CHEMUNG RIVER AND UPPER SUSQUEHANNA COMBINED SUBBASIN SURVEY YEAR-2

Final Data Report
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Introduction

The Susquehanna River Basin Commission (SRBC) has been conducting water quality and biological surveys on selected streams within each major subbasin on a rotating cycle, as part of SRBC's continuing program for assessment of water quality in the Susquehanna River Basin since the mid-1980s. In 1998, SRBC reevaluated this subbasin survey program and added a Year-2 component to better address local interests and Commission objectives by implementing more detailed studies on selected watersheds, regions, or issues. Typically, Year-2 surveys focus only on the major subbasin that was sampled for the Year-1 survey during the prior year. However, because of a unique opportunity to collect baseline data prior to the potential onset of shale gas development in New York State, successive Year-2 surveys of the Chemung River Subbasin and the Upper Susquehanna River Subbasin were combined as one project and were completed over two years.

In summer 2012, SRBC staff conducted the Year-1 broad-brush survey of the Chemung River Subbasin; in summer 2013, the same was completed in the Upper Susquehanna Subbasin. The data collected during these Year-1 surveys provided a snapshot assessment of conditions at many sites within the Chemung and Upper Susquehanna Subbasins. Reports for both the Chemung and Upper Susquehanna subbasins are available at http://www.srbc.net/pubinfo/techdocs/Publications/techreports.htm. This Year-2 project, initiated in April 2013, focused on watersheds in three counties (Chemung, Tioga, and Broome) in the southern tier of New York and sought to establish a robust baseline dataset for water chemistry, biological indicators, and physical habitat conditions, capturing both spatial and temporal variability. Figure 1 shows the location of the Chemung River and Upper Susquehanna River Subbasins within the entire Susquehanna River Basin, indicates the three targeted counties, and displays the locations of the 22 monitoring sites.

Approximately 85 percent of the Susquehanna River Basin is underlain by shale containing natural gas, including the Marcellus Shale formation. In recent years, extracting gas from these deep shale formations has become economically feasible through methods of horizontal drilling and hydraulic fracturing (fracking). This combination is sometimes referred to as unconventional natural gas drilling. The horizontal drilling technique uses large volumes of water, along with a mix of additives, to fracture deep shales and release trapped gas. Because of the large volumes of water needed to fracture the shales, as well as the construction of associated drilling infrastructure (i.e., roads through forest land, clearing for pipelines) and the possibility of leaks, spills, or improper disposal of fracking flowback, the potential for negative impacts on streams and rivers is high.

Prior to the initiation of this project, SRBC has been and continues to be involved in several monitoring projects that focused on potential impacts of unconventional gas drilling and associated infrastructure building activities. However, SRBC's efforts to monitor for these impacts have mainly been focused in Pennsylvania, where unconventional gas drilling has been in progress since 2008, with the initiation of the Remote Water Quality Monitoring Network (RWQMN) in early 2010. SRBC staff also conducts Aquatic Resource Surveys at a subset of proposed gas industry water withdrawal sites to document and ensure the protection of high quality waters, fish spawning periods, and rare, threatened, and endangered species. In addition, all of SRBC's routine water sampling within the Marcellus Shale region includes lab analysis of parameters that could be related to unconventional drilling practices (i.e., total dissolved solids (TDS), chloride, bromide, lithium). In the absence of an acute event such as a spill, the most likely stream impacts associated with gas drilling are altered stream flows, water quality impairment, increased turbidity, and increased sedimentation, all of which can negatively impact aquatic ecosystems.

New York State has permitted traditional gas drilling for decades but currently prohibits the use of unconventional drilling techniques. As a result of this moratorium, SRBC recognized the unique opportunity to collect baseline data in streams that may be most immediately impacted if the drilling ban was lifted. When this project was initiated in 2012, there was some indication that Marcellus Shale gas drilling and fracking may be allowed experimentally in New York in Chemung, Tioga, and Broome Counties, before more of the state would potentially be opened up for development. However, in late 2014, New York Governor Andrew Cuomo banned fracking anywhere in New York State, citing human health risks. As a result, the urgency of need for the baseline data collected for this study declined, but the data are valuable in a number of ways. In addition to providing a baseline dataset for select New York streams, the data collection helped fill fish community data gaps that exist in the New York portion of the basin and served as a pilot for numerous sampling methods not previously used by SRBC. Because this was a baseline assessment, the report will focus on summarizing conditions, detecting seasonal variations, and identifying existing ecological relationships between abiotic and biotic variables that were observed at these study sites.

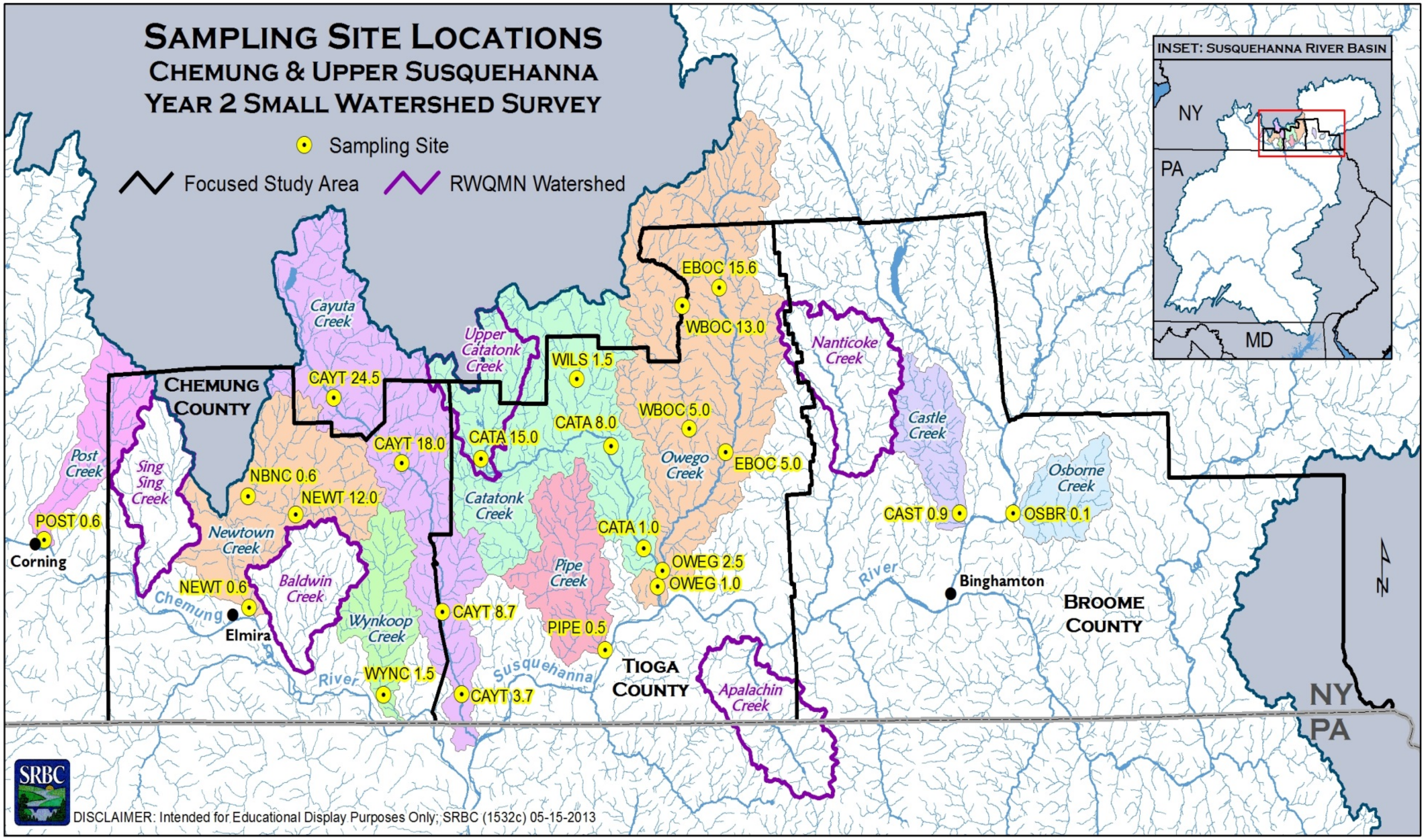


Figure 1. Map of Sampling Locations within the Study Area

Study Design and Rationale

The New York portion of the Chemung and Upper Susquehanna Subbasins was chosen for this two-year focused monitoring project for numerous reasons. Since the onset of unconventional gas drilling within the Marcellus Shale region in Pennsylvania, SRBC has led the effort to collect baseline data prior to gas development. This includes the initiation of an alert system based on continuous monitoring data that allows for early detection of potential instream water quality problems. This project, particularly when it was originated, provided an excellent opportunity to document pre-fracking conditions in streams where there were previously little data available.

Sampling locations within the nine targeted watersheds (Figure 1) were chosen based on the project goals of collecting baseline data in areas that could potentially be impacted by drilling. The number of sites per watershed was based primarily on size. Targeted watersheds were picked based on the following factors: location within the three counties of interest, drainage fully isolated to New York State, and likelihood for Marcellus-related development based on current leases and infrastructure that already in place. SRBC's RWQMN project includes 10 streams in New York State where both continuous field water chemistry and periodic supplemental lab chemistry have been collected since January 2011. These stations are spread throughout the Chemung and Upper Subbasins, and five stations drain areas that are located at least partially in Chemung, Tioga, or Broome Counties (Figure 1). The drainages already covered by the RWQMN network are not included in this study.

One sampling site (Post Creek) was located outside of the targeted counties, but the majority of Post Creek's headwaters are located within Chemung County in an area that could potentially be heavily drilled, based on the high density of existing gas pipelines. In addition, one reference site was chosen in the upstream portion on Cayuta Creek. This site is located in Schulyer County, which was not expected to be immediately impacted by gas development, but the remainder of the sites downstream on Cayuta Creek are within the targeted counties. Table 1 provides additional information about each monitoring location. This study included the collection of seasonal water quality, periphyton, and macroinvertebrate samples and one assessment of fish communities in an attempt to enhance the quality of baseline data by better understanding the temporal variability inherent in biological monitoring.

Table 1. Sampling Site Information

Alias	Stream	Latitude	Longitude	Drainage Area (mi^2)	County	Watershed
CAST 0.9	Castle Creek	42.168740	-75.899520	28.8	Broome	Chenango River
OSBR 0.1	Osborne Creek	42.168480	-75.832210	24.8	Broome	Chenango River
CAYT 24.5	Cayuta Creek	42.268889	-76.682500	50.5	Schuyler	Cayuta Creek
CAYT 18.0	Cayuta Creek	42.217222	-76.503333	89.9	Chemung	Cayuta Creek
CAYT 8.7	Cayuta Creek	42.091928	-76.547119	121	Tioga	Cayuta Creek
CAYT 3.7	Cayuta Creek	42.024167	-76.523889	137	Tioga	Cayuta Creek
NEWT 12.0	Newtown Creek	42.172700	-76.730600	20.6	Chemung	Newtown Creek
NEWT 0.6	Newtown Creek	42.096111	-76.788611	79.1	Chemung	Newtown Creek
NBNC 0.6	North Branch Newtown Creek	42.187620	-76.789650	18.2	Chemung	Newtown Creek
WYNC 1.5	Wyncoop Creek	41.991667	76.589167	30	Chemung	Chemung River
POST 0.6	Post Creek	42.151944	-77.045000	33.3	Steuben	Chemung River
PIPE 0.5	Pipe Creek	42.059433	-76.344067	45	Tioga	Susquehanna River
CATA 15.0	Catatonk Creek	42.217778	-76.498333	72.7	Tioga	Owego Creek
CATA 8.0	Catatonk Creek	42.227720	-76.334700	125	Tioga	Owego Creek
CATA 1.0	Catatonk Creek	42.142900	-76.295000	147	Tioga	Owego Creek
WILS 1.5	Wilseyville Creek	42.283056	-76.377222	15	Tioga	Owego Creek
WBOC 13.0	West Branch Owego Creek	42.342400	-76.244400	24.4	Tioga	Owego Creek
WBOC 5.0	West Branch Owego Creek	42.241553	-76.236636	51.5	Tioga	Owego Creek
EBOC 15.6	East Branch Owego Creek	42.356950	-76.197850	39.6	Tioga	Owego Creek
EBOC 5.0	East Branch Owego Creek	42.221730	-76.191740	86.9	Tioga	Owego Creek
OWEG 2.5	Owego Creek	42.124245	-76.271676	187	Tioga	Owego Creek
OWEG 1.0	Owego Creek	42.111590	-76.277820	340	Tioga	Owego Creek

Methods

All sampling was completed as described in detail in the Quality Assurance Project Plan (QAPP) which was approved by the U.S. Environmental Protection Agency (USEPA) prior to initiation of the project (Steffy, 2013). A brief and generalized description of sampling methods is included below. Seasonal water quality and biological sampling began in April 2013 and continued through February 2015. Biological sampling was conducted in spring, summer, and fall. Water quality parameters for three of the four sampling rounds consisted solely of constituents that would be related to unconventional shale, including various metals and gross radioactive compounds (Table 2). During the summer sampling, additional nutrient and major cation/anion parameters were added to the list of analytes measured. Water samples were collected and preserved in the field, then delivered to a certified laboratory within 24 hours for analysis. Field chemistry was collected in-situ using a hand-held multi-meter. Raw data can be found in Appendix A.

Table 2. Water Quality Parameters

Quarterly Sampling Parameters	Additional Parameters (sampled annually)
Temperature	Alkalinity
Dissolved Oxygen	Nitrate
Conductivity	Total Phosphorus
pH	Potassium
Turbidity	Sodium
Total Suspended Solids	Total Organic Carbon
Total Dissolved Solids	Calcium
Bromide, Total	Magnesium
Chloride, Total	
Barium, Total	
Gross Alpha	
Gross Beta	
Lithium, Total	
Strontium, Total	
Aluminum, Total	

Macroinvertebrates were collected using a six kick D-frame net composite during spring, summer, and fall of 2013 and 2014. Macroinvertebrate samples were processed to a 200-count subsample and assessed using numerous community level metrics based on genus-level identification as well as the Pennsylvania Department of Environmental Protection's (PADEP's) Index of Biotic Integrity (IBI) for comparative analysis (PADEP, 2013). This IBI is a multi-metric index that integrates numerous community level and tolerance-based metrics to rank sites according to watershed size and sampling period on a scale of 0-100. Community similarity-based analysis was a secondary method used to evaluate and compare macroinvertebrate assemblages. Macroinvertebrate metric data can be found in Appendix B.

Periphyton – algae that grow on the surface of rocks – were sampled using USEPA protocols (USEPA, 2007), and a 25-ml aliquot of the composite sample was filtered for ash free dry mass (AFDM) analysis. AFDM was used as a relative measure of periphyton biomass. Periphyton were sampled in spring, summer, and fall in 2013 and 2014 in order to capture natural seasonal differences in algal biomass at each site.

Fish were sampled during the summer months at 20 of the 22 sampling location one time in either 2013 or 2014. A stream reach of ten times the average wetted width was used to determine fish sampling reach length, and three passes of the same reach were completed. Depending on stream size, fish were captured using either a backpack or tow barge electroshocking technique. Aggregate weight for each species was measured to better establish baseline fish community metrics, including total biomass. Game fish and large individual fish were identified and weighed in the field, while small fish were preserved in formalin and processed in the laboratory. Numerous metrics, including trophic guilds, habitat preference, and tolerance, were calculated in order to describe fish communities. Community similarity-based analysis was also used to categorize and classify fish assemblages. Fish assemblage data and metric scores can be found in Appendices C and D, respectively.

Qualitative and quantitative measures of physical habitat were measured during the two summer sampling rounds in an effort to characterize substrate, describe basic current stream morphology, and evaluate riparian canopy cover. Pebble counts, bankfull widths and heights, densiometer readings, and a modified Rapid Bioassessment Protocol (RBP) Habitat Assessment were used. The RBP is a qualitative ranking of instream habitat based on ten descriptive categories, including embeddedness, epifaunal substrate, and bank stability sediment deposition. Zig-zag pebble counts involved size classification of 100 substrate particles from a representative reach of stream containing all available habitat unit types (NYSDEC, 2012). Cumulative frequency distributions were created for each site, and several metrics were calculated from the pebble count data, including percent fines, number of size classes, sorting coefficient, and Shannon Diversity.

Nonparametric statistical analysis was used heavily as the data were not normally distributed. To compare datasets, Kruskal-Wallis tests were used to determine if any significant differences between groups existed, and then Mann-Whitney pairwise tests were used to identify differences between specific groups. A Bonferroni correction was used to modify the p-value of the pairwise tests in order to decrease the likelihood of Type I errors.

Results and Discussion

Water Quality

Water chemistry samples were taken seasonally over the course of the two-year project for a total of eight samples per site. In general, water quality at all sampling locations was within the acceptable and expected range for all parameters analyzed. The one exception was total aluminum, which exceeded the New York State Department of Environmental Conservation’s (NYSDEC’s) water quality standard of 100 ug/l in about 30 percent of the samples. Of those exceedances, a large majority occurred during the spring sampling. Streams in the southern tier of New York commonly exceed 100 ug/l standard for total aluminum (SRBC unpublished data), which is much lower than surrounding states such as Pennsylvania, whose standard is 750 ug/l. This elevated aluminum is most often seen during high flows, suggesting aluminum may be correlated with erosion of local surficial geology or soil and may be related to acid precipitation.

