs. The sampling site is indicated by the pale blue dot and the arrow. All samples collected from the west branch of Sandy Creek, Orleans County, NY, 8 July 2010 - 19 August 2010, 31 May 2011 - 31 July 2011 and 8-9 October 2011.

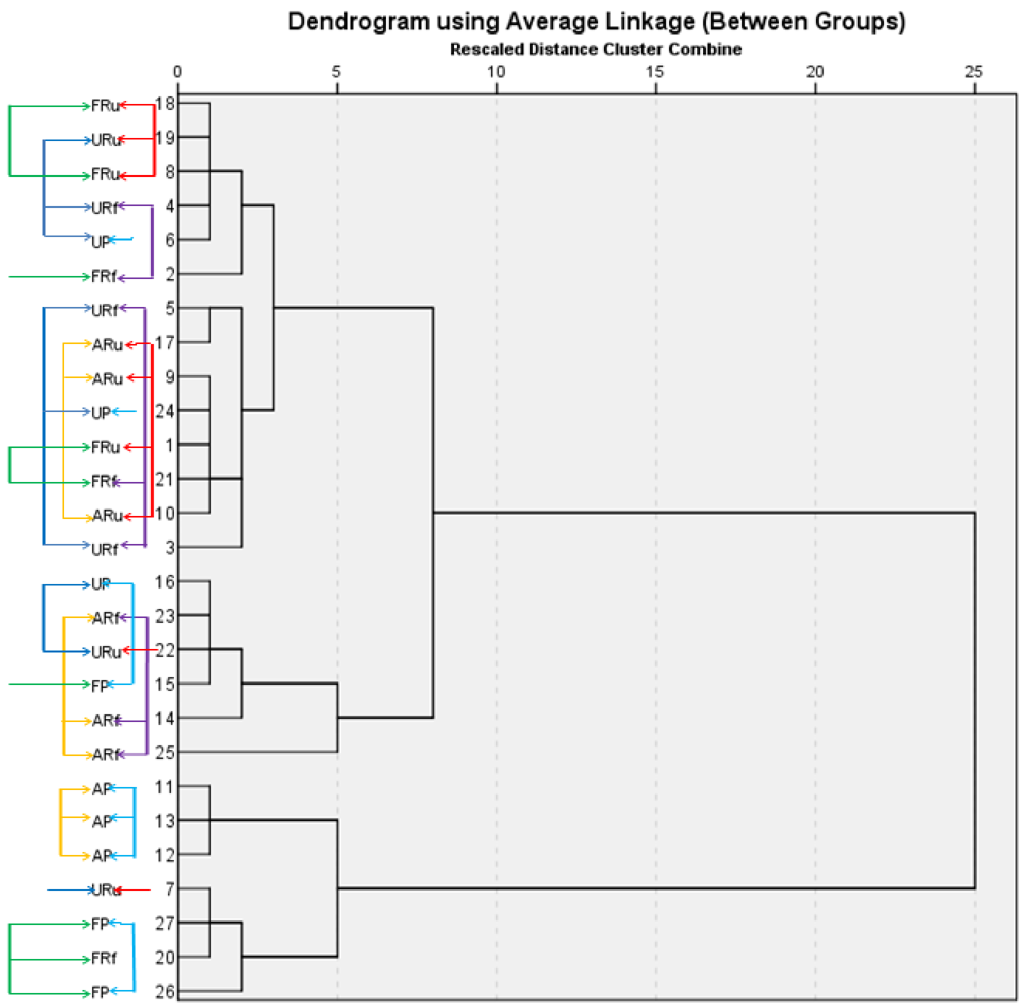

Figure 4. SPSS cluster analysis of minnows. This is using the influential habitat variables (stream depth, stream width, substrate composition, and turbidity) and species found at ≥4 sites. Removal of any additional species causes clustering to change. Numbers 1-27 on the vertical axis indicate location (Table 1). The far left column indicates the type of land use and stream habitat. Stream habitat is indicated with colored arrows on the right: Red = Ru = run, purple = Rf = riffle, Pale blue = P = pool. Land use is indicated with colored arrows on the left: dark blue = U = urban, yellow = A = agricultural, and green = F = forested. Closely related clusters (≤ second level) are bridged.