All sampling sites were located in the same ecoregion, the Northern Appalachian Plateau and Uplands (NAPU), and as such, they should be expected to have similar basic ion chemistry despite differences in size, land use, and point sources. Using a piper plot, a visual summary of ion chemistry for each sampling site was plotted and, as expected, all sites plotted very close together. Slight variation was observed at two sites (Osborne Creek and Castle Creek), which had minimally higher chloride concentrations and lower alkalinity. These two sites were the only two streams in Broome County and in the Chenango River drainage, and are noted by the open circles in the piper plot (Figure 2). Reasons for these differences are largely unknown, as these sites are located in areas with similar geology and land use to all other sampling locations.

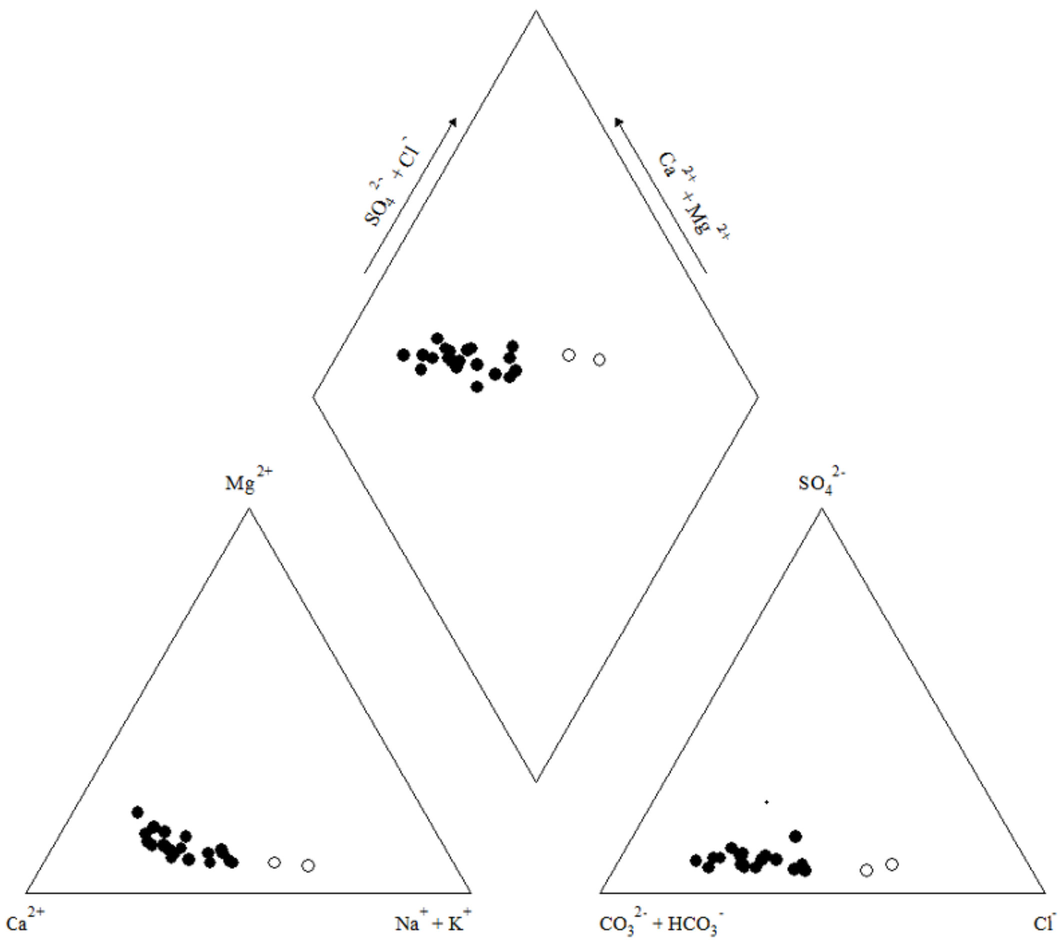


Figure 2. Piper Diagram of Major Ion Chemistry for all Sampling Locations (Osborne and Castle Creeks are sites shown as open circles.)

At all sites, all measured constituents related to Marcellus Shale drilling were either present below detection limits or found in very low concentrations. Gross alpha radioactivity was detected at four sites, and gross beta radioactivity was found at 18 sites. Both gross alpha and beta radioactivity were only detected in low concentrations and were in line with what has been documented in other streams in the NAPU ecoregion (SRBC unpublished data). Detection of gross alpha and beta was most common in the summer samples. Several landfills in NY are accepting radioactive waste from mine cuttings and unconventional drilling techniques in Pennsylvania, so the importance of documenting background levels of radioactivity in essential.

Nutrients were only sampled in the summer, and nitrate and phosphorus were generally low, with less than 30 percent of sites exceeding natural background concentrations for nitrate (0.6 mg/l) and none exceeding the same for total phosphorus (0.1 mg/l) (USGS, 1999). Sites within Owego Creek Watershed were responsible for the five highest mean nitrate loads. Nutrient loading is most often attributable to agricultural land uses within a watershed and can be intensified when agriculture is adjacent to stream channels with little or no riparian buffer. Catatonk Creek, the largest tributary to Owego Creek, had the highest nitrate concentrations of anywhere in the study area. Catatonk Creek Watershed is nearly 20 percent agricultural land use, and much of the agriculture is adjacent to the stream channels.

The most developed watershed, Newtown Creek, showed characteristic signs of an urban watershed, such as consistently higher chloride, TDS, and conductivity than all other streams in the area. Chloride is often used as an indicator of human influence in a watershed as it is not found naturally in high concentrations (Fischer et al., 2004). Anthropogenic sources of chloride in surface water include treated sewage, livestock waste, water conditioning salt, synthetic fertilizer, brine disposal pits, and road salt runoff (Kelly et al., 2012). Conductivity is the measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of dissolved solids such as chloride, nitrate, sulfate, and phosphate anions or sodium, magnesium, calcium, iron, and aluminum cations. TDS is a composite measurement of all organic and inorganic substances dissolved in the water. Conductivity and TDS are also both typically higher in more developed watersheds. Further support for increased chloride, conductivity, and TDS being related to development was evident as all three parameters are negatively and significantly ($\alpha=0.05$) correlated to percent forest. As percent forest decreases, concentrations of chloride (Pearson r= -0.531 p=0.016) and TDS (Pearson r= -0.475 p=0.034) and conductivity (Pearson r= -0.573 p=0.008) values increase.

Both conductivity and TDS are influenced by chloride, although not exclusively, which results in all three parameters exhibiting a similar relationship to macroinvertebrate IBI score (Figure 3). Chloride concentration and macroinvertebrate IBI score were significantly and moderately negatively correlated (Pearson r= -0.343 p<0.001). While none of the samples exceeded the water quality standard for chloride (150 mg/l), there was a downward trend in IBI scores as chloride concentrations increased. Conductivity (Pearson r= -0.313 p=<0.001) and TDS (Pearson r= -0.327 p=<0.001) also showed significant and moderately negative correlations with macroinvertebrate IBI score (Figure 3).

One of the main sources of chloride in surface water particularly in winter and spring is runoff of de-icing road salt. Chloride to bromide ratios are often used to identify sources of chloride in surface water; streams that are heavily influenced by de-icing road salts typically have a Cl/Br ratio between 1000-10,000 (Davis et al., 1998; Panno et al., 2006). While there is not a significant correlation with Cl/Br ratio and IBI score (Pearson r= 0.136 p=0.169), a majority of sites indicate a Cl/Br ratio that reflects an influence of road salts (Figure 3). The Cl/Br ratio for the entire two-year sampling period was 1447 ± 467 (mean ± 1 standard deviation). Spring had significantly higher Cl/Br ratios (Kruskal-Wallis H= 29.24 $p<0.001$) than any other season, which is not surprising given the spring snow melt and increased runoff from surfaces that were salted all winter. Additional analysis of (Ba+Sr)/Mg ratios confirm that the influence of natural brines in these streams is negligible, leaving road salt as source of chloride (Johnson, 2014).

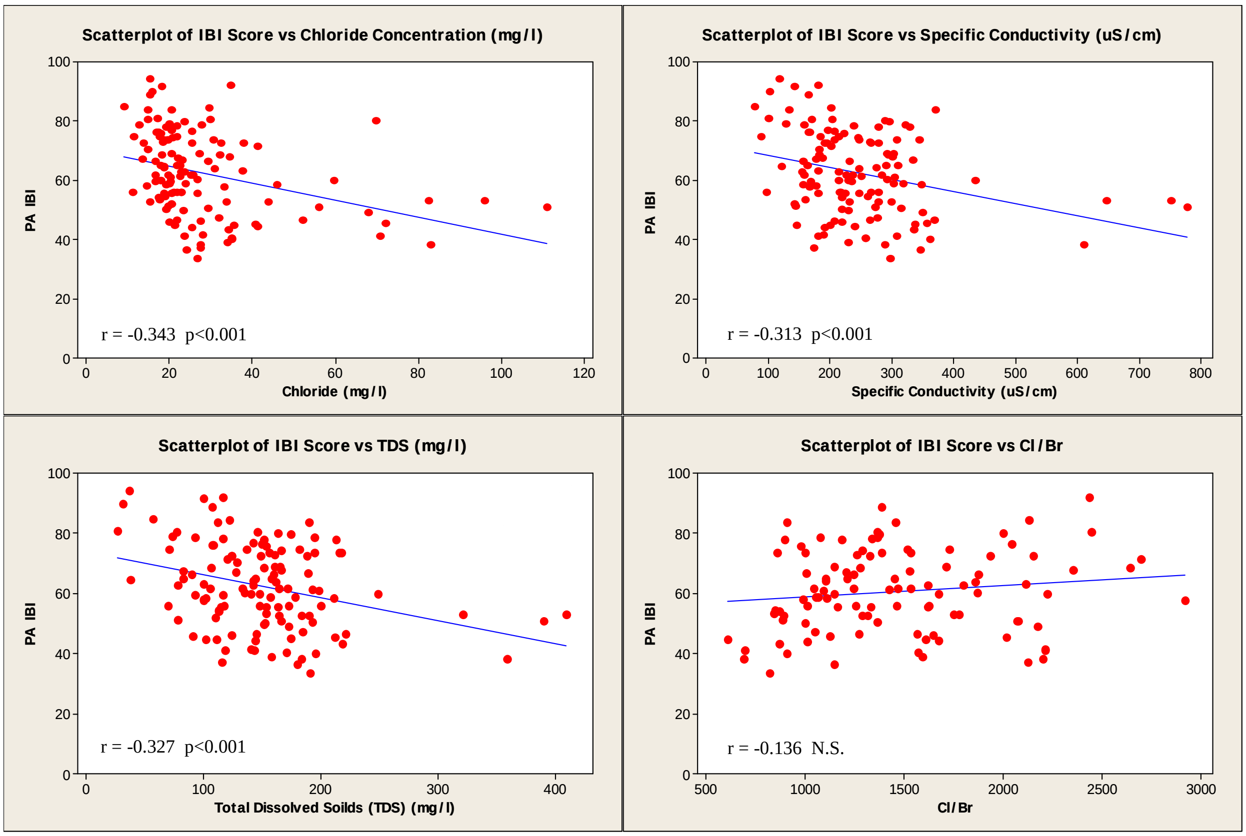


Figure 3. ***Scatterplots of PA IBI Score vs. Chloride, Conductivity, TDS, and Cl/Br (Pearson r and p-values, when significant, are indicated on each plot.)***

<u>Periphyton</u>

Periphyton are algae that grow on rocks and can be an important link in stream food webs. However, in the presence of elevated nutrient concentrations and loss of riparian canopy cover due to development, periphyton can reach nuisance levels and be detrimental to stream health. Nuisance levels of periphyton biomass are defined by USEPA as greater than 5 mg (AFDM)/cm^2 (Barbour et al., 1999). Periphyton biomass, as estimated by AFDM density, was quite variable both in density and seasonal patterns. Results showed substantial variation in biomass, although discernable patterns were difficult to find as there was not a significant difference between seasons. AFDM densities ranged from 0.0492 –

0.8863 mg/cm^2 in 2013 with both minimum and maximum densities collected in the spring. However, in 2014, AFDM densities ranged from 0.0151 – 13.7583 mg/cm^2, with both minimum and maximum collected in the fall. In 2013, no sites had greater than the 5 mg/cm^2 that would put them at nuisance levels. However, in 2014, six sites demonstrated nuisance levels of periphyton biomass in the fall (Figure 4). Five of the six sites with nuisance level periphyton were in the Owego Creek Watershed, but the most dense periphyton community was in Castle Creek during fall 2014, with a density more than two and half times what is considered to be nuisance level.

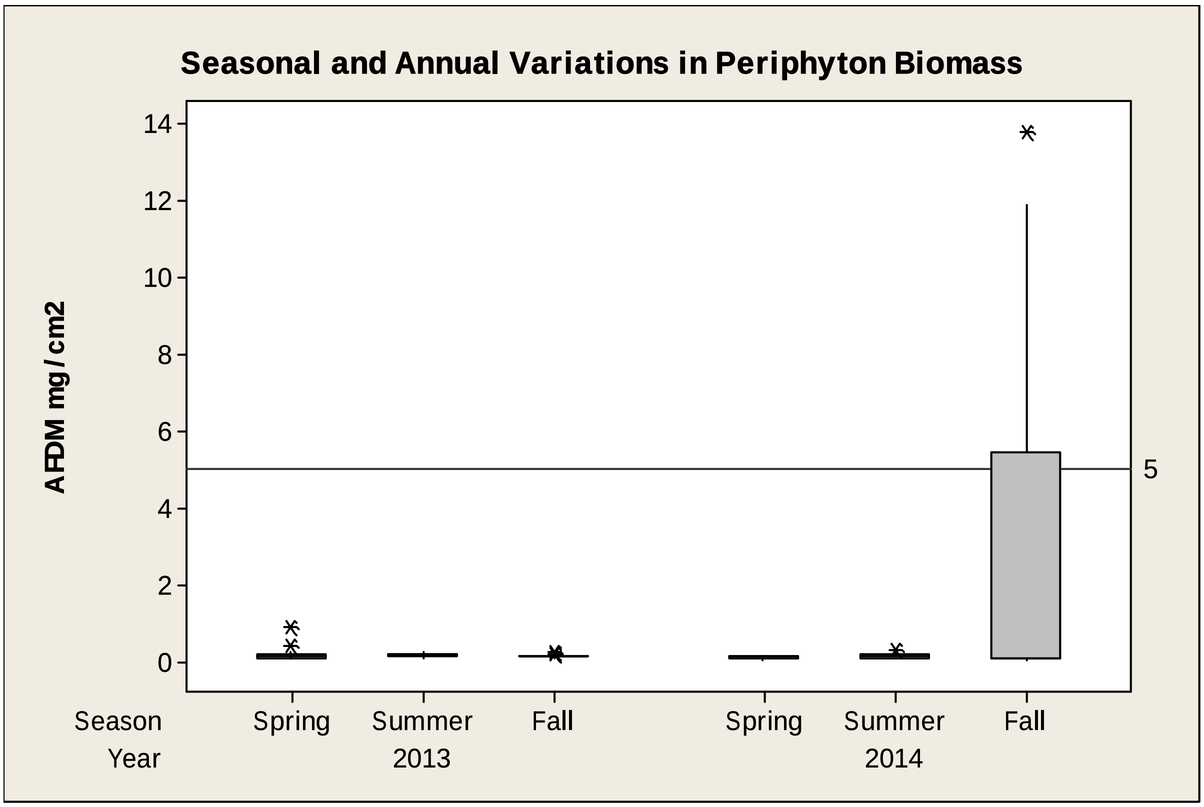


Figure 4. Box Plot Displaying Variation in Periphyton Biomass between Season and Years (Anything over 5 mg/cm^2 is considered nuisance level.)

Somewhat surprisingly, neither riparian canopy cover nor instream nitrate concentration were good predictors of periphyton biomass. Additionally, there was no significant correlation between AFDM density and drainage area, sediment composition, or stream flow. While increased periphyton density often results in increased stream pH, this dataset showed only a slight, but insignificant positive correlation (r = 0.122).

No significant correlations existed between AFDM and any of the macroinvertebrate metrics or IBI scores. However, periphyton biomass did show some interesting correlations with fish community metrics, including percent native individuals (Figure 5). There was a strong negative correlation between increasing periphyton biomass and a decrease in percent native fish individuals (r= -0.693 p= 0.001). This correlation was primarily driven by the introduced species mimic shiner, banded darter, and greenside darter, which were found in greater abundance at sites where periphyton biomass was relatively higher than other sites in the study area.