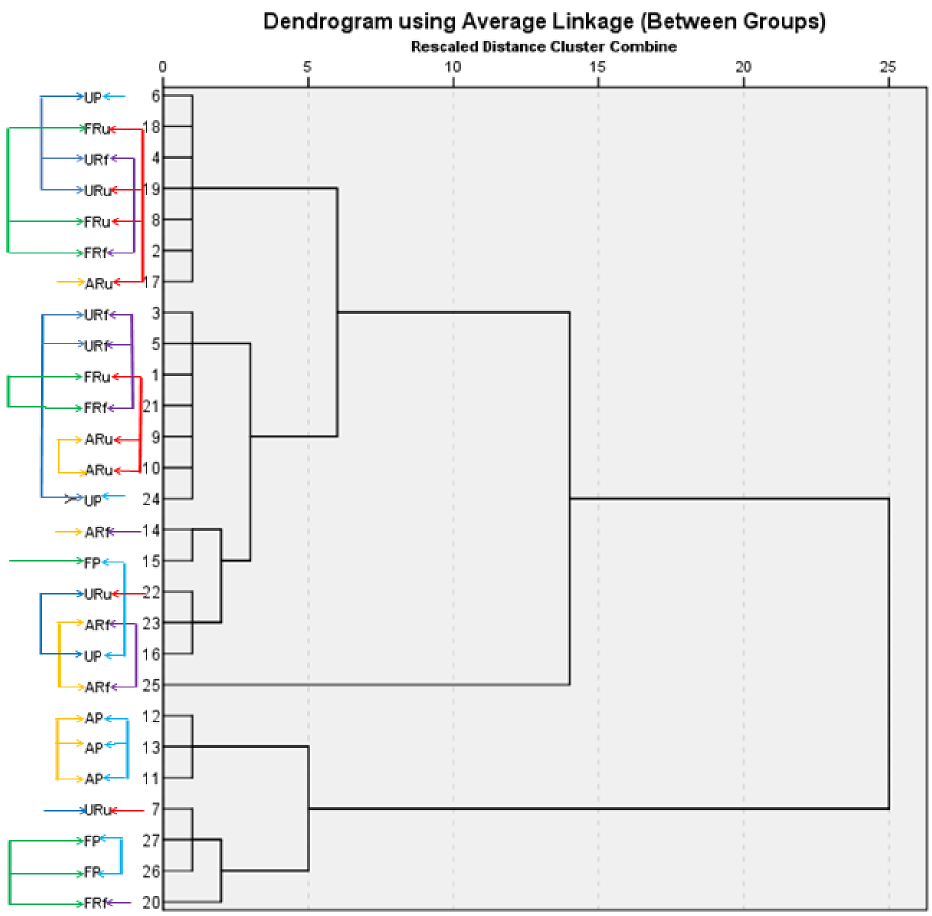

Figure 5. SPSS cluster analysis of non-minnows. This is using the influential habitat variables (depth, width, substrate, and turbidity) and species found at ≥4 sites. Removal of any additional species causes the clustering to change. Numbers 1-27 on the vertical axis indicate location (Table 1). The far left column indicates the type of land use and stream habitat. Stream habitat is indicated with colored arrows on the right: Red = Ru = run, purple = Rf = riffle, Pale blue = P = pool. Land use is indicated with colored arrows on the left: dark blue = U = urban, yellow = A = agricultural, and green = F = forested. Closely related clusters (≤ second level) are bridged.

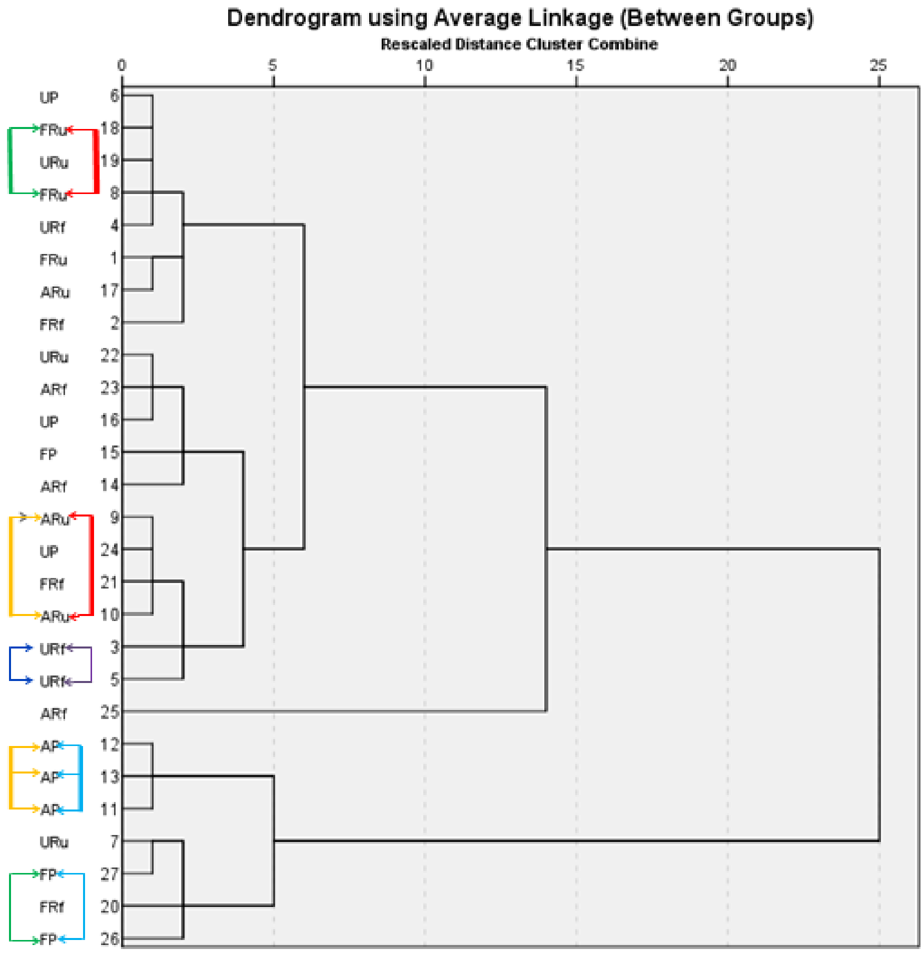

Figure 6. SPSS cluster analysis of minnows, non-minnows, and significant habitat variables with consistant clustering. Numbers 1-27 on the vertical axis indicate location (Table 1). The far left column indicates the type of land use and stream habitat. Stream habitat is indicated with an arrow on the right: Red = Ru = run, purple = Rf = riffle, Pale blue = P = pool. Land use is indicated with an arrow on the left: dark blue = U = urban, yellow = A = agricultural, and green = F = forested. Closely related clusters that were found in all cluster analyses are bridged.

APPENDICES

Appendix I. Fish associations and aquatic habitat variables.

Appendix I-A. Water velocity and depth. Both depth and velocity were recorded every 60 cm across the span of the creek and averaged for each sampling site. Total distance (cm) from left stream bank indicated in the far left column. Sampling site designation indicated in top row. Depth (cm) was measured with a meter stick from water surface to substrate. Velocity (m/s) was measured with a pigmy Gurley meter with readings taken 5 cm above the substrate. All samples collected from the west branch of Sandy Creek, Orleans County, NY, 8 July 2010 - 19 August 2010, 31 May 2011 - 31 July 2011 and 8-9 October 2011.

Distance from bank (cm)	Site 52		Site 50		Site 244		Site 81	
	Velocity (m/s)	Depth (cm)	Velocity (m/s)	Depth (cm)	Velocity (m/s)	Depth (cm)	Velocity (m/s)	Depth (cm)
60	0.04	13.50	0.29	5.00	0.07	8.70	0.00	24.00
120	0.08	23.00	0.28	7.50	0.49	6.30	0.00	27.90
180	0.18	24.00	0.32	6.90	0.00	3.90	0.01	49.90
240	0.31	17.00	0.41	6.50	0.43	6.60	0.00	51.20
300	0.23	16.00	0.36	9.50	0.53	7.10	0.38	54.10
360	0.23	13.00	0.58	9.60	0.66	9.30	0.33	55.50
420	0.38	14.00	0.51	10.80	0.75	9.50	0.39	53.70

480	0.33	13.00	0.58	5.20	0.84	9.70	0.33	55.20
540	0.30	12.00	0.61	7.90	0.98	13.00	0.27	54.60
600	0.07	9.00	0.58	14.10	0.05	12.20	0.30	46.70
660			0.67	17.00	0.08	13.00	0.22	42.80
720			0.54	19.70			0.17	29.50
780							0.14	21.90
840							0.01	9.00
mean	0.22	15.45	0.48	9.98	0.44	9.03	0.18	41.14

Appendix I-A. Calculation of water velocity and depth continued.