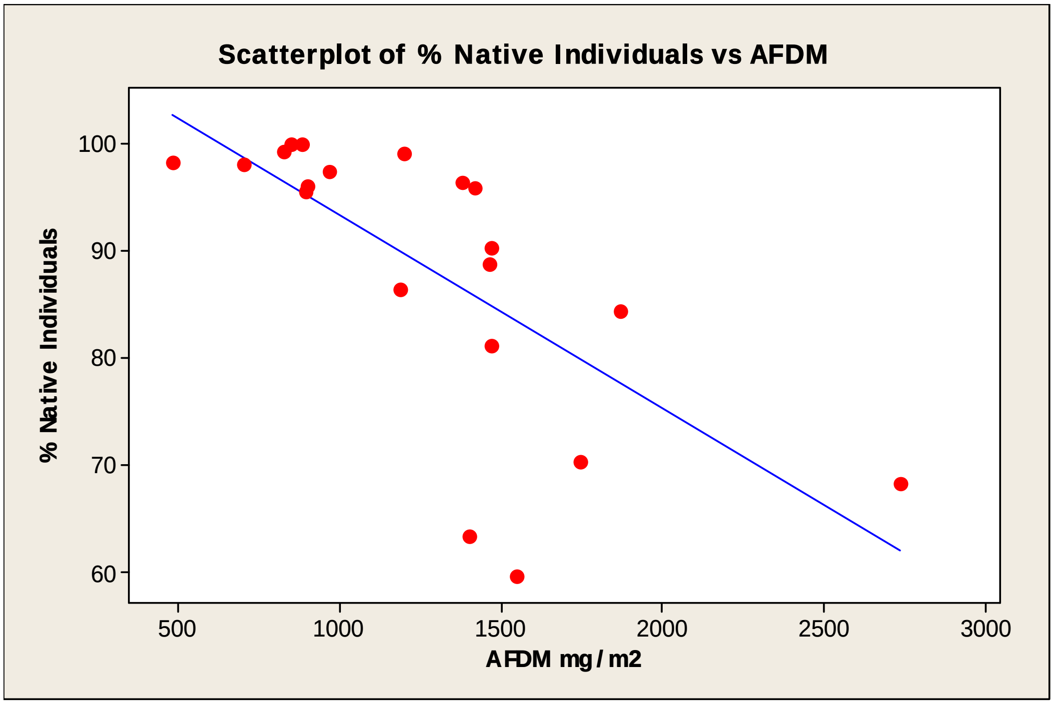


Figure 5. Relationship between Percent Native Fish and Periphyton Biomass (Pearson r= -0.69 p=0.001)

Additionally, relative abundance of three fish families was significantly correlated with periphyton biomass (Table 3). Both Catostomidae and Centrarchidae were positively correlated with periphyton density, meaning relative abundance of these families increased within the fish assemblage at sites where periphyton biomass was greater. Conversely, species from the family Cyprinidae decreased in relative abundance as periphyton biomass increased. Despite being the only true herbivore in any of the fish assemblages, there was no correlation with relative abundance of central stonerollers and periphyton. This observation has been noted in other datasets within the Susquehanna River Basin (SRBC unpublished data). Scatterplots showing the relationships between AFDM and fish family relative abundance are shown in Figure 6. The families of Percidae (perches and darters), Cottidae (sculpins), Ictaluridae (bullheads and madtoms), and Salmonidae (trout) showed no significant correlation with periphyton density.

Table 3. Pearson Correlation Results between Fish Families and Periphyton Density

	AFDM (mg/m^2)	
	Pearson r	p-value
Catostomidae (suckers)	0.730	<0.001
Centrarchidae (bass and sunfish)	0.511	0.021
Cyprinidae (minnows)	-0.435	0.050

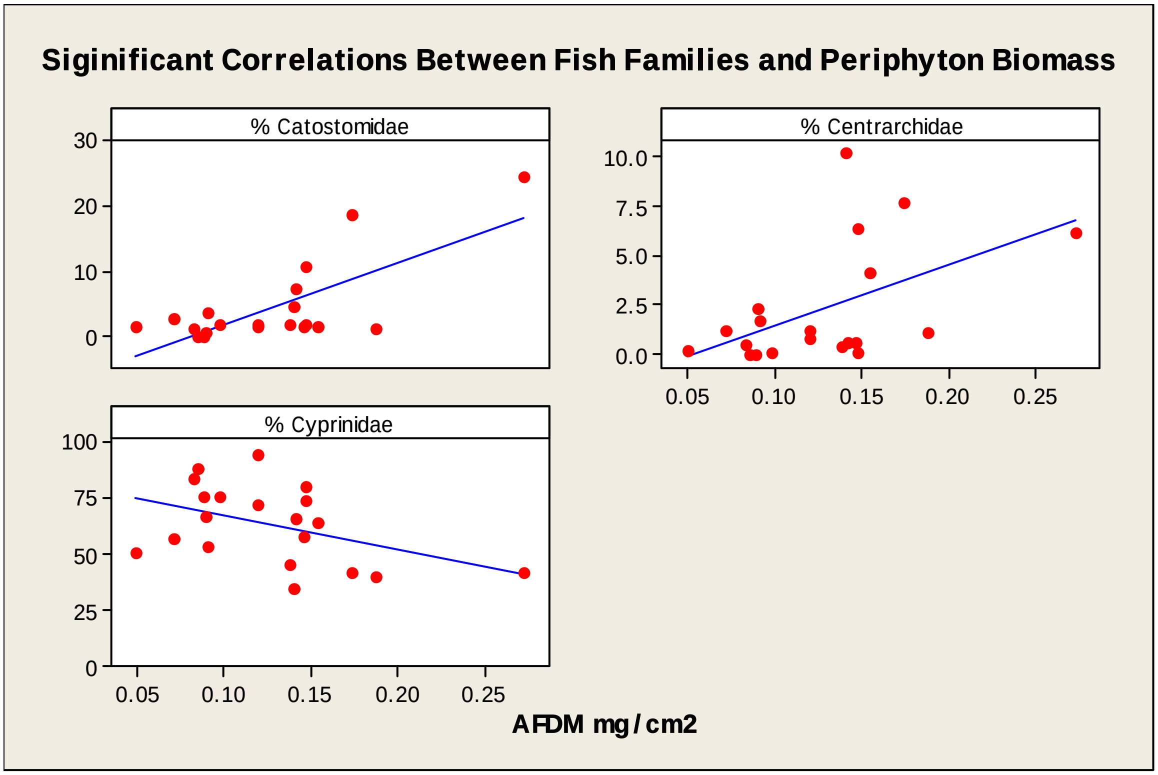


Figure 6. Correlations between Specific Fish Families and Periphyton Density

<u>Macroinvertebrates</u>

Macroinvertebrates were collected at all sites during spring, summer, and fall each year for a total of six samples per site. The purpose of seasonal sampling was to develop a better understanding of the temporal variations in macroinvertebrate communities. The macroinvertebrate assemblages were analyzed using two primary methods: a multimetric IBI and community similarity. Seasonal patterns in macroinvertebrate communities were reflected in both.

Multimetric Analysis

A biological metric quantifies measurable characteristics of the biota that change in predictable ways with increased anthropogenic stress. A multimetric approach, such as an IBI, utilizes a suite of metrics that measure diverse biological attributes and response to different stressors. A major advantage of the multimetric approach is the ability to incorporate information from a number of metrics that, when integrated into a single numerical index, can provide a meaningful measure of overall biological condition (Barbour et al., 1995).

PADEP's PA IBI is used in this analysis (PADEP, 2013). This method is applicable in the southern tier of NY State because this area is in the NAPU ecoregion, which also encompasses a large part of the northern tier of Pennsylvania. The NAPU ecoregion was included in the development of the PA IBI. However, dissimilar macroinvertebrate assemblages can have similar metric and IBI scores, so community similarity using Bray-Curtis similarity matrices was also examined to further dissect the seasonal differences. An understanding of seasonal patterns is crucial to establishing an accurate baseline dataset.

Streams with healthier macroinvertebrate assemblages showed the biggest seasonal differences in taxa, individual metric scores, and IBI. At the most degraded sites, macroinvertebrate communities were poor regardless of season. Approximately 10 percent of all samples taken over the two years at all sites ranked as impaired (scored lower than 43) on the PA IBI. All three sites in Newtown Creek Watershed were routinely some of the worst sites. East and West Branch Owego Creeks and Pipe Creek all had IBI scores over 90 at least once during the sampling period. Overall, IBI scores ranged from 33 to 94 ($\bar{x}$ =62 ±14). The highest IBI scores were found during the spring, which is not surprising given the general tendency of greater macroinvertebrate diversity in the spring (Figure 6). Kruskal-Wallis analysis revealed a significant difference in IBI score between seasons ($p<0.001$), with spring showing the highest Z-score meaning it was the most different. Using Mann-Whitney test with the Bonferroni correction, IBI scores were significantly higher in spring than summer ($p<0.001$) or fall ($p<0.001$), but summer IBI scores were not significantly different from ones in the fall. In general, the highest percentages of mayfly taxa were collected in the spring, while caddisfly occurrence peaked in the fall and was lowest in the spring. Few stoneflies were found in summer or fall, and many Plecoptera taxa were only found in the spring. IBI scores routinely varied by 20-30 points at the same site depending on season.

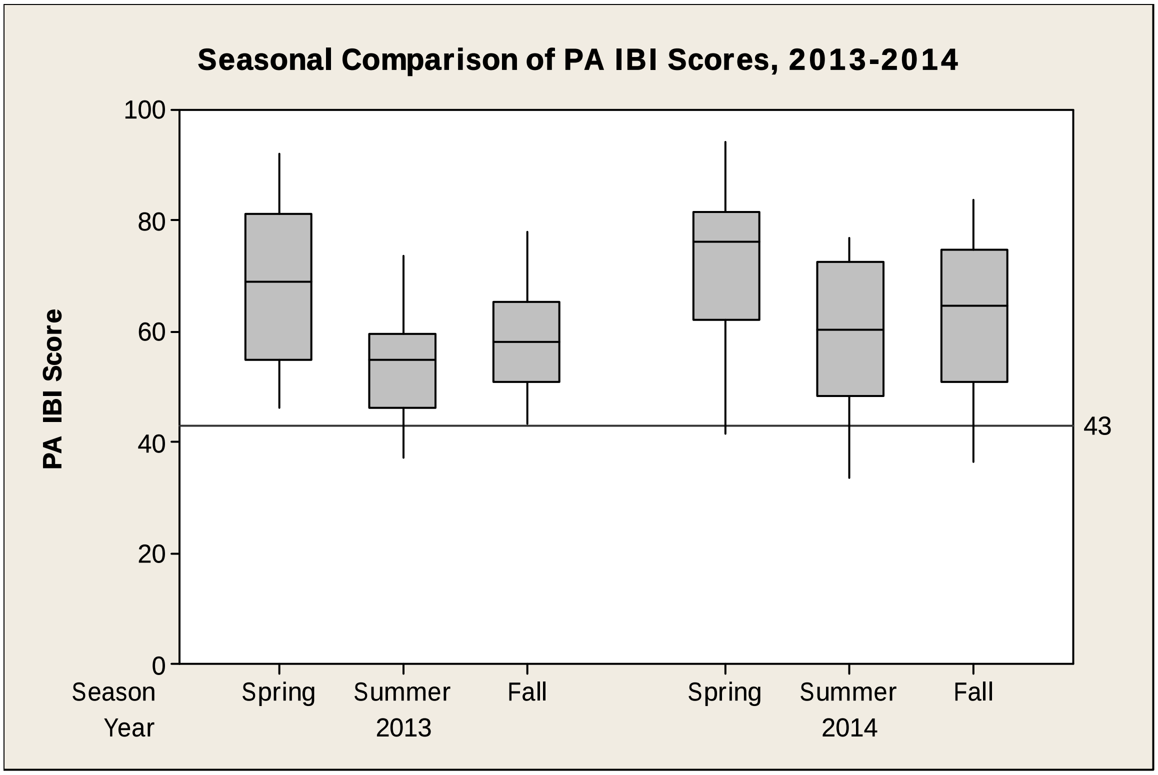


Figure 6. Box Plot Showing Seasonal and Yearly Variation in PA IBI Scores

Six individual metrics (Table 4) make up the PA IBI. These metrics quantify various aspects of a macroinvertebrate assemblage at a site and are combined to calculate an overall IBI score ranging from 0-100 (PADEP, 2013). PADEP assigns numeric pollution tolerance values (PTVs) to most benthic macroinvertebrate taxa. Most of the PTVs used by PADEP to date reflect organismal responses to pollution related to nutrient enrichment and sedimentation, and these PTVs are not necessarily reflective of organismal responses to other types of pollution. Four of the six metrics are based on a PTV, and these metrics are the primary drivers behind the seasonal differences in IBI score.

Results from Kruskal-Wallis analysis revealed significant seasonal differences in each individual metric, with the exception of Shannon Diversity Index. Most often spring samples exhibited the highest Z-scores, indicating the most deviation from the median values. When comparing pairwise seasonal samples for each individual metric using the Mann-Whitney test, spring was significantly different from summer and fall for a majority of metrics, while summer and fall were only different for Hilsenhoff Biotic Index and percent tolerant individuals (Table 4). Spring samples generally contain more pollution intolerant taxa which greatly impacts the IBI score. However, even between fall and summer samples, two metrics, percent sensitive taxa and Hilsenhoff Biotic Index, were also significantly different. Summer samples typically showed the lowest IBI scores, driven by a lower relative abundance of intolerant taxa. Shannon Diversity was not significantly different between seasons.

Table 4. Mann-Whitney p-values (α=0.05) between Seasons for Select Metrics (Metrics in bold are based on PTV values)

	Spring vs. Summer	Spring vs. Fall	Summer vs. Fall	Season with highest metric scores
Taxa Richness	< 0.001	< 0.001	N.S.	spring
Shannon Diversity	N.S.	N.S.	N.S.	N/A
EPT Taxa (PTV 0-4)	< 0.001	< 0.001	N.S.	spring
Becks Index	< 0.001	< 0.001	N.S.	spring
Hilsenhoff Biotic Index*	< 0.001	N.S.	< 0.001	spring
Percent Sensitive Individuals (PTV 0-3)	< 0.001	0.012	< 0.001	spring

*For Hilsenhoff Biotic Index, lower scores indicate better conditions, so season with lowest HBI is listed.

Community Similarity

Community similarity analysis affords an important perspective to macroinvertebrate assemblages that are not evident by just considering individual metrics or a composite multi-metric index score. Comparing similarity of taxa occurrence and abundance between sites and seasons provides valuable insight and improves the strength of the baseline dataset. The analysis of similarity (termed ANOSIM) showed a significant difference between all seasons ($p < 0.001$), even in cases where IBI scores were not significantly different (Table 5). Additionally, there was a significant difference in community similarity between spring 2013 and spring 2014. This may be a result of numerous factors such as warming days before sampling, higher antecedent flows, or higher flows during sampling. Nearly 9 percent of the difference between the two springs was attributed to the greater relative abundance of black fly larva (*Prosimulium*).

Table 5. Comparison of Differences in IBI Score and Community Similarity

	IBI (Mann-Whitney)	Community Similarity (ANOSIM)
Comparative Groups	**p-value**	**p-value**
Spring vs. Summer	<0.001	<0.001
Summer vs. Fall	N.S.	<0.001
Spring vs. Fall	<0.001	<0.001
Spring 2013 vs. Spring 2014	N.S.	<0.001
Summer 2013 vs. Summer 2014	N.S.	N.S.
Fall 2013 vs. Fall 2014	N.S.	N.S.

Nonmetric multidimensional scaling (NMDS) is a distance-based ordination method that allows for visual comparison of the similarity of biological communities (Field, 1982; Clarke, 1993). Similarity indices, such as the Bray-Curtis similarity index used here, compare common taxa and abundance of those taxa between samples. By using the resulting similarity matrix as a basis, the NMDS plot uses proximity as a measure of similarity. Sites that fall nearest each other on the NMDS ordination plot are most similar. By assigning descriptive factors to each sample (e.g., year, size, ecoregion) plots can be used to assess groupings within all samples.

NMDS was applied to macroinvertebrate communities to allow for a visual comparison of community similarity; the most similar sites in terms of taxa type and abundance plot closest together. The grouping of spring samples apart from summer and fall samples is very evident (Figure 7). By using a similarity percentage and taxa contribution analysis (termed SIMPER), the overall similarity of groups can be defined as which and how many specific taxa are contributing to the dissimilarity and in what proportion. On average, spring and summer samples were 65 percent dissimilar as were spring and fall samples. However, summer and fall communities were also 54 percent dissimilar on average. Spring samples showed much more spread between 2013 and 2014, although both years were still distinct from summer and fall samples (Figure 7).

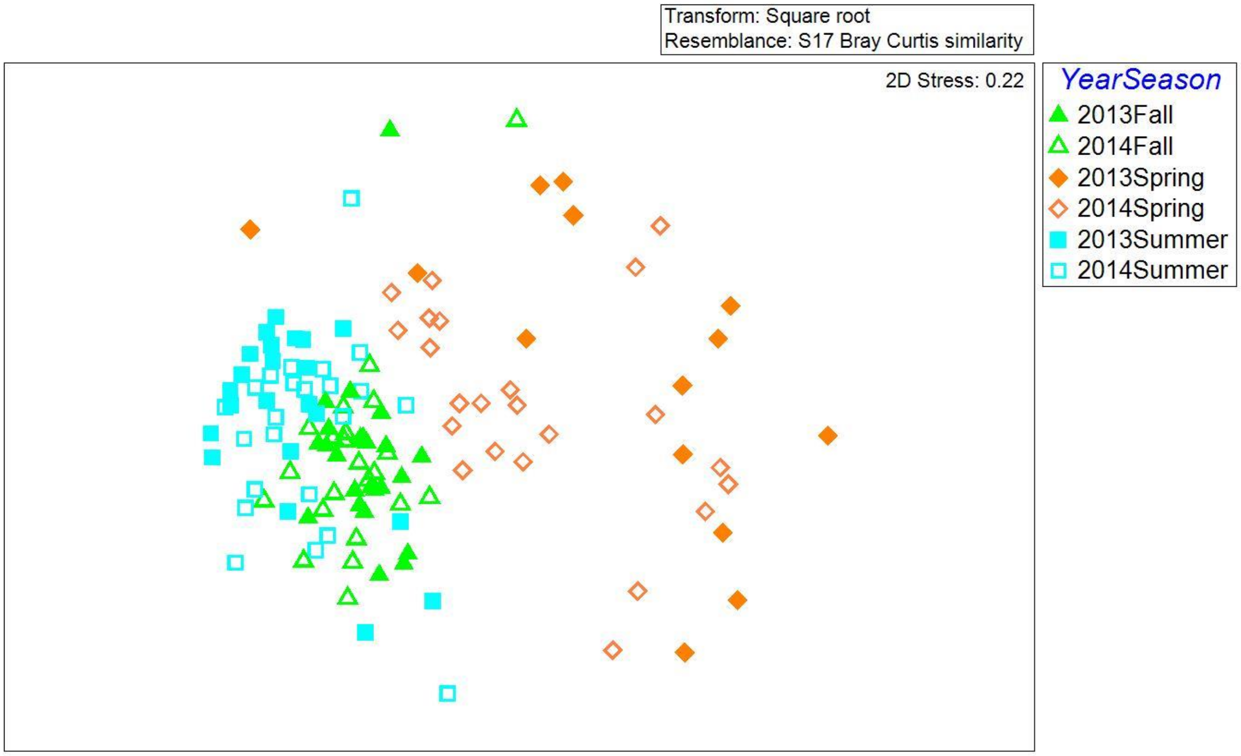


Figure 7. NMDS Plot of Seasonal and Annual Comparisons in Macroinvertebrate Communities, 2013-2014

With macroinvertebrate sampling, there is always some intrinsic variability even among samples taken at the same site at the same time. This is due to heterogeneity in the stream as well as variation inherent in subsampling techniques. Individual fall and summer samples, regardless of year or site, were greater than 50 percent similar to other samples within the respective season. Conversely, individual spring samples were only 38 percent similar; this is evident in the degree of scatter shown within spring samples as shown in Figure 7. As seen in Table 5, the spring macroinvertebrate communities were significantly different by year but both years were significantly different than any summer or fall samples. This variability is further illustrated using the SIMPER analysis results. In describing the dissimilarity of all spring samples, 15 individual taxa were needed to explain 90 percent of the differences within the season. However, in fall and summer, only eight taxa were needed to explain the same 90 percent level of dissimilarity. The more taxa needed to explain the same percentage of dissimilarity, the greater the differences within that group.