Distance from bank (cm)	Site 79		Site 75		Site 213		Site 215	
	Velocity (m/s)	Depth (cm)	Velocity (m/s)	Depth (cm)	Velocity (m/s)	Depth (cm)	Velocity (m/s)	Depth (cm)
60	0.1	33.5	0.16	7.7	0	27.9	0	21.5
120	0.1	31.5	0.19	15.6	0.13	44.5	0	39.8
180	0.3	30.5	0.21	18.7	0.19	49	0.11	48.9
240	0.3	31.0	0.19	18	0.07	45.7	0.17	55.7
300	0.2	36.0	0.27	22.7	0.15	39	0.1	40.1
360	0.1	36.5	0.32	29.1	0.03	42.7	0.17	51.3
420	0.1	31.5	0.25	22.3	0	26.5	0.18	46.2
480	0.1	32.0	0.22	5.6	0	12.5	0.08	31.9

540	0.2	35.1	0.31	21.9			0.06	14.5
600	0.2	34.7	0.45	15.7				
660	0.3	35.0	0.27	23.5				
720	0.3	37.1	0.48	15.4				
780	0.3	35.4	0.3	33.2				
840	0.3	26.3	0.29	27.3				
mean	0.17	30.06	0.28	19.76	0.07	35.98	0.10	38.88

Appendix I- A. Calculation of water velocity and depth continued.

Distance from bank (cm)	169		Site 204		Site 43		Site 174	
	Velocity (m/s)	Depth (cm)	Velocity (m/s)	Depth (cm)	Velocity (m/s)	Depth (cm)	Velocity (m/s)	Depth (cm)
60	0	13.2	0	8.8	0	27.4	0.06	13.7
120	0.09	25.6	0	15.9	0	39.9	0.18	21.2
180	0.02	31.7	0	22.1	0	64	0.17	26.5
240	0.11	42.2	0	41	0	71.2	0.28	34
300	0.1	46.1	0	40.4	0	71.7	0.21	29.4
360	0.1	58.9	0	42.3	0	69.4	0.28	20.1
420	0.25	69	0	52.6	0	43.8	0.26	14
480	0.01	74.1	0.01	62.8	0	40.7	0.11	4.6
540	0	73.8	0.02	63.7	0.17	36.4		
600	0	76.8	0.03	57.2	0.15	37.8		

660	0	72.2	0.06	53.1	0.1	37.5		
720	0	76.9	0.03	38.8	0.07	38.3		
780	0	75.6	0.15	39.1	0.02	35		
840	0.03	61.2	0.01	37.4	0.08	29.9		
900	0	27.8	0	23.9	0.03	32.2		
960			0	22.5	0	19.4		
1020			0	12.8				
mean	0.05	55.01	0.02	37.32	0.04	43.41	0.19	20.44

Appendix I- A. Calculation of water velocity and depth continued.

Distance from bank (cm)	Site 238		Site 243		Site 111		Site 108	
	Velocity (m/s)	Depth (cm)	Velocity (m/s)	Depth (cm)	Velocity (m/s)	Depth (cm)	Velocity (m/s)	Depth (cm)
60	0.15	52	0.03	21.4	0.19	6.5	0.21	9.1
120	0.12	57	0.04	25.9	0.33	10.75	0.3	12.6
180	0.24	55	0.1	25.2	0.27	11.4	0.37	16.3
240	0.27	50.3	0.22	29.2	0.31	14.1	0.42	21.5
300	0.25	67.5	0.15	30.5	0.36	16.2	0.41	25
360	0.27	65	0.32	32	0.44	19.4	0.47	27.5
420	0.32	53.8	0.3	31.9	0.37	16.5	0.54	29.1
480	0.39	44.5	0.08	32	0.38	18	0.41	29.8
540	0.4	38	0.03	20.7	0.34	14	0.37	20.6

600			0.01	15	0.32	12.5	0.32	19.3
660			0.01	10.5	0.24	10.1	0.06	14.2
720			0.02	8	0.1	9	0.24	18.1
780							0.08	18.3
mean	0.27	53.68	0.11	23.53	0.30	13.20	0.32	20.11

Appendix I- A. Calculation of water velocity and depth continued.