Aside from Chironomidae, which were only identified to family and showed the largest variation from site to site, within season and between seasons, some of the main drivers in seasonal differences were the presence or absence of *Isonychia* and *Optioservus* in the fall, *Stenelmis* and *Psephenus* in the summer, and *Prosimulium* and *Ephemerella* in the spring. Some taxa were only collected in the spring, including: *Prosimulium*, *Soyedina*, *Cultus*, *Strophopteryx*, *Clinocera*, and *Cinygmula*. Figures 9 and 10 show the same NMDS plot as in Figure 7 but the symbology is adjusted to show relative abundance of two taxa and how they are more likely to be found in fall or spring respectively. Each sample is represented by a circle with the number of the specific taxa found in the subsample labeled inside the circle, for sites where no individuals of that genus were found a zero is shown in place of a circle.

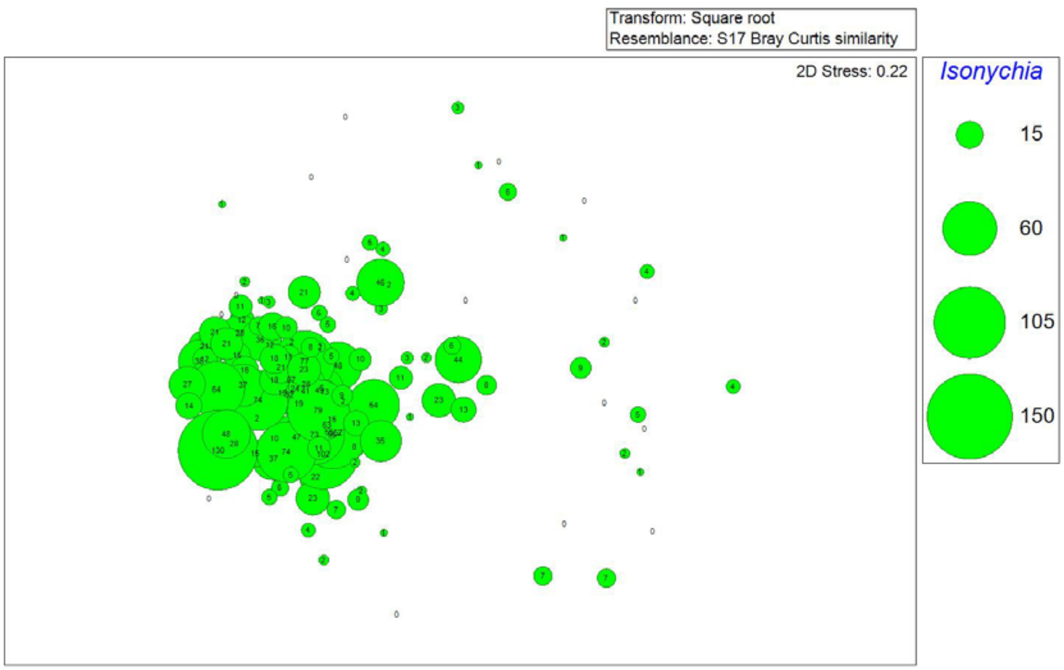


Figure 9. Distribution of Isonychia Showing Fall Predominance

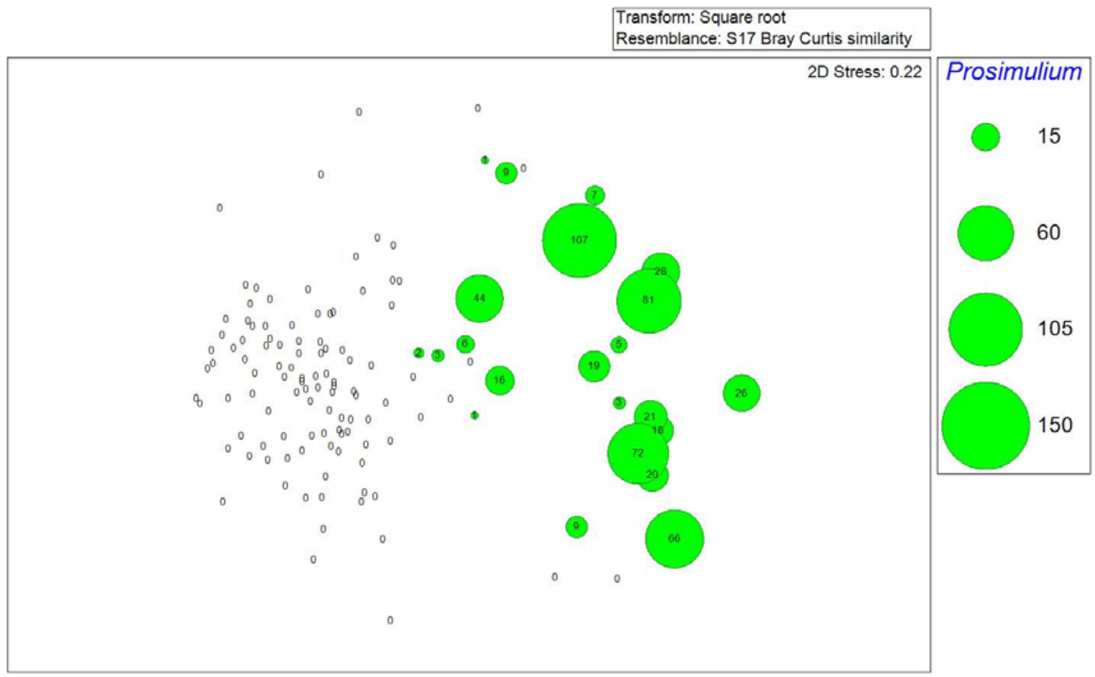


Figure 10. Distribution of Prosimulium Showing Spring Predominance

Owego Creek was the largest watershed sampled with a drainage area of nearly 350 square miles. This watershed includes Catatonk Creek and the East and West Branches of Owego Creek. A total of 10 sites were sampled within the watershed, and the seasonal community grouping is clear as well as the variability between the two spring samples (Figure 11). Some sites were only plotted once for spring because high flows precluded sampling at a few large sites in spring 2013. Note the fall outlier C8; this site was bulldozed and totally re-structured for flood control purposes approximately two weeks prior to fall 2014 sampling, and all established macroinvertebrate habitat was removed. This drastically impacted the assemblage that was there during time of sampling as evidenced by less than 25 percent similarity to previous samples at that site.

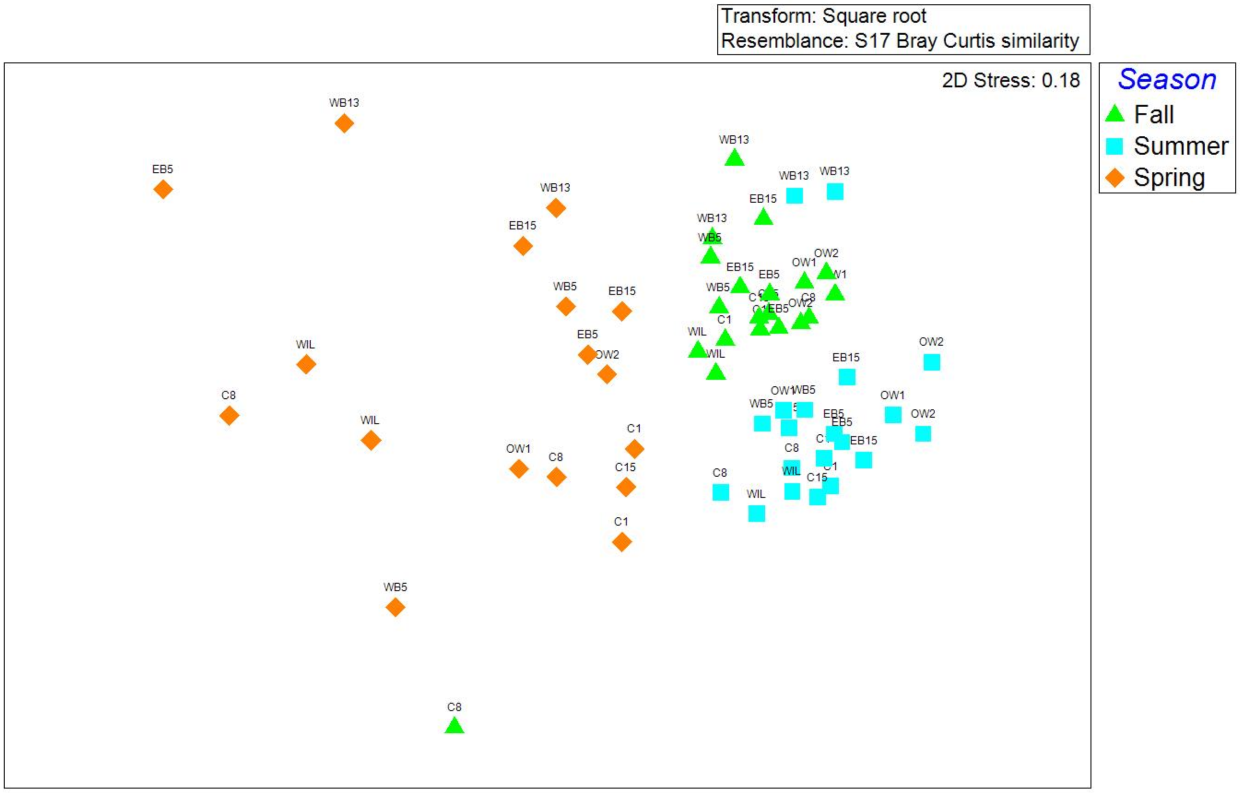
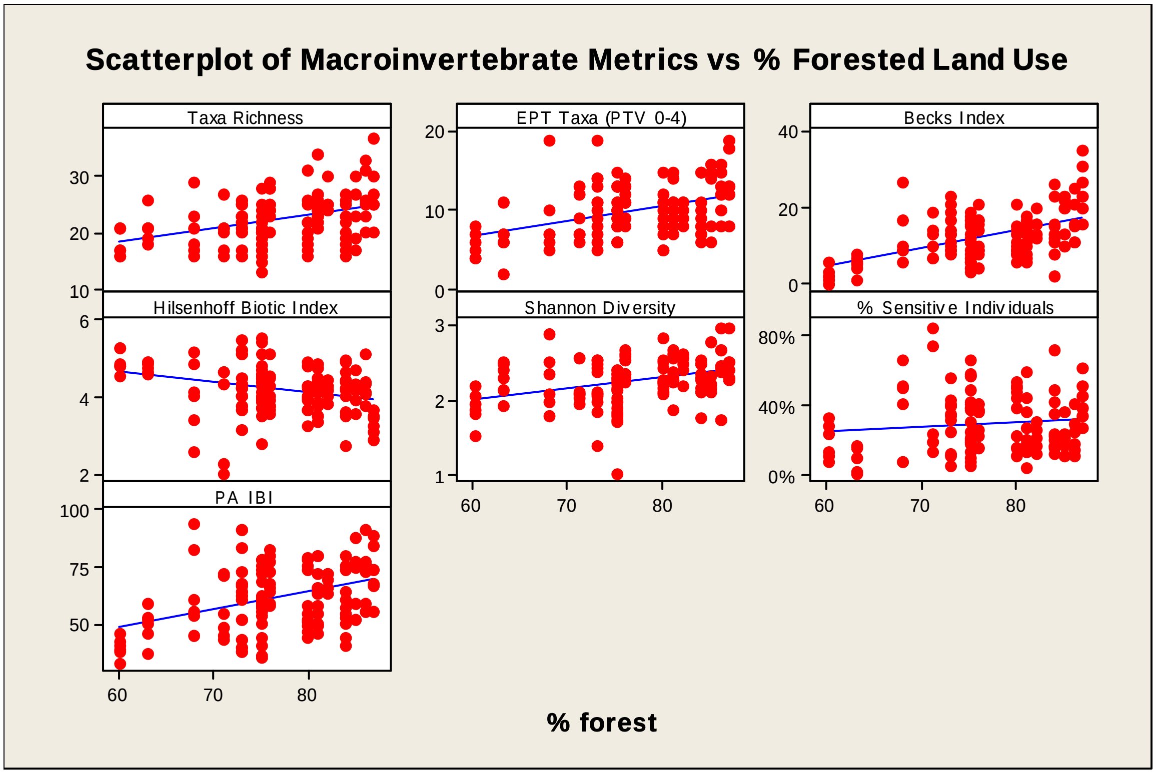


Figure 11. Seasonal Macroinvertebrate Comparisons for Owego Creek

Macroinvertebrate IBI score was positively and significantly correlated with (Pearson r=0.470 p=0.001) instream habitat, as rated by Rapid Bioassessment Protocol (RBP) habitat assessment score. Additionally, percent forested land use in each catchment was calculated using GIS and an estimate of canopy cover was determined from instream densiometer readings. Results suggest that forested land use within an entire catchment is more strongly correlated with numerous macroinvertebrate metrics and IBI score than instream cover (Figure 12). Table 6 lists the Pearson correlation values and p-values for data shown in scatterplots in Figure 12. Drainage area was not significantly correlated with any macroinvertebrate metric.



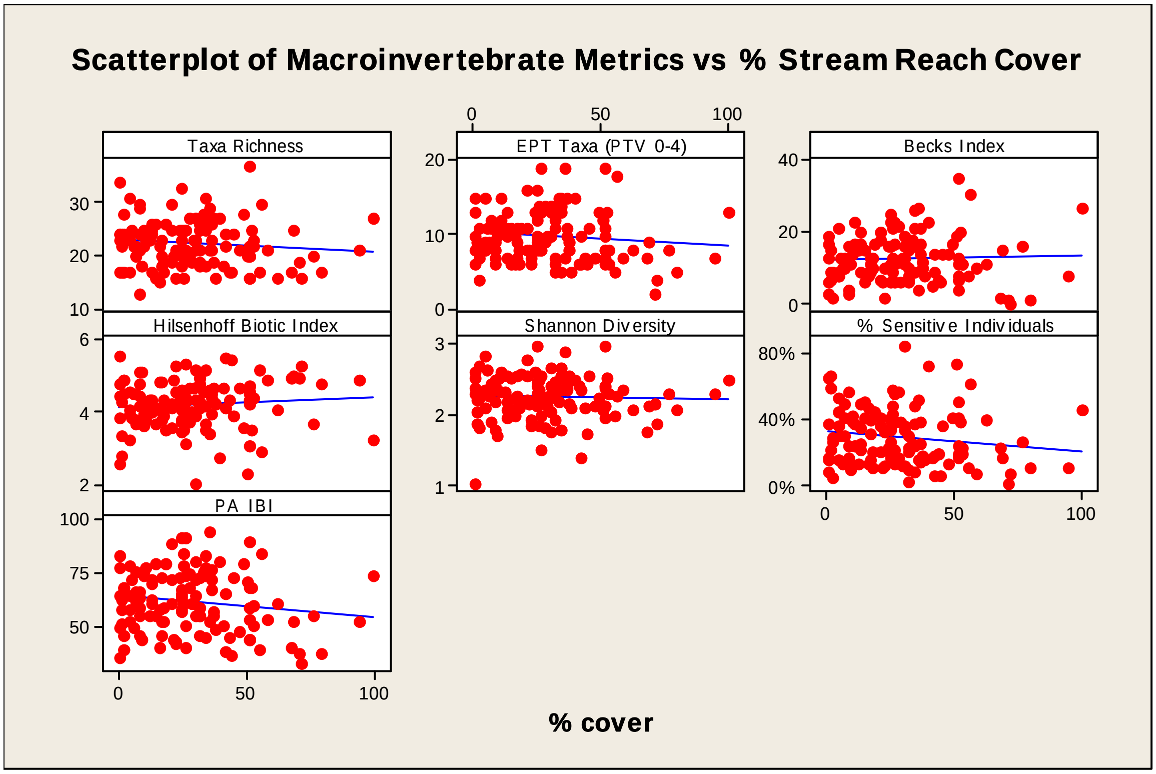


Figure 12. Scatterplots of Macroinvertebrate Metrics with Percent Forested Land Use and Percent Riparian Canopy Cover

Table 6. Pearson Correlation Values and p-values Associated with Scatterplots in Figure 12

	Percent Forest		**Percent Riparian Canopy Cover**	
	Pearson r	**p-value**	**Pearson r**	**p-value**
Taxa Richness	0.388	< 0.001	-0.095	N.S.
EPT Taxa (0-4)	0.392	< 0.001	-0.106	N.S.
Becks Index	0.516	< 0.001	0.039	N.S.
Hilsenhoff Biotic Index	-0.289	0.001	0.089	N.S.
Shannon Diversity	0.334	< 0.001	-0.038	N.S.
Percent Sensitive Taxa (PTV 0-3)	0.103	N.S	-0.152	N.S.
PA IBI	0.393	< 0.001	-0.147	N.S.

Fish

Fish have been widely documented as useful indicators of water quality because of their differential sensitivity to pollution, preferred thermal regimes, and habitat requirements. As fish are more mobile and longer-lived than macroinvertebrates, they add value as another bioindicator in an aquatic ecological assessment. Fish communities revealed a variety of relationships and patterns that were not evident in macroinvertebrate community data. There was no temporal component to the fish sampling, as fish generally do not exhibit the same type of seasonal variability as macroinvertebrates. Each site was only sampled for fish one time over the two-year duration of the project, resulting in a considerably smaller dataset. Fish community data were analyzed using numerous descriptive metrics, including functional feeding groups, relative family abundance, and preferred habitat in addition to community similarity and overall biomass (Table 7).

Table 7. Fish Metrics Used To Describe Fish Communities

Fish Metrics	
Richness	% Omnivores
Abundance	% Generalist Feeders
Density (fish/m^2)	% Insectivores
Biomass (kg/ha)	% Invertivores
% Native Individuals	% Herbivores
% Introduced Individuals	% Catostomidae
% Benthic Individuals	% Centrarchidae
% Darters, Sculpins and Madtoms	% Cottidae
% Tolerant Individuals	% Cyprinidae
% Intolerant Individuals	% Ictaluridae
% Lithophilic Individuals	% Percidae
% Top Predators	% Salmonidae

Biomass estimates were quite variable and were not well correlated with drainage area or percent forested land use. Total biomass ranged from 5.0 to 73.3 kg/ha ($\bar{x}$ = 21.5 ± 17.5). Brown trout were collected at seven of the 20 sites (two sites were not fished), but trout never accounted for more than 1 percent of relative abundance at any site. Species richness ranged from eight to 25 species ($\bar{x}$ =17.7 ± 4.75). All fish communities were dominated by native species, and most were dominated by minnow species of the Cyprinidae family in particular. Top predator richness was low. A few species that are uncommonly found in the New York portion of the Susquehanna River Basin were collected during this survey, including brook stickleback, creek chubsucker, pearl dace, and redside dace.

Each fish metric was compared to several abiotic factors (Table 8) using Pearson correlation analysis (r) to determine the presence, strength, and significance of correlation between the two. Table 9 presents a summary of fish metrics which were significantly correlated with at least one abiotic parameter. No fish metrics were correlated with riparian canopy cover, percent fines, sediment diversity, or sediment sorting coefficient. As expected, based on the general river continuum concept (Vannote et al., 1980), drainage area was positively correlated with species richness and percent top predators. However, drainage area was also negatively correlated with percent native individuals and percent omnivores. This correlation has also been seen elsewhere within the Susquehanna River Basin (Shank, 2015, publication under review).

Table 8. List of Abiotic Variables used in Correlation Analysis

Drainage Area
Percent Riparian Canopy Cover
Percent Forest
Substrate Diversity
Sediment Sorting Coefficient
Number of Substrate Size Classes
Percent Fines
RBP Habitat Assessment

The catchment scale land use descriptor, percent forest, was correlated with numerous fish metrics, all of which fall in line with the general assumption that smaller, cooler, higher gradient, riffle-run streams are located in more forested watersheds. Percent forest was positively correlated with percent lithophilic individuals, percent insectivores, percent intolerant species, and relative abundance of the family Cottidae (sculpins). Conversely, Centrarchids (basses and sunfish), which are typically found in larger warmer water systems, were negatively correlated with percent forest.

Overall instream habitat score, as recorded by the RBP assessment, was only correlated with percent lithophilic individuals (positively) and percent omnivores (negatively). Of all the sediment metrics that were calculated, only number of substrate size classes was correlated with any fish metric. As the number of sediment size classes represented within the sampling reach increased, the percent benthic fish species as well as percent darters, sculpins, and madtoms, decreased. However, as number of sediment size classes increased, so did the relative abundance of minnows (family Cyprinidae).

Table 9. Pearson Correlation (r) and Associated p-values for Fish Metric Correlation with Select Abiotic Factors (Blank cells indicate the relationship was not significant.)

	Drainage Area		Percent Forest		RBP Habitat Score		# of sediment size classes	
Metrics	r	p	r	p	r	p	r	p
Richness	0.477	0.033						
% Native Individuals	-0.702	0.001						
% Introduced Individuals	0.702	0.001						
% Benthic Individuals							-0.488	0.029
% Darters, Sculpins and madtoms							-0.463	0.040
% Tolerant Individuals	-0.470	0.037						
% Intolerant Individuals			0.566	0.009				
% Lithophilic Individuals			0.576	0.008	0.610	0.004		
% Top Predators	0.621	0.003						
% Omnivores	-0.515	0.020			-0.453	0.045		
% Insectivores			0.459	0.042				
% Centrarchidae			-0.445	0.049				
% Cottidae			0.602	0.005				
% Cyprinidae							0.490	0.028

While macroinvertebrate communities are nearly always influenced by season, and can vary annually in response to regional climatic variables like flow and precipitation (Hintz and Steffy, 2015), fish communities respond more to site-specific variables such as instream habitat and temperature. Within this dataset and as seen in other SRB datasets, drainage area was the only factor that significantly explained differences in fish community similarity (SRBC unpublished data). Most sites with drainage areas less than 100 square miles plotted fairly close together and were 50 percent similar (Figure 13). Pipe Creek (PIPE 0.5) and Newtown Creek (NEWT 0.6) had different fish communities than any other sites and plotted separately. Pipe Creek had a unique combination of largemouth bass, bluegill, and bluntnose minnow, while NEWT 0.6 had a greater proportion of rock bass, green sunfish, and redbreast sunfish than any other site.

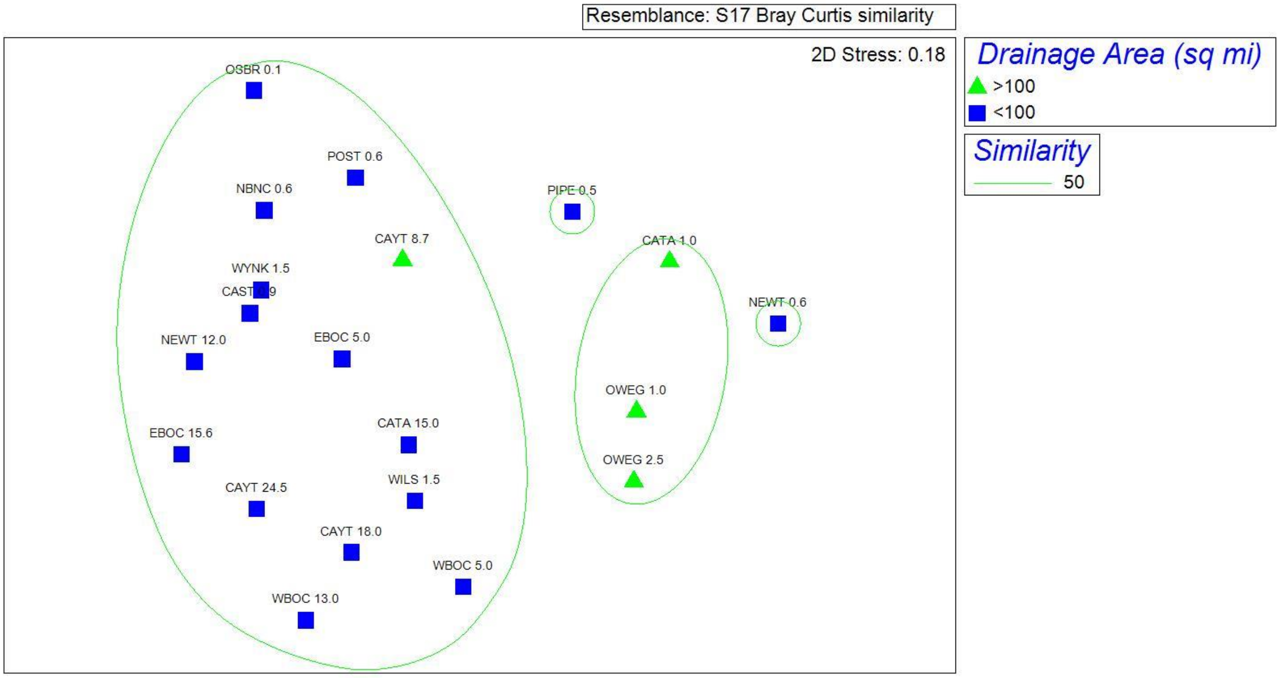


Figure 13. Fish Community Similarity by Drainage Area

Sampling locations with drainage areas greater than 100 square miles were 66 percent dissimilar from smaller drainage areas, and five species accounted for more than half of that dissimilarity. Blacknose dace and sculpin species were much more abundant in smaller streams, while central stonerollers, mimic shiners, and white suckers were more abundant in larger systems. No other variable, including major drainage basin, RBP score, reach length, substrate classifications, or summer water temperature, showed meaningful discriminatory power in grouping sites.

Physical Habitat

Physical habitat measurements were completed at each site during the summer sampling period during both years. The goal of these sediment and geomorphological calculations was to quantify and document current physical conditions as a baseline for future development of any sort. For instance, changes in substrate characterization may be evident after a pipeline crossing or land clearing for a well pad. Depending on the length of time between when these measurements were taken and any future unconventional gas development, these types of physical stream characteristics may need to be updated given the potential natural impacts of high flows, particularly in the glacial till dominated streams of New York’s southern tier.

The qualitative RBP habitat assessment identified riparian buffer width, instream cover, and sediment deposition as the most common physical habitat inadequacies, with overall score ranging from

133-177 out of a possible 200. Data from the zig-zag pebble counts were used to create cumulative frequency distribution curves which can be compared over time. Results from consecutive years revealed repeatable results between years when no major land use changes have occurred, which lends credibility to observed differences being linked to an event and not just inherent variation in the method. Impacts from drilling or drilling-related development could potentially cause a shift in substrate composition to more fine particles, which may be detrimental to biological communities. Examples of similarity of cumulative frequency distribution data at both small and large sites for consecutive years are shown in Figures 14 and 15.

Pebble count data were used to calculate substrate diversity, sorting coefficient, median particle size, and number of size classes represented. Additional metrics based on particle size were also calculated, revealing a large range in median particle size (19-128 mm) and number of size classes represented (7-16). Sorting coefficient is a measurement of the homogeneity or heterogeneity of the substrate at a particular site. A sorting coefficient greater than one indicates high heterogeneity (Stamp, 2004). All 22 sites had a sorting coefficient greater than one for both years, which is not surprising given the very mobile glacial till surficial geology. Sediment diversity was consistent throughout most sites, with the exception of Pipe Creek, which had the most homogenous mix of substrate classes.

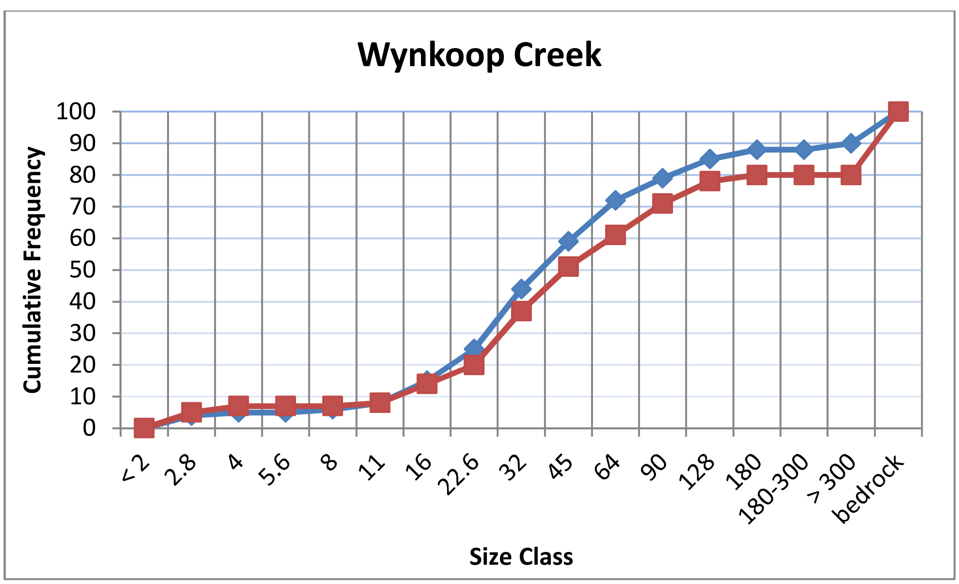


Figure 14. Cumulative Frequency Distribution of Substrate Size for Wynkoop Creek (30-square-mile drainage area; blue line is 2013, red line is 2014)

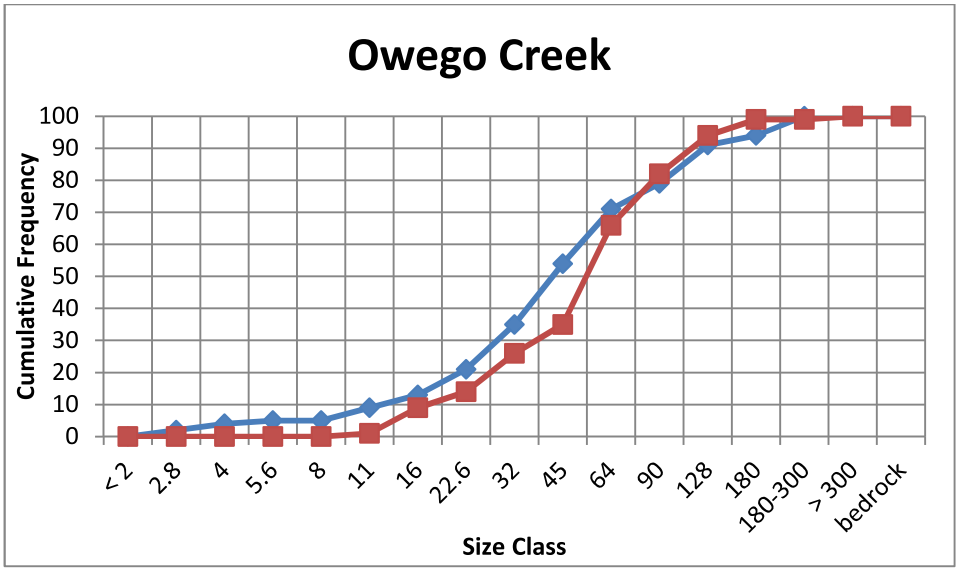


Figure 15. Cumulative Frequency Distribution of Substrate Size for Owego Creek (340-square-mile drainage area; blue line is 2013, red line is 2014)

Conclusions

The successful completion of two years of diverse and seasonal data collection at 22 sampling sites within Chemung, Tioga, and Broome Counties in the southern tier of New York resulted in a robust contemporary baseline dataset that was previously lacking for this area. While fracking in New York does not appear to be imminent at this time, these data may prove to be even more essential if policies regarding unconventional gas drilling change in the future. In addition to providing baseline information, this dataset provides insight into variations observed in biological data that can be attributed to seasonal influences, both natural and anthropogenic. Data analysis and exploratory methods revealed numerous findings based on this dataset:

- Water quality, while generally good, was influenced by road salt from de-icing, particularly in spring samples.
- Water quality parameters related to Marcellus Shale development were detected in very low amounts, including gross radioactivity.
- Watersheds with greater amounts of developed land had elevated chloride, conductivity, and total dissolved solids, and poorer macroinvertebrate communities.
- Physical habitat was quantified using pebble counts, sediment metrics, RBP assessments, and stream morphology measurements.

- Nuisance periphyton blooms were not uncommon, particularly in the fall when flows were lowest. The Owego Creek Watershed had the most frequent nuisance periphyton occurrences.
- Macroinvertebrate communities were largely ranked as non-impaired using the PA IBI, although some sites routinely rated as impaired regardless of year or season.
- Macroinvertebrate communities were heavily influenced by season, with greatest differences driven by relative abundance of intolerant taxa in the spring.
- Fish communities were most influenced by drainage area.
- Fish community metrics had greater correlation with periphyton biomass than macroinvertebrates.