Distance from bank (cm)	Site 272		Site 85		Site 68		Site 71	
	Velocity (m/s)	Depth (cm)	Velocity (m/s)	Depth (cm)	Velocity (m/s)	Depth (cm)	Velocity (m/s)	Depth (cm)
60	0.1	13.2	0.02	22.9	0.01	15	0.21	10.1
120	0.2	21.8	0.01	26	0.1	28.5	0.22	13
180	0.19	31.5	0.01	26.5	0.18	37.4	0.12	9.8
240	0.26	42.1	0.1	27.5	0.44	36.9	0.11	7.5
300	0.34	57.2	0.18	26.1	0.48	20.7	0.12	6.5
360	0.32	42.6	0.2	27.8	0.23	21	0.23	5
420	0.32	40.1	0.23	29.5	0.34	20.3	0.3	17
480	0.32	43.4	0.25	30	0.18	22.1	0.31	14
540	0.26	46.3	0.25	30.5			0.25	28.2
600	0.17	43.3	0.37	32.2			0.3	18.8
660	0	36.2	0.35	32.9			0.27	19.7
720			0.12	32.7			0.32	19

780			0.13	25.2			0.11	16.8
840			0.15	19.8			0.16	17
900							0.01	14
mean	0.23	37.97	0.17	27.83	0.25	25.24	0.20	14.43

Appendix I- A. Calculation of water velocity and depth continued.

Distance from bank (cm)	Site 93		Site 231		Site 209		Site 256	
	Velocity (m/s)	Depth (cm)	Velocity (m/s)	Depth (cm)	Velocity (m/s)	Depth (cm)	Velocity (m/s)	Depth (cm)
60	0.28	10.5	0.26	12.2	0.2	10	0.13	18.1
120	0.48	4.6	0.11	26.3	0.41	13	0.19	27.7
180	0.87	12.1	0.21	38.8	0.48	15.7	0.24	25.8
240	0.85	14.7	0.22	45.3	0.49	15.8	0.33	41.1
300	0.89	29.5	0.37	46.2	0.67	16.2	0.12	43.9
360	0.7	29.1	0.25	42	0.45	21.3	0.09	46.2
420	0.52	26.2	0.31	31.1	0.5	18.1	0.15	48
480	0	18.1	0.27	37	0.33	23.1	0.04	55.5
540			0.17	28.7	0.21	18.3	0	55
600							0.02	46.5
660							0.09	35
mean	0.57	18.10	0.24	34.18	0.42	16.83	0.13	40.25

Appendix I- A. Calculation of water velocity and depth continued.

Distance from bank (cm)	Site 152		Site 10		Site 70	
	Velocity (m/s)	Depth (cm)	Velocity (m/s)	Depth (cm)	Velocity (m/s)	Depth (cm)
60	0.13	15.3	0	72.8	0.25	34
120	0.41	43.5	0	88.1	0.26	35
180	0.49	31.5	0.07	105.7	0.34	60.7
240	0.89	44.3	0	105.9	0.22	35.2
300	0.5	25.6	0.07	96.8	0.18	47.3
360	0.38	22.4	0.06	82.2	0.4	40.4
420			0.08	79.3	0.41	45.2
480			0.12	73.9	0.26	51.2
540			0.11	71.5	0.18	40.5
600			0.08	71.2	0.04	40.5
660			0.02	70.2	0	43
720			0	67.4	0.9	43.1
780			0	51	0.14	38.3
840					0.11	25.4
mean	0.47	30.43	0.05	79.69	0.26	41.41

Appendix I-B. Wentworth classification. This classification was used to determine substrate particle code for use in waypoint substrate calculation.

Size range (metric)	Aggregate name	Substrate particle code
n/a	Bedrock	14
256 mm <	Boulder	13
64–256 mm	Cobble	12
32–64 mm	Very coarse gravel	11
16–32 mm	Coarse gravel	10
8–16 mm	Medium gravel	9
4–8 mm	Fine gravel	8
2–4 mm	Very fine gravel	7
1–2 mm	Very coarse sand	6
0.50–1 mm	Coarse sand	5
.025–0.50 mm	Medium sand	4
125–250 µm	Fine sand	3
62.5–125 µm	Very fine sand	2
3.90625–62.5 µm	Silt/mud	1
< 3.90625 µm	Clay	0.1
< 1 µm	Colloid	0.01

Appendix I-C. Substrate particle size. This was determined at each sampling site (waypoint) and was estimated in two ways: 1) picking up and measuring all rocks (where possible) along a 1 m transect at each sampling site and 2) visually estimated percent of area for large immobile rocks, sand, gravel and silt. Each particle size class was assigned a number and a weighted average was computed to provide one number as an overall index of substrate composition for each site. This overall index of substrate composition was assigned a code using the Wentworth classification (Table I-B).