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APPENDIX A
Water Chemistry Data

Site ID	Date	Time	Alkalinity, Total (mg/l)	Aluminum (mg/l)	Barium (mg/l)	Bromide (ug/l)	Calcium (mg/l)	Chloride (mg/l)	Gross Alpha (pCi/L)	Gross Beta (pCi/L)	Lithium (mg/l)	Mg (mg/l)	Nitrate (mg/l)	TP (mg/l)	K (mg/l)	Sodium (mg/l)	Strontium (mg/l)	Sulfate (mg/l)	Total Org Carbon (mg/l)	TDS (mg/l)	TSS (mg/l)
CAST 0.9	09-Apr-13	12:30		0.15	0.01	19.6		37.9	ND	ND	PBQ						0.037			124	PBQ
CAST 0.9	24-Jul-13	10:30	49	0.15	0.011	16.5	15.6	26.7	0	0	PBQ		0.12	0.031	1.3	19.8	0.04		5.5	114	10
CAST 0.9	04-Nov-13	13:30		PBQ	0.011	24.7		41.3	0	0	PBQ						0.046			144	PBQ
CAST 0.9	04-Feb-14	15:45		PBQ	0.015	29.5		59.6	PBQ	PBQ	PBQ						0.061			185	PBQ
CAST 0.9	17-Apr-14	13:15		0.17	0.011	15.3		41.2	3.3	3.3	PBQ	2.4					0.034	7.3		120	5
CAST 0.9	22-Jul-14	14:00	67	PBQ	0.017	31.3	25.3	68	0	2.29	PBQ		PBQ	PBQ	1.6	39.4	0.067		2.7	172	PBQ
CAST 0.9	29-Oct-14	14:00		PBQ	0.017	35.7		72	PBQ	PBQ	PBQ						0.066			212	PBQ
CAST 0.9	23-Jan-15	7:30		PBQ	0.016	27.1		64.2	PBQ	PBQ	PBQ						0.063			167	PBQ
CATA 1.0	10-Apr-13	12:00		0.18	0.03	12.1		15	ND	ND	PBQ						0.04			89	10
CATA 1.0	17-Jul-13	13:30	128	0.14	0.054	22.5	37.4	23.9	PBQ	PBQ	PBQ		0.98	0.02	1.4	13.4	0.063		2.4	157	6
CATA 1.0	30-Oct-13	11:30		PBQ	0.052	19.8		21.8	0	0	PBQ						0.069			144	6
CATA 1.0	29-Jan-14	10:30		0.056	0.051	19.2		21.6	0	0	PBQ						0.066			182	6
CATA 1.0	08-May-14	11:30		0.073	0.027	10.7		17.9	0	0	PBQ	4.7					0.036	9.2		140	PBQ
CATA 1.0	22-Jul-14	9:00	117	0.12	0.053	17.8	38.4	20.4	0	0	PBQ		0.71	0.015	1.2	12.6	0.068		2.7	165	9
CATA 1.0	28-Oct-14	11:30		PBQ	0.055	23		23.1	PBQ	PBQ	PBQ						0.072			189	PBQ
CATA 1.0	22-Jan-15	12:50		0.089	0.051	20.7		22.6	PBQ	PBQ	PBQ						0.066			209	PBQ
CATA 15.0	10-Apr-13	10:30		0.59	0.033	14.9		16.5	ND	ND	PBQ						0.036			79	21
CATA 15.0	17-Jul-13	16:40	143	0.081	0.064	22.7	43.2	19.5	PBQ	PBQ	PBQ	11.6	0.84	0.017	1.3	10.7	0.068	12.5	2.1	217	PBQ
CATA 15.0	29-Oct-13	12:45		PBQ	0.062	21.5		19.2	0	0	PBQ						0.071			213	PBQ
CATA 15.0	29-Jan-14	13:30		0.12	0.057	19.2		17	0	0	PBQ						0.065			185	PBQ
CATA 15.0	22-Apr-14	11:00		0.17	0.037	10.8		14.7	0	0	PBQ	5.9					0.042	11.1		146	8
CATA 15.0	08-Jul-14	16:15	126	0.09	0.065	19.8	46.8	19.8	0	0	PBQ		0.83	0.025	1.3	11.6	0.075		3.2	215	PBQ
CATA 15.0	28-Oct-14	10:30		PBQ	0.071	22.6		20.5	PBQ	PBQ	PBQ						0.076			190	PBQ
CATA 15.0	22-Jan-15	8:15		0.1	0.058	22.1		18.4	PBQ	PBQ	PBQ						0.065			147	PBQ
CATA 8.0	10-Apr-13	11:15		0.24	0.03	11.9		12.8	ND	ND	PBQ						0.036			92	6
CATA 8.0	25-Jul-13	7:30	104	0.18	0.05	22.4	35.3	18.9	0	0	PBQ		0.6	0.031	1.3	11.5	0.063		3.5	113	14
CATA 8.0	29-Oct-13	11:45		PBQ	0.054	18.5		20.2	0	0	PBQ						0.067			198	5
CATA 8.0	29-Jan-14	11:15		0.064	0.052	18.4		19.3	0	0	PBQ						0.064			205	6
CATA 8.0	08-May-14	9:45		0.11	0.031	11.6		17.6	0	0	PBQ	5.3					0.039	11.3		181	9
CATA 8.0	22-Jul-14	7:00	119	0.11	0.056	19.1	39.9	20.1	0	0	PBQ		0.81	0.017	1.2	12.4	0.068		2.7	178	9
CATA 8.0	28-Oct-14	12:30		PBQ	0.059	21.1		24.1	PBQ	PBQ	PBQ						0.073			180	PBQ
CATA 8.0	22-Jan-15	9:45		PBQ	0.052	21		20.8	PBQ	PBQ	PBQ						0.064			158	PBQ
CAYT 18.0	10-Apr-13	17:15		0.43	0.032	PBQ		11.7	ND	ND	PBQ						0.033			87	14
CAYT 18.0	17-Jul-13	7:30	89	0.089	0.051	11.9	29.1	15.3	PBQ	2.4	PBQ		0.3	0.031	1.3	9.8	0.059		3	164	PBQ
CAYT 18.0	28-Oct-13	16:45		PBQ	0.054	15.6		17.9	0	0	PBQ						0.062			147	PBQ
CAYT 18.0	29-Jan-14	14:15		0.11	0.051	14.6		16.1	0	0	PBQ						0.062			151	PBQ
CAYT 18.0	08-May-14	15:30		0.079	0.027	11		15.2	0	0	PBQ	3.3					0.034	9.2		107	PBQ
CAYT 18.0	21-Jul-14	14:30	82	PBQ	0.053	18.4	27.8	18	0	0	PBQ		0.25	0.015	1.2	10.7	0.06		2.8	153	7
CAYT 18.0	22-Oct-14	10:00		PBQ	0.068	17.6		20.8	PBQ	3.6	PBQ						0.073			151	PBQ
CAYT 18.0	21-Jan-15	15:15		0.12	0.05	14.7		17.7	PBQ	PBQ	PBQ						0.063			156	6
CAYT 24.5	10-Apr-13	16:30		0.28	0.024	PBQ		9.5	ND	ND	PBQ						0.033			62	11
CAYT 24.5	14-Aug-13	9:00	74	0.23	0.033	11.3	23.2	13.6	0	2.8	PBQ	4.7	0.18	0.094	1.5	7.9	0.048	10	6.1	127	14
CAYT 24.5	28-Oct-13	15:45		0.11	0.048	17.1		18.8	0	0	PBQ						0.073			142	6
CAYT 24.5	30-Jan-14	8:00		0.096	0.044	14.7		16.7	0	0	PBQ						0.07			138	8
CAYT 24.5	08-May-14	14:30		0.14	0.024	PBQ		14.8	0	0	PBQ	3.7					0.037	11		128	5
CAYT 24.5	08-Jul-14	17:50	72	0.11	0.036	PBQ	27.2	13.7	0	0	PBQ		0.27	0.035	1.2	9.2	0.059		3.9	148	7
CAYT 24.5	22-Oct-14	8:30		0.061	0.046	14.6		18.4	PBQ	PBQ	PBQ						0.07			160	PBQ
CAYT 24.5	21-Jan-15	14:45		0.15	0.045	14.6		18.9	PBQ	PBQ	PBQ						0.073			172	6

Site ID	Date	Time	Alkalinity, Total (mg/l)	Aluminum (mg/l)	Barium (mg/l)	Bromide (ug/l)	Calcium (mg/l)	Chloride (mg/l)	Gross Alpha (pCi/L)	Gross Beta (pCi/L)	Lithium (mg/l)	Mg (mg/l)	Nitrate (mg/l)	TP (mg/l)	K (mg/l)	Sodium (mg/l)	Strontium (mg/l)	Sulfate (mg/l)	Total Org Carbon (mg/l)	TDS (mg/l)	TSS (mg/l)
CAYT 3.7	10-Apr-13	14:10		0.81	0.039	PBQ		16.4	ND	ND	PBQ						0.034			116	21
CAYT 3.7	16-Jul-13	16:00	87	0.053	0.051		28.7	23.3	PBQ	1.84	PBQ	5.6	PBQ	0.01	1.4	11.5	0.059	9.3	2.7	151	PBQ
CAYT 3.7	29-Oct-13	16:15		PBQ	0.055	16.1		20.7	0	0	PBQ						0.061			166	PBQ
CAYT 3.7	08-May-14	16:45		0.051	0.026	PBQ		17.4	0	0	PBQ	3.1					0.033	11.2		108	PBQ
CAYT 3.7	21-Jul-14	11:45	81	PBQ	0.052	16.2	27.1	18.8	0	0	PBQ		PBQ	0.01	1.2	11.7	0.058		2.5	153	5
CAYT 3.7	22-Oct-14	11:45		PBQ	0.071	17.2		23.6	PBQ	PBQ	PBQ						0.074			174	PBQ
CAYT 3.7	21-Jan-15	11:45		PBQ	0.055	17.2		21	PBQ	2.6	PBQ						0.064			110	PBQ
CAYT 8.7	10-Apr-13	13:30		0.76	0.038	PBQ		14.9	ND	ND	PBQ						0.032			109	27
CAYT 8.7	13-Aug-13	14:00	68	0.21	0.046	14.7	22.1	14.5	0	0	PBQ		0.17	0.053	1.5	9.4	0.051		4	100	PBQ
CAYT 8.7	29-Oct-13	15:00		PBQ	0.061	15.5		20.6	0	0	PBQ						0.064			163	PBQ
CAYT 8.7	29-Jan-14	15:00		0.091	0.053	15.7		18.6	0	0	PBQ						0.06			121	PBQ
CAYT 8.7	08-May-14	16:15		0.071	0.027	PBQ		16.9	0	0	PBQ	3.2					0.034	9.1		107	6
CAYT 8.7	21-Jul-14	15:45	79	PBQ	0.055	18.8	28.3	19.6	0	0	PBQ		0.11	0.01	1.3	12.2	0.061		2.3	171	PBQ
CAYT 8.7	22-Oct-14	11:00		PBQ	0.072	18.7		22.6	PBQ	PBQ	PBQ						0.072			158	PBQ
CAYT 8.7	21-Jan-15	16:00		0.22	0.057	16.2		20.9	PBQ	PBQ	PBQ						0.064			114	PBQ
EBOC 15.6	09-Apr-13	14:30		0.068	0.011	34.9		69.7	ND	ND	PBQ						0.03			163	PBQ
EBOC 15.6	23-Jul-13	12:30	69	0.55	0.022	15.7	20.9	29.4	0	0	PBQ		0.94	0.065	1.3	20.8	0.042		3.9	159	30
EBOC 15.6	04-Nov-13	11:00		PBQ	0.013	13.3		16.5	0	0	PBQ						0.03			90	PBQ
EBOC 15.6	30-Jan-14	16:00		0.097	0.02	14.7		24.5	0	0	PBQ						0.051			125	PBQ
EBOC 15.6	17-Apr-14	11:00		0.12	0.012	12.2		29.8	0	0	PBQ	2.4					0.026	6.9		77	PBQ
EBOC 15.6	15-Jul-14	10:00	79	0.062	0.023	15.1	26.4	32.5	11.2	0	PBQ		1	0.021	1.1	23	0.056		2.1	188	PBQ
EBOC 15.6	29-Oct-14	10:00		PBQ	0.02	16.6		30.8	PBQ	PBQ	PBQ						0.047			161	PBQ
EBOC 15.6	22-Jan-15	14:45		PBQ	0.019	23.7		26.9	PBQ	PBQ	PBQ						0.05			149	PBQ
EBOC 5.0	09-Apr-13	15:40		0.1	0.011	14.3		34.8	ND	ND	PBQ						0.028			116	PBQ
EBOC 5.0	17-Jul-13	11:30	98	0.067	0.023	12.2	30.6	32.2	PBQ	2	PBQ		0.71	0.021	1.2	21.5	0.056		1.8	151	PBQ
EBOC 5.0	04-Nov-13	10:15		PBQ	0.014	11.4		16.7	0	0	PBQ						0.033			105	6
EBOC 5.0	31-Jan-14	9:00		0.056	0.021	16.1		24.7	0	0	PBQ						0.054			158	PBQ
EBOC 5.0	22-Apr-14	7:45		0.13	0.016	13.9		29.6	0	0	PBQ	3.6					0.036	8.1		122	10
EBOC 5.0	22-Jul-14	11:45	95	PBQ	0.025	14.7	31	34.6	0	0	PBQ		0.67	PBQ	1.2	24.3	0.062		2.1	166	PBQ
EBOC 5.0	29-Oct-14	11:00		PBQ	0.019	19.9		30.5	PBQ	PBQ	PBQ						0.049			156	PBQ
EBOC 5.0	22-Jan-15	15:15		PBQ	0.02	18.1		27	PBQ	PBQ	PBQ						0.052			145	PBQ
NBNC 0.6	24-Apr-13	13:30		0.092	0.057	16.8		27.6	ND	ND	PBQ						0.059			124	5
NBNC 0.6	16-Jul-13	11:30	97	PBQ	0.086	40.1	32.3	27.6	PBQ	PBQ	PBQ		PBQ	0.013	1.9	17.5	0.093		3.3	183	PBQ
NBNC 0.6	28-Oct-13	11:00		0.06	0.11	39.5		34.2	0	0	PBQ						0.11			218	PBQ
NBNC 0.6	30-Jan-14	10:15		0.13	0.083	24.1		35.1	0	0	PBQ						0.087			170	PBQ
NBNC 0.6	16-Apr-14	10:00		1.7	0.063	12.7		28.1	0	4	PBQ	4.2					0.046	12.3		140	35
NBNC 0.6	09-Jul-14	9:00	97	0.13	0.1	32.5	36.5	26.6	0	2.9	PBQ		0.15	0.031	2.2	19.2	0.1		4	191	PBQ
NBNC 0.6	21-Oct-14	15:45		0.17	0.1	38.6		34.9	0	4.5	PBQ						0.11			195	PBQ
NBNC 0.6	21-Jan-15	13:15		0.089	0.084	21.1		35.5	PBQ	PBQ	PBQ						0.095			154	PBQ
NEWT 0.6	24-Apr-13	14:30		0.12	0.077	33.3		52.1	ND	ND	PBQ						0.074			221	5
NEWT 0.6	23-Jul-13	15:00	149	0.14	0.1	37.6	51.6	82.8	0	2.5	PBQ		0.48	0.051	2.1	48.9	0.1		3.2	359	13
NEWT 0.6	28-Oct-13	13:00		PBQ	0.12	46.4		82.3	0	0	PBQ						0.11			321	PBQ
NEWT 0.6	30-Jan-14	11:20		0.05	0.13	46.7		85.2	0	0	PBQ						0.12			328	12
NEWT 0.6	22-Apr-14	14:15		0.17	0.079	26.9		59.7	0	0	PBQ	7.7					0.073	15.6		248	7
NEWT 0.6	09-Jul-14	10:45	188	0.074	0.15	54.9	73.6	96	0	3.5	PBQ		0.47	0.03	2.3	60.3	0.14		2.3	409	PBQ
NEWT 0.6	21-Oct-14	13:30		PBQ	0.14	53.5		111	0	0	PBQ						0.12			390	PBQ
NEWT 0.6	21-Jan-15	10:15		0.11	0.13	48.2		93.6	PBQ	PBQ	PBQ						0.12			313	PBQ