way point	52	50	244	81	79	75	213	215	169
	9.5	6.5	4	11	9	37	23	40	mud
	11	12.3	4.3	25	30	15	23	40	
	8.5	5	5	25	3	33	23	40	
	11	7.1	1.53	23	2	26	35	40	
	4.5	2	5	22.5	6	15	38		
	8.7	2	1.6	28	2.5	17	40		
	4	2	1	4	4	17	28		
	10.5	2	1	15	2	12	5		
	6.4	2	3.5	11	8	10	30		
	1.5	2	3.8	13		5	24		
	9	2	1.8	0.5			38		
	7.5	2	1	0.5					
	3	2	2.2	0.5					
	8.7	6.1	2						

	8	9.1	2.1						
	8.7	6.5	1						
	5.5	6.8	25						
	5.5	4	25						
	6.3	9	25						
	2.4	4.04	0.04						
	8.7	9	0.04						
	3.7	4	0.04						
	4.5	4							
	3.5	4							
	3.3	4							
	7	8							
	5.1	8							
	5.3	8							
	3.7	8							
mean (cm)	6.4	5.2	5.3	13.8	7.4	18.7	27.9	40.0	n/a
mean (mm)	63.8	52.2	52.7	137.7	73.9	187.0	279.1	400.0	n/a
particle code	11.0	11.0	11.0	12.0	12.0	12.0	13.0	13.0	1.0
% presence	1.00	0.85	0.50	0.75	0.25	0.75	0.25	0.10	1.00
other aggregate	0.0	7.0	13.0	3.0	13.0	10.0	1.0	1.0	
% presence	0.00	0.15	0.25	0.15	0.25	0.25	0.75	0.90	
other aggregate	0.0	0.0	8.0	10.0	14.0	0.0	0.0	0.0	0.0
% presence	0.00	0.00	0.25	0.10	0.50	0.00	0.00	0.00	0.00

final particle code	11	10	11	10	13	12	4	2	1

Appendix I-C. Substrate particle size continued.

way point	204	43	174	238	243	111	108	272	85
	18	2	7.2	6	8	2	mud	1	0.5
	17	3	5.9	45	17	4		5	20
	10		7.7	7	14	4		0.5	0.8
	26		4.2	8	13	1		0.5	3.1
	8		6.4	15	11	3.5		0.2	2.2
	6		5.8	4.5	3	2		0.2	8.1
	4		8.1	2	10	1.5		0.05	30.1
	7		9	3	5	2.5		0.2	4
	9		7	1	4	1		3	5.1
	6		9.6	2	8	3		1	50.2
	7		5.1	1	11	1.5		12	
			3.6	3		1		13	
			3.8	3		3			
			5.6	2		2.5			
			4.5	3		1			
			6.8	5		1			
			4.2	2		1			
			7.1	21		2			
			5.2	1		3			

			6.7	3		1.5			
			11.9	8					
			4.6						
			5.5						
			6						
mean (cm)	10.7	2.5	6.3	6.9	9.5	2.1	n/a	3.1	12.4
mean (mm)	107.3	25.0	63.1	69.3	94.5	21.0	n/a	30.5	124.1
particle code	12.0	11.0	11.0	12.0	12.0	10.0	1.0	10.0	12.0
percent presence	0.90	0.10	0.85	0.75	1.00	0.50	0.75	0.25	0.15
other Aggregate	2.0	13.0	1.0	10.0		11.0	11.0	12.0	14.0
percent presence	0.10	0.80	0.15	0.25		0.50	0.25	0.50	0.75
other Aggregate	0.0	1.0	0.0	0.0	0.0	0.0	0.0	13.0	13.0
percent presence	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.25	0.10
final particle code	11	12	10	12	12	11	4	12	14

Appendix I-C. Substrate particle size continued.

way point	68	71	93	231	209	256	152	10	70
	12.5	6	7.5	6	4	6	30	15	3
	6	4	7.3	9	11	4	14	11	30
	3.2	5	7.3	12	7	3	16	11.2	10
	7.4	7	6.9	13.5	4	5	19	15.8	8.5