Site ID	Date	Time	Alkalinity, Total (mg/l)	Aluminum (mg/l)	Barium (mg/l)	Bromide (ug/l)	Calcium (mg/l)	Chloride (mg/l)	Gross Alpha (pCi/L)	Gross Beta (pCi/L)	Lithium (mg/l)	Mg (mg/l)	Nitrate (mg/l)	TP (mg/l)	K (mg/l)	Sodium (mg/l)	Strontium (mg/l)	Sulfate (mg/l)	Total Org Carbon (mg/l)	TDS (mg/l)	TSS (mg/l)
NEWT 12.0	24-Apr-13	12:15		0.051	0.036	14.5		23.5	ND	ND	PBQ						0.033			78	PBQ
NEWT 12.0	16-Jul-13	11:30	71	PBQ	0.063	22.3	24.6	35	PBQ	PBQ	PBQ		0.11	0.011	1.7	19.8	0.061		1.7	170	PBQ
NEWT 12.0	28-Oct-13	11:45		PBQ	0.045	25.3		25.5	0	0	PBQ						0.046			PBQ	PBQ
NEWT 12.0	30-Jan-14	10:45		PBQ	0.053	17.8		26.8	0	0	PBQ						0.052			79	PBQ
NEWT 12.0	16-Apr-14	11:30		0.61	0.04	PBQ		18.7	0	4.1	PBQ	2.2					0.028	7.2		37	28
NEWT 12.0	15-Jul-14	7:15	56	0.054	0.066	21.3	19.9	33.9	1.53	0	PBQ		0.2	0.01	1.8	22	0.06		1.9	158	PBQ
NEWT 12.0	21-Oct-14	15:00		PBQ	0.069	33.3		43.8	0	0	PBQ						0.067			183	PBQ
NEWT 12.0	21-Jan-15	13:30		PBQ	0.052	22.1		34.3	PBQ	PBQ	PBQ						0.053			74	PBQ
OSBR 0.1	09-Apr-13	9:30		0.052	0.01	17.8		37.6	ND	ND	PBQ						0.037			100	PBQ
OSBR 0.1	24-Jul-13	7:30	40	0.082	0.012	13	11.9	27.6	0	0	PBQ		0.22	0.025	1.6	20	0.04		4	115	6
OSBR 0.1	04-Nov-13	14:30		PBQ	0.011	22.1		35.5	0	0	PBQ						0.043			102	PBQ
OSBR 0.1	04-Feb-14	15:15		PBQ	0.013	26		49	PBQ	PBQ	PBQ						0.053			149	PBQ
OSBR 0.1	17-Apr-14	14:00		0.11	0.0094	11.4		33.3	0	3.8	PBQ	1.9					0.029	7.4		100	PBQ
OSBR 0.1	22-Jul-14	15:15	37	PBQ	0.012	32	16.7	70.8	0	1.95	PBQ		PBQ	0.011	1.9	37.4	0.054		2.3	143	6
OSBR 0.1	29-Oct-14	14:30		PBQ	0.013	27		55.9	PBQ	PBQ	PBQ						0.054			166	PBQ
OSBR 0.1	23-Jan-15	8:00		PBQ	0.015	25.9		57.8	PBQ	0	PBQ						0.057			66	PBQ
OWEG 1.0	10-Apr-13	8:30		0.22	0.02	13.2		25.8	ND	ND	PBQ						0.033			90	6
OWEG 1.0	25-Jul-13	10:15	87	0.082	0.03	PBQ	29	20.2	0	1.82	PBQ		0.5	0.018	1.3	12.6	0.052		3.2	116	6
OWEG 1.0	30-Oct-13	10:30		PBQ	0.034	15.7		22.9	0	0	PBQ						0.06			200	PBQ
OWEG 1.0	29-Jan-14	10:00		0.051	0.034	18.6		22.7	0	0	PBQ						0.059			160	PBQ
OWEG 1.0	08-May-14	12:15		0.05	0.018	12.7		22.8	0	0	PBQ	4					0.033	8.8		142	PBQ
OWEG 1.0	08-Jul-14	15:00	107	0.077	0.04	16.7	38.9	25.6	0	0	PBQ		0.66	0.019	1.4	17.3	0.069		2.7	164	PBQ
OWEG 1.0	29-Oct-14	8:00		PBQ	0.039	20.3		27.7	PBQ	PBQ	PBQ						0.065			194	PBQ
OWEG 1.0	22-Jan-15	15:30		PBQ	0.034	20.5		24.9	PBQ	PBQ	PBQ						0.06			184	PBQ
OWEG 2.5	10-Apr-13	7:30		0.24	0.015	13.1		29.3	ND	ND	PBQ						0.03			104	10
OWEG 2.5	18-Jul-13	12:30	98	PBQ	0.026	14.3	34.2	26.7	PBQ	2.1	PBQ		0.7	0.016	1.3	17.2	0.059		1.5	135	PBQ
OWEG 2.5	30-Oct-13	12:15		PBQ	0.021	15.9		22.6	0	2.5	PBQ						0.052			192	PBQ
OWEG 2.5	29-Jan-14	12:00		0.078	0.023	16.4		22.6	0	0	PBQ						0.055			167	7
OWEG 2.5	08-May-14	10:30		PBQ	0.014	12.4		25.3	0	0	PBQ	3.6					0.034	8.2		149	PBQ
OWEG 2.5	22-Jul-14	10:15	98	PBQ	0.026	15.9	35	27.2	0	0	PBQ		0.59	PBQ	1.2	17.8	0.062		1.5	160	PBQ
OWEG 2.5	28-Oct-14	16:30		PBQ	0.021	19.1		25.3	PBQ	PBQ	PBQ						0.056			124	PBQ
OWEG 2.5	22-Jan-15	11:30		PBQ	0.022	17.5		25.4	PBQ	PBQ	PBQ						0.055			136	PBQ
PIPE 0.5	10-Apr-13	14:45		0.41	0.018	10.1		14.7	ND	ND	PBQ						0.033			112	13
PIPE 0.5	18-Jul-13	14:00	81	PBQ	0.026	19.9	25.9	17.3	PBQ	PBQ	PBQ		0.26	0.02	2	11.6	0.057		2	113	PBQ
PIPE 0.5	30-Oct-13	13:30		PBQ	0.024	20.9		21.1	0	0	PBQ						0.062			147	8
PIPE 0.5	30-Jan-14	13:30		PBQ	0.021	16.7		18.3	0	0	PBQ						0.049			88	PBQ
PIPE 0.5	17-Apr-14	8:30		0.22	0.014	PBQ		15.4	0	3.4	PBQ	2.5					0.026	10.2		36	7
PIPE 0.5	08-Jul-14	11:45	75	PBQ	0.03	17.9	28.6	20.1	0	0	PBQ		0.22	0.022	2	14.3	0.066		2.4	91	PBQ
PIPE 0.5	22-Oct-14	15:00		PBQ	0.025	20.3		25.2	PBQ	PBQ	PBQ						0.06			133	PBQ
PIPE 0.5	22-Jan-15	16:15		PBQ	0.019	15.4		21.6	PBQ	PBQ	PBQ						0.05			93	PBQ
POST 0.6	25-Apr-13	7:30		0.093	0.044	PBQ		20.6	ND	ND	PBQ						0.04			110	8
POST 0.6	18-Jul-13	7:00	99	0.05	0.1	43.7	30.2	40.6	PBQ	2.9	PBQ		PBQ	0.026	1.8	23	0.1		3.1	174	PBQ
POST 0.6	28-Oct-13	9:45		PBQ	0.09	37.7		33.6	0	0	PBQ						0.089			190	PBQ
POST 0.6	30-Jan-14	9:30		PBQ	0.087	25.8		33.3	0	0	PBQ						0.083			122	PBQ
POST 0.6	16-Apr-14	16:45		0.18	0.039	PBQ		20.1	0	4.3	PBQ	2.5					0.034	10.8		73	16
POST 0.6	21-Jul-14	9:30	81	PBQ	0.076	30.6	25.6	32	0	0	PBQ		0.14	0.015	1.7	19.6	0.081		3.5	184	PBQ
POST 0.6	21-Oct-14	11:30		PBQ	0.11	41.5		46	0	3.3	PBQ						0.11			211	PBQ
POST 0.6	21-Jan-15	9:45		PBQ	0.094	21		37	PBQ	PBQ	PBQ						0.09			172	PBQ

Site ID	Date	Time	Alkalinity, Total (mg/l)	Aluminum (mg/l)	Barium (mg/l)	Bromide (ug/l)	Calcium (mg/l)	Chloride (mg/l)	Gross Alpha (pCi/L)	Gross Beta (pCi/L)	Lithium (mg/l)	Mg (mg/l)	Nitrate (mg/l)	TP (mg/l)	K (mg/l)	Sodium (mg/l)	Strontium (mg/l)	Sulfate (mg/l)	Total Org Carbon (mg/l)	TDS (mg/l)	TSS (mg/l)
WBOC 13.0	09-Apr-13	16:45		0.11	0.0091	PBQ		9	ND	ND	PBQ						0.018			57	PBQ
WBOC 13.0	17-Jul-13	10:30	67	0.15	0.022	14.1	23.6	22.9	PBQ	PBQ	PBQ		0.63	0.03	0.98	12.5	0.046		4.5	117	6
WBOC 13.0	30-Oct-13	8:00		PBQ	0.019	14.3		18.2	0	0	PBQ						0.043			106	7
WBOC 13.0	30-Jan-14	15:30		0.062	0.019	14.3		20.6	0	0	PBQ						0.044			50	PBQ
WBOC 13.0	17-Apr-14	10:00		0.15	0.011	PBQ		15.9	0	0	PBQ	2					0.021	7.2		31	PBQ
WBOC 13.0	14-Jul-14	10:30	53	0.11	0.019	12.7	19.8	21.9	1.31	0	PBQ		0.33	0.034	1.1	14	0.045		2.5	136	PBQ
WBOC 13.0	23-Oct-14	8:00		PBQ	0.02	14.4		22	PBQ	PBQ	PBQ						0.043			82	PBQ
WBOC 13.0	05-Feb-15	7:45		PBQ	0.021	13.2		26	PBQ	PBQ	PBQ						0.05			112	PBQ
WBOC 5.0	09-Apr-13	17:45		0.13	0.011	PBQ		11.2	ND	ND	PBQ						0.022			69	PBQ
WBOC 5.0	24-Jul-13	16:45	57	0.12	0.02		20.1	16.5	0	0	PBQ	3.8	0.46	0.018	1.2	10.5	0.041	6.6	3.3	92	7
WBOC 5.0	30-Oct-13	9:30		PBQ	0.024	13.6		18.8	0	0	PBQ						0.049			194	PBQ
WBOC 5.0	31-Jan-14	8:30		0.05	0.023	14.3		19.6	0	0	PBQ						0.048			120	9
WBOC 5.0	22-Apr-14	9:30		0.14	0.016	PBQ		18.2	0	0	PBQ	2.9					0.03	7.4		100	6
WBOC 5.0	14-Jul-14	17:15	62	0.16	0.022	PBQ	22.9	20.6	0	0	PBQ		0.35	0.027	1.3	13.2	0.049		3	142	PBQ
WBOC 5.0	28-Oct-14	15:30		PBQ	0.025	16.3		21.8	PBQ	PBQ	PBQ						0.055			116	PBQ
WBOC 5.0	22-Jan-15	11:00		PBQ	0.024	10.1		23.1	PBQ	PBQ	PBQ						0.051			120	PBQ
WILS 1.5	10-Apr-13	9:40		0.22	0.028	12.3		17.8	ND	ND	PBQ						0.038			82	50
WILS 1.5	17-Jul-13	14:45	96	PBQ	0.047	17.2	29.7	21.8	PBQ	PBQ	PBQ		0.31	0.036	0.7	13.7	0.057		3.4	145	PBQ
WILS 1.5	29-Oct-13	10:45		PBQ	0.044	17.5		21.9	0	0	PBQ						0.067			172	PBQ
WILS 1.5	30-Jan-14	14:45		PBQ	0.047	18.1		23	0	0	PBQ						0.062			143	PBQ
WILS 1.5	16-Apr-14	13:30		0.12	0.024	PBQ		19.1	0	2.6	PBQ	3.3					0.032	7.8		102	9
WILS 1.5	09-Jul-14	14:30	79	0.15	0.042	19.3	29.5	19.3	0	0	PBQ		PBQ	0.061	1.1	14.3	0.059		6.9	152	8
WILS 1.5	28-Oct-14	14:15		0.05	0.051	21.6		29.4	PBQ	PBQ	PBQ						0.071			192	PBQ
WILS 1.5	22-Jan-15	9:00		0.053	0.046	21.4		26.3	PBQ	PBQ	PBQ						0.061			152	PBQ
WYNK 1.5	24-Apr-13	16:30		0.093	0.015	PBQ		11.5	ND	ND	PBQ						0.023			70	PBQ
WYNK 1.5	23-Jul-13	7:30	50	0.13	0.031	20.9	16.3	17.6	0	0	PBQ		0.11	0.03	1.8	10.9	0.051		1.7	153	7
WYNK 1.5	29-Oct-13	8:45		PBQ	0.023	35		21.3	0	3.1	PBQ						0.043			111	8
WYNK 1.5	30-Jan-14	12:00		0.075	0.023	16.8		17.6	0	0	PBQ						0.039			80	5
WYNK 1.5	16-Apr-14	15:15		0.25	0.019	PBQ		17	0	3.6	PBQ	2					0.024	10.1		26	12
WYNK 1.5	08-Jul-14	10:15	36	PBQ	0.023	22.3	12.9	19.7	0	0	PBQ		PBQ	0.023	1.5	12.8	0.044		2.4	78	PBQ
WYNK 1.5	22-Oct-14	13:45		0.053	0.026	33.9		23.5	PBQ	PBQ	PBQ						0.054			118	PBQ
WYNK 1.5	21-Jan-15	11:15		0.077	0.024	28.3		26.3	PBQ	PBQ	PBQ						0.05			37	PBQ

Site ID	Date	Time	Dissolved Oxygen (mg/l)	Flow (cfs)	pH	Sp Cond (umho/cm)	Turbidity (NTU)	Water Temp (deg C)
CAST 0.9	09-Apr-13	12:30	9.16	24.815	7.72	194	11.4	9.3
CAST 0.9	24-Jul-13	10:30	8.55	51.925	7.63	197.2	5.6	19.9
CAST 0.9	04-Nov-13	13:30	13.02	12.62	7.79	266.2	1	6.5
CAST 0.9	04-Feb-14	15:45	13.52		7.58	292.5	1.38	0.2
CAST 0.9	17-Apr-14	13:15	13.4	89.791	7.71	191.8	8.31	6.1
CAST 0.9	22-Jul-14	14:00	10.12	3.77	8.05	375.3	2.08	23.9
CAST 0.9	29-Oct-14	14:00	10.43	6.221	7.87	251.8	1.13	11.4
CAST 0.9	23-Jan-15	7:30	13.98		7.35	330.2	1.43	0.6
CATA 1.0	10-Apr-13	12:00	7.54		7.75	178.2	7.6	11.2
CATA 1.0	17-Jul-13	13:30	9.74	58.819	8.22	342.3	6.2	25.5
CATA 1.0	30-Oct-13	11:30	11.25	45.917	8.16	336.6	1.57	7.9
CATA 1.0	29-Jan-14	10:30	16.14		7.95	332	2.86	-0.01
CATA 1.0	08-May-14	11:30	11.65	165.548	8.16	230.7	4.33	12.8
CATA 1.0	22-Jul-14	9:00	8.28	68.349	8.68	263.9	4.46	21.5
CATA 1.0	28-Oct-14	11:30	12.07	34.239	8.29	237.1	2.43	10.4
CATA 1.0	22-Jan-15	12:50						
CATA 15.0	10-Apr-13	10:30	7.47		7.32	176.3	2.78	9.9
CATA 15.0	17-Jul-13	16:40	10.49	18.631	8.4	377.5	5.3	25.9
CATA 15.0	29-Oct-13	12:45	12.44	21.827	8.02	361.8	1.15	7.6
CATA 15.0	29-Jan-14	13:30	15.3		7.77	333	5.7	0.1
CATA 15.0	22-Apr-14	11:00	9.41	51.37	7.86	204.7	6.01	10.7
CATA 15.0	08-Jul-14	16:15	11.21		8.5	333.1	6.11	22.3
CATA 15.0	28-Oct-14	10:30	11	16.271	7.6	264.5	2.34	9.1
CATA 15.0	22-Jan-15	8:15	11.75	32.07	7.57	325.6	3.15	0.4
CATA 8.0	10-Apr-13	11:15	7.68		7.34	173.6	10.3	10.1
CATA 8.0	25-Jul-13	7:30	8.14	61.053	7.59	282.7	6	18.2
CATA 8.0	29-Oct-13	11:45	11.99	39.492	8.07	333.8	1.48	7.5
CATA 8.0	29-Jan-14	11:15	16.02		7.81	315	3.8	0.05
CATA 8.0	08-May-14	9:45	10.55		7.84	232	5.18	11.8
CATA 8.0	22-Jul-14	7:00	7.71	57.461	7.84	312.4	4.65	20.6
CATA 8.0	28-Oct-14	12:30	13.55		8.34	247.6	2.56	10.8
CATA 8.0	22-Jan-15	9:45	12.78	62.63	7.83	323.5	2.6	0.6
CAYT 18.0	10-Apr-13	17:15	9.22		7.3	117.7	17.3	8.1
CAYT 18.0	17-Jul-13	7:30	7.01	33.667	7.59	252.2	4	20.4
CAYT 18.0	28-Oct-13	16:45	11.82	23.855	8.04	255.4	1.69	8.6
CAYT 18.0	29-Jan-14	14:15	14.69		7.64	242	5.15	0.25
CAYT 18.0	08-May-14	15:30	11.56	105.311	8.33	175.9	3.83	15
CAYT 18.0	21-Jul-14	14:30	9.94	32.95	8.41	243.2	2.32	20
CAYT 18.0	22-Oct-14	10:00	9.92	19.862	7.72	192	3.02	9.8
CAYT 18.0	21-Jan-15	15:15	12.52	56.925	7.93	249	5.17	0.4
CAYT 24.5	10-Apr-13	16:30	8.58	141.744	7.22	127.1	11.8	8.3
CAYT 24.5	14-Aug-13	9:00	7.89		8.07	200.2		16.7
CAYT 24.5	28-Oct-13	15:45	11.52	11.659	7.85	305.7	4.64	8.7
CAYT 24.5	30-Jan-14	8:00	12.6		7.85	272.1	6.6	0.1
CAYT 24.5	08-May-14	14:30	10.47		7.89	194.4	6.72	14.4
CAYT 24.5	08-Jul-14	17:50	9.17	36.142	8.13	206	5.34	20.7
CAYT 24.5	22-Oct-14	8:30	9.8	11.263	7.12	192.8	2.73	9.5
CAYT 24.5	21-Jan-15	14:45	12.47	24.326	7.79	281.9	6.76	1.6
CAYT 3.7	10-Apr-13	14:10	8.18		7.27	139.3	30.8	9.7
CAYT 3.7	16-Jul-13	16:00	8.44	48.647	8.41	258.2	2	26.7
CAYT 3.7	29-Oct-13	16:15	11.97	39.191	8.28	269.1	0.89	8.1
CAYT 3.7	08-May-14	16:45	11.57		8.87	178.6	3.85	15.7
CAYT 3.7	21-Jul-14	11:45	10.63	49.462	8.51	245.5	2.1	21
CAYT 3.7	22-Oct-14	11:45	9.82	25.775	8.14	210.7	1.7	9.9
CAYT 3.7	21-Jan-15	11:45	14.81		7.98	258.5	2.47	0
CAYT 8.7	10-Apr-13	13:30	8.32		7.12	132.5	29.2	9
CAYT 8.7	13-Aug-13	14:00	9.33	207.137	7.87	198.7		19.9
CAYT 8.7	29-Oct-13	15:00	11.84	34.995	8.17	273	0.88	8.2
CAYT 8.7	29-Jan-14	15:00	16.23		7.59	242.4	4.35	0.2
CAYT 8.7	08-May-14	16:15	11.8		8.78	179.9	3.19	16.2
CAYT 8.7	21-Jul-14	15:45	10.48	48.372	8.56	246.4	2.23	22.6
CAYT 8.7	22-Oct-14	11:00	10.41	24.7	7.9	205	1.57	10
CAYT 8.7	21-Jan-15	16:00	13.16	61.577	7.95	261.4	3.98	0.2
EBOC 15.6	09-Apr-13	14:30	9.08	153.508	7.61	316	8.4	8.6
EBOC 15.6	23-Jul-13	12:30	10.07	161.583	7.49	235.3	19.4	18.1
EBOC 15.6	04-Nov-13	11:00	12.84	38.021	7.61	130.9	2.3	5.4
EBOC 15.6	30-Jan-14	16:00	15.5		7.52	264.6	3.94	0
EBOC 15.6	17-Apr-14	11:00	14.22	170.795	7.59	163.1	6.19	3.4
EBOC 15.6	15-Jul-14	10:00	8.75	26.078	7.93	283.2	3.08	17.4
EBOC 15.6	29-Oct-14	10:00	9.59	19.435	7.85	178.4	1.93	11.3
EBOC 15.6	22-Jan-15	14:45	13.2	21.81	8.13	208.3	3.17	1.3
EBOC 5.0	09-Apr-13	15:40	8.67	210.361	7.99	198.6	4.2	11.5
EBOC 5.0	17-Jul-13	11:30	10.18	29.61	8.4	319.6	3.4	23.3
EBOC 5.0	04-Nov-13	10:15	13.31	61.463	6.89	180.3	1.5	3.9
EBOC 5.0	31-Jan-14	9:00	14.54		7.42	277.1	2.81	0.1
EBOC 5.0	22-Apr-14	7:45	9.81	133.616	7.57	206.5	4.76	9.9
EBOC 5.0	22-Jul-14	11:45	10.67	18.686	8.47	320.1	1.96	22.9
EBOC 5.0	29-Oct-14	11:00	10.46	20.599	8.21	177.6	1.7	11.8
EBOC 5.0	22-Jan-15	15:15	14.08		8.3	265.4	3.24	0.2
NBNC 0.6	24-Apr-13	13:30	12.04	13.394	8.13	224.5	5.6	12.2
NBNC 0.6	16-Jul-13	11:30						
NBNC 0.6	28-Oct-13	11:00	11.49	2.723	7.77	366.5	3.32	7.4
NBNC 0.6	30-Jan-14	10:15	15.66		7.58	307.1	6.96	0
NBNC 0.6	16-Apr-14	10:00	12.11	99.746	7.47	175.6	84.9	4.1
NBNC 0.6	09-Jul-14	9:00	9.12	4.593	8.1	318.4	6.51	21.5
NBNC 0.6	21-Oct-14	15:45	10.47	4.028	7.92	245.8	9.54	12
NBNC 0.6	21-Jan-15	13:15	14.73		8.16	317.8	4.41	1.9
NEWT 0.6	24-Apr-13	14:30	12	78.999	7.68	394.3	5	10.8
NEWT 0.6	23-Jul-13	15:00	9.11	66.174	7.67	591	9.4	21.3
NEWT 0.6	28-Oct-13	13:00	11.59	27.942	7.61	652.4	1.76	9.1
NEWT 0.6	30-Jan-14	11:20	14.71		7.57	636.1	4.42	0.4
NEWT 0.6	22-Apr-14	14:15	9.37	81.207	7.75	349.9	8.72	11
NEWT 0.6	09-Jul-14	10:45	7.93	24.225	7.86	719	4.06	19.3
NEWT 0.6	21-Oct-14	13:30	10.45	15.322	7.71	477.2	2.75	10.6
NEWT 0.6	21-Jan-15	10:15	12.99		7.46	669.2	3.89	1.1