	3	14	7.5	5	5	3	15	12	6.5
	2.8	0.5	8.5	5	2	9	30	7.9	4.5
	10.5	0.5		2	2			11.4	14
	5.5	0.5		6	2.5			5.3	4.7
	10.5	3		10	3			10.9	5.5
	5.3	5.5		30	1			8.9	4
	10.5	6.5		25	2			3	16
	11	0.5		9	3			2.2	2
	10			2	1			5.5	8
	11.5			2	4			1	5.5
				7.5					6
				9.5					4
mean (cm)	7.8	4.4	7.5	9.6	3.7	5.0	20.7	8.7	8.3
mean (mm)	78.4	44.2	75.0	95.9	36.8	50.0	206.7	86.5	82.6
particle code	12.0	11.0	12.0	12.0	11.0	11.0	12.0	12.0	12.0
percent presence	0.90	0.85	0.75	0.85	0.75	0.50	0.50	0.25	0.25
other Aggregate	0.1	12.0	11.0	1.0	13.0	5.0	13.0	10.0	8.0
percent presence	0.10	0.15	0.25	0.15	0.10	0.50	0.25	0.75	0.25
other Aggregate	0.0	0.0	0.0	0.0	5.0	0.0	1.0	0.0	14.0
percent presence	0.00	0.00	0.00	0.00	0.15	0.00	0.25	0.00	0.50
final particle code	11	11	12	10	10	8	10	11	12

Appendix I-D. Habitat variable data. All sampling sites were on the west branch of Sandy Creek, NY.

Way point	[1] land use	[2] aquatic habitat	air temp °C	[3] cloud cover	water temp °C	DO	turbidity	pH
52	1	1	33	4	26.40	9.26	4.03	7.88
50	1	1	29	4	26.10	8.94	8.73	8.01
244	1	1	24	4	24.30	8.01	3.30	7.97
81	1	3	28	1	21.60	7.94	9.93	8.28
79	1	2	28	1	23.60	9.07	11.50	7.89
243	1	3	24	3	20.60	9.51	10.50	8.1
85	1	2	22	4	20.70	9.85	3.30	7.79
231	1	2	20	4	22.80	8.20	4.92	7.61
256	1	3	22	1	21.40	8.60	4.10	7.66
213	2	2	28	1	23.30	7.43	11.90	7.92
215	2	2	30	2	23.90	6.92	8.02	7.55
169	2	3	24	1	23.60	8.18	5.03	8.01
204	2	3	24	1	23.60	8.18	5.03	8.01
43	2	3	29	1	23.30	9.79	6.54	8.09
174	2	1	24	2	23.00	9.42	5.35	7.79
108	2	2	14	4	19.60	7.35	3.48	7.04
209	2	1	24	4	22.90	8.82	1.72	7.19
152	2	1	28	2	25.00	8.13	7.77	7.4
111	3	2	22	1	18.70	10.70	15.70	7.48
68	3	1	25	1	22.80	8.95	5.79	7.96
75	3	2	26	4	21.20	9.21	6.81	8.05
238	3	3	36	4	21.70	8.96	12.30	7.11

272	3	2	23	4	19.50	8.70	10.30	6.99
71	3	1	21	1	21.20	8.11	6.43	7.99
93	3	1	22	1	20.60	9.10	8.52	8.02
10	3	3	24	1	26.00	7.86	5.01	7.4
70	3	3	26	4	27.00	7.57	6.37	7.48

Appendix I-D. Habitat variable data continued.

Way point	velocity	depth	width	Substrate	[3] % wood	[3] % veg	[3] % canopy	riparian minimum
52	0.22	15.5	670.6	10.0	1	1	1	1
50	0.48	10.0	853.4	10.4	1	1	1	1
244	0.44	9.0	729.0	10.8	1	1	2	1
81	0.18	41.1	856.0	10.5	1	1	2	3
79	0.17	30.1	1270.5	13.3	1	1	3	4
243	0.11	23.5	602.0	12.0	2	1	1	1
85	0.17	27.8	856.0	13.6	1	3	2	2
231	0.24	34.2	572.0	10.4	1	1	2	1
256	0.13	40.3	703.6	8.0	2	1	3	1
213	0.07	36.0	706.1	4.0	1	1	1	2
215	0.10	38.9	662.9	2.2	1	1	2	4
169	0.02	37.3	1094.7	11.0	1	1	4	1
204	0.02	37.3	1094.7	11.0	1	1	4	1
43	0.04	43.4	1087.1	11.7	1	1	3	3
174	0.19	20.4	487.7	9.5	2	1	1	3
108	0.32	20.1	792.5	3.5	2	1	4	2

209	0.42	16.8	586.7	10.3	1	1	4	3
152	0.47	30.4	358.0	9.5	1	1	2	2
111	0.30	13.2	703.6	10.5	1	1	2	3
68	0.25	25.2	823.0	10.8	1	1	4	4
75	0.28	19.8	914.4	11.5	1	1	3	3
238	0.27	53.7	500.4	11.5	1	1	2	4
272	0.23	38.0	869.0	11.8	1	1	2	2
71	0.20	14.4	1332.0	11.2	1	1	4	4
93	0.57	18.1	695.0	11.8	1	3	3	3
10	0.05	79.7	1243.0	10.5	2	1	3	3
70	0.26	41.4	1250.0	12.0	1	1	4	3

[1]Codes for land use: urban-1, agricultural-2, wooded-3.

[2]Codes for stream habitat: riffle-1, run-2, pool-3.

[3]Percent cloud cover, percent in-stream wood (% wood), percent aquatic vegetation (% veg), and percent canopy cover (% cover) are all coded as 0-25=1, >25-50=2, >50-75=3, >75-100=4.

[4]Riparian zone width in meters is coded as 0-5=1, >5-10=2, >10-20=3, >20=4 and the minimum score for both sides was used.

Appendix II Riparian zone analysis

Appendix II-A. Ground cover (understory vegetation). The percent of cover of understory vegetation (<1.37 m tall), or ground cover, found at riparian analysis way points for wooded and agricultural land use. Sampled within a 1x1 m square (north orientation) at five randomly selected sites along a 50 m transect. Plants were categorized as woody plants (trees and shrubs), graminoid (grasses, sedges, and rushes), and forbs (herbaceous [annual] plants that are not a graminoid, including ferns) using the classes (0) none, (1) 1-5%, (2) 5-25%, (3) 25-25%, (4) 50-75%, and (5) 75-100%. Data from 8 -9 November 2011, west branch of Sandy Creek, Orleans County, New York.

Location	Woody	Graminoid	Forbs
Agriculture 317	0	4	1
Agriculture 315	0	5	1
Agriculture 316	0	4	1
Average Agriculture	**0**	**5**	**1**
Wooded 318	0	1	3
Wooded 320	1	0	0
Wooded 319	0	1	4
Average Wooded	**1**	**0**	**2**

Appendix II-B. Densiometer data. Densiometer data or percent of canopy cover, the amount of total small debris (< 8 cm circumference), and total large woody debris (> 8 cm circumference). Date from riparian analysis way points for wooded and agricultural land use. Sampled within a 1x1 m square at five randomly selected sites along a 50 m transect. Data collected on the west branch of Sandy Creek, Orleans County, New York, 8 - 9 November 2011.

Location	**total small woody debris**	**total large woody debris**
Wooded 318	4	1
Wooded 320	3	11
Wooded 319	10	9
Average	**5.67**	**7.00**
Agriculture 317	0	0
Agriculture 315	0	1
Agriculture 316	0	0
Average	**0.00**	**0.33**
Densiometer	**percent canopy cover**	
Agricultural	6.6%	
Wooded	73.3%	

Appendix II- C. The density of trees in riparian zone. Density of trees (trees/ha) at sampled waypoints for wooded sites and for agricultural sites with adjacent corn fields or with apple orchards. Designated as large trees ≥ 10cm and small trees <10cm. The west branch of Sandy Creek, Orleans County, New York, 8 -9 October 2011.

Density of trees at wooded sites (waypoints: 318, 319, 321)	
Avg. distance large trees (m)	Avg. distance small trees (m)
4.01	3.93
Total density of large trees (trees/ha)	Total density small trees (trees/ha)
622.4	648.01
Density of trees at apple orchard agriculture site (waypoint: 317)	
Avg. distance to large trees (m)	Avg. distance to small trees (m)
3.9	3.46
Total density of Large trees (trees/ha)	Total density of small trees(trees/ha)
659.15	835.31
Density of trees at corn agriculture sites (waypoints: 315, 316)	
Avg. distance to large trees (m)	Avg. distance to small trees (m)
>50	>50
Total density of large trees (trees/ha)	Total density of small trees (trees/ha)
negligible due to corn dominance	negligible due to corn dominance