Site ID	Date	Time	Dissolved Oxygen (mg/l)	Flow (cfs)	pH	Sp Cond (umho/cm)	Turbidity (NTU)	Water Temp (deg C)
NEWT 12.0	24-Apr-13	12:15	12.23	23.669	8.08	119.8	2.8	10.3
NEWT 12.0	16-Jul-13	11:30	7.34	3.933	7.72	237.6	1.2	23.1
NEWT 12.0	28-Oct-13	11:45	12.38	6.228	7.85	216.6	1.29	8.8
NEWT 12.0	30-Jan-14	10:45	15.06		7.81	215.2	1.97	0.6
NEWT 12.0	16-Apr-14	11:30	11.56	87.542	7.49	113.5	35.6	5
NEWT 12.0	15-Jul-14	7:15	8.55	8.619	7.75	245.5	2.43	18.4
NEWT 12.0	21-Oct-14	15:00	10.44	3.728	8.08	176.1	0.67	12
NEWT 12.0	21-Jan-15	13:30	13.92	7.086	8.02	232	1.65	0.6
OSBR 0.1	09-Apr-13	9:30	9.49	22.735	7.68	196.8	2.7	7.6
OSBR 0.1	24-Jul-13	7:30	7.95	27.685	7.83	192.2	3.2	19.8
OSBR 0.1	04-Nov-13	14:30	12.72	8.092	8.57	222.6	1	7.8
OSBR 0.1	04-Feb-14	15:15	15.32		7.58	231	1.08	0
OSBR 0.1	17-Apr-14	14:00	13.29	96.142	7.63	156.8	7.31	7.5
OSBR 0.1	22-Jul-14	15:15	9.78	1.77	9.37	332.1	1.99	27.2
OSBR 0.1	29-Oct-14	14:30	10.79	11.334	8.9	194.2	0.56	12
OSBR 0.1	23-Jan-15	8:00	14.88		7.41	281.7	1.54	0
OWEG 1.0	10-Apr-13	8:30	7.61		7.31	194.1	9.5	10.1
OWEG 1.0	25-Jul-13	10:15	8.27	302.049	7.9	253.5	2.8	17.4
OWEG 1.0	30-Oct-13	10:30	10.6	105	8.02	303.1	1.03	7.5
OWEG 1.0	29-Jan-14	10:00	14.74		7.66	247.8	3.67	0
OWEG 1.0	08-May-14	12:15	12.62		8.68	227.4	2.98	13.7
OWEG 1.0	08-Jul-14	15:00	10.05	214.997	8.58	300.3	2.8	22.5
OWEG 1.0	29-Oct-14	8:00	8.85		7.62	226.5	1.93	11.4
OWEG 1.0	22-Jan-15	15:30	13.46		8.45	272.1	2.12	1.3
OWEG 2.5	10-Apr-13	7:30	8.37		7.44	192.7	9.8	9.7
OWEG 2.5	18-Jul-13	12:30	9.32	75.55	8.12	304.1	2.9	23
OWEG 2.5	30-Oct-13	12:15	11.31	59	7.92	275.5	0.3	8.6
OWEG 2.5	29-Jan-14	12:00	16.84		7.98	231	3.25	-0.05
OWEG 2.5	22-Jul-14	10:15	9.72		8.12	307.2	1.73	19.5
OWEG 2.5	28-Oct-14	16:30	13.12		8.42	221	1.3	11.7
OWEG 2.5	22-Jan-15	11:30	13.07	104.976	8.21	276.8	3.71	1.3
PIPE 0.5	10-Apr-13	14:45	8.44	105.008	7.71	145.3	19.8	9.6
PIPE 0.5	18-Jul-13	14:00	8.54	7.85	7.94	230.6	2.3	26.2
PIPE 0.5	30-Oct-13	13:30	11.76	6.413	8.13	234.5	0.52	10
PIPE 0.5	30-Jan-14	13:30	15.54		7.46	201.7	1.89	0.2
PIPE 0.5	17-Apr-14	8:30	14.04	129.186	7.69	113.4	16	3.2
PIPE 0.5	08-Jul-14	11:45	8.13	6.011	7.8	214.6	0.96	21.1
PIPE 0.5	22-Oct-14	15:00	9.81	8.062	7.97	171.9	0.77	11.7
PIPE 0.5	22-Jan-15	16:15	13.13	10.834	8.28	204.2	1.04	0.2
POST 0.6	25-Apr-13	7:30	11.13	63.963	7.47	154.5	4.11	7.7
POST 0.6	18-Jul-13	7:00	5.29	3.205	7.99	512.1	2.3	23
POST 0.6	28-Oct-13	9:45	13.33	5.636	7.81	230.2	1.72	4.9
POST 0.6	30-Jan-14	9:30	16.12		7.78	284.6	4.44	0
POST 0.6	16-Apr-14	16:45	11.38	160.241	7.55	119.1	18	7
POST 0.6	21-Jul-14	9:30	10.71	8.783	8.29	298.1	3.79	19.7
POST 0.6	21-Oct-14	11:30	11.91	5.668	7.94	236.9	1.54	10.2
POST 0.6	21-Jan-15	9:45	15.02		6.89	301.4	2.47	0.1

Site ID	Date	Time	Dissolved Oxygen (mg/l)	Flow (cfs)	pH	Sp Cond (umho/cm)	Turbidity (NTU)	Water Temp (deg C)
WBOC 13.0	09-Apr-13	16:45	8.45	97.342	7.5	87.2	6.6	9.6
WBOC 13.0	17-Jul-13	10:30	7.96	8.664	7.54	238.7	5.8	18.7
WBOC 13.0	30-Oct-13	8:00	10.19	9.062	6.63	199.9	1.62	6
WBOC 13.0	30-Jan-14	15:30	14.88		7.54	205.1	3.06	0
WBOC 13.0	17-Apr-14	10:00	14.36	132.087	7.53	98.3	7.11	3
WBOC 13.0	14-Jul-14	10:30	10.67	14.751	7.89	196.5	4.93	17.8
WBOC 13.0	23-Oct-14	8:00	11.22	9.437	7.22	116.6	1.94	8.8
WBOC 13.0	05-Feb-15	7:45						
WBOC 5.0	09-Apr-13	17:45	7.8	136.4789	7.44	105.1	6.9	11.3
WBOC 5.0	24-Jul-13	16:45	9.43	48.088	7.72	163.4	3.9	18.7
WBOC 5.0	30-Oct-13	9:30	10.73	18.28	7.6	227.8	1.36	6.8
WBOC 5.0	31-Jan-14	8:30	13.25		7.25	220.6	2.58	0
WBOC 5.0	22-Apr-14	9:30	10.5	81.508	7.64	142.4	6.1	8.9
WBOC 5.0	14-Jul-14	17:15	9.97	29.553	8.44	212.5	5.23	22
WBOC 5.0	28-Oct-14	15:30	11.95	12.898	8.64	173.2	2.13	12
WBOC 5.0	22-Jan-15	11:00	13.11	24.246	7.88	230.5	2.91	0.2
WILS 1.5	10-Apr-13	9:40	7.95	50.75	7.46	179.1	8.4	10.7
WILS 1.5	17-Jul-13	14:45	7.38	3.464	7.4	284.6	5.6	23.6
WILS 1.5	29-Oct-13	10:45	12.09	9.138	7.28	296.8	1.24	5.9
WILS 1.5	30-Jan-14	14:45	12.6		7.45	286.4	2.66	1.2
WILS 1.5	16-Apr-14	13:30	12.48	112.947	7.67	145	6.21	5.3
WILS 1.5	09-Jul-14	14:30	8.04	31.786	7.87	233.1	5.89	21.8
WILS 1.5	28-Oct-14	14:15	11.45	5.303	7.96	225.3	2.31	11.7
WILS 1.5	22-Jan-15	9:00	10.32	12.445	7.47	274.3	3.27	1.4
WYNK 1.5	24-Apr-13	16:30	11.66	42.215	7.51	94.1	4.1	11.6
WYNK 1.5	23-Jul-13	7:30	8.66	6.981	7.25	170.4	4.8	21.3
WYNK 1.5	29-Oct-13	8:45	10.22	4.219	7.12	162.1	0.63	7.8
WYNK 1.5	30-Jan-14	12:00	15.81		7.67	141.3	4.11	0
WYNK 1.5	16-Apr-14	15:15	11.44	132.359	7.39	92.9	16.9	7
WYNK 1.5	08-Jul-14	10:15	9.22	8.595	7.76	153	2.01	19.3
WYNK 1.5	22-Oct-14	13:45	9.3	2.459	7.77	129.6	4.03	11.6
WYNK 1.5	21-Jan-15	11:15	14.92		7.83	176.1	1.48	0

APPENDIX B
Macroinvertebrate Metrics

	CAST 0.9	CAST 0.9	CAST 0.9	CAST 0.9	CAST 0.9	CAST 0.9	NEWT 12.0	NEWT 12.0	NEWT 12.0	NEWT 12.0	NEWT 12.0	NEWT 12.0	CAYT 24.5	CAYT 24.5	CAYT 24.5	CAYT 24.5	CAYT 24.5	
	4/9/2013	7/24/2013	11/4/2013	4/17/2014	7/22/2014	10/29/2014	4/24/2013	7/16/2013	10/28/2013	4/16/2014	7/15/2014	10/21/2014	9/9/2013	10/28/2013	5/8/2014	7/8/2014	10/22/2014	
Taxa Richness	21	27	16	20	21	17	26	17	21	23	22	20	24	30	24	25	25	
EPT Taxa (PTV 0-4)	13	9	6	12	7	7	13	5	7	14	6	9	9	8	10	11	11	
Beck's Index	13	10	7	19	14	7	17	8	10	19	9	9	16	12	16	13	20	
Hilsenhoff Biotic Index	2.04	4.68	4.36	2.32	4.71	4.38	4.28	5.17	5.28	4.36	5.52	4.08	4.20	4.47	4.34	3.85	4.05	
Shannon Diversity	2.06	2.57	1.97	2.09	2.14	2.10	2.08	2.00	1.86	2.44	1.39	2.11	2.50	2.42	2.57	2.64	2.20	
Percent Sensitive Individuals (PTV 0-3)	85.2%	19.2%	24.8%	74.7%	14.1%	20.3%	35.9%	11.5%	12.6%	34.3%	6.4%	32.6%	17.1%	13.0%	26.0%	31.2%	22.4%	
PAIBI SCORE	72.72	55.62	44.39	71.64	48.99	45.56	62.97	40.33	44.17	64.79	38.90	52.82	56.88	55.47	59.67	62.16	60.52	
	OSBR 0.1	OSBR 0.1	OSBR 0.1	OSBR 0.1	OSBR 0.1	OSBR 0.1	EBOC 15.6	EBOC 15.6	EBOC 15.6	EBOC 15.6	EBOC 15.6	EBOC 15.6	WBOC 13.0	WBOC 13.0	WBOC 13.0	WBOC 13.0	WBOC 13.0	WBOC 13.0
	4/9/2013	7/24/2013	11/4/2013	5/8/2014	7/22/2014	10/29/2014	4/9/2013	7/24/2013	11/4/2013	4/17/2014	7/15/2014	10/29/2014	4/9/2013	7/17/2013	10/30/2013	4/17/2014	7/14/2014	10/23/2014
Taxa Richness	17	17	18	18	15	20	26	24	23	27	25	21	30	20	25	37	27	25
EPT Taxa (PTV 0-4)	9	6	10	9	6	8	11	10	10	14	11	9	18	8	13	19	13	12
Beck's Index	15	6	11	16	8	11	17	14	16	16	18	11	31	16	20	35	27	23
Hilsenhoff Biotic Index	2.83	5.46	5.15	3.77	4.87	4.42	3.53	4.15	4.15	3.92	4.27	3.82	2.93	3.70	3.55	3.11	3.28	3.48
Shannon Diversity	2.05	1.74	1.71	2.15	1.99	2.27	2.60	2.36	2.30	2.68	2.57	2.29	2.29	2.32	2.53	2.99	2.52	2.42
Percent Sensitive Individuals (PTV 0-3)	67.3%	6.0%	10.4%	42.3%	13.9%	22.4%	45.4%	18.8%	16.9%	36.9%	21.1%	27.6%	62.7%	27.3%	38.9%	52.0%	46.6%	35.0%
PAIBI SCORE	63.00	37.14	44.69	57.65	41.21	51.08	67.62	56.52	56.16	68.33	61.08	54.81	84.80	55.98	68.47	89.77	74.58	67.66
	PIPE 0.5	PIPE 0.5	PIPE 0.5	PIPE 0.5	PIPE 0.5	PIPE 0.5	POST 0.6	POST 0.6	POST 0.6	POST 0.6	POST 0.6	POST 0.6	WYNK 1.5	WYNK 1.5	WYNK 1.5	WYNK 1.5	WYNK 1.5	WYNK 1.5
	4/10/2013	7/18/2013	10/30/2013	4/17/2014	7/8/2014	10/22/2014	4/25/2013	7/18/2013	10/28/2013	4/16/2014	7/21/2014	10/21/2014	4/24/2013	7/23/2013	10/29/2013	4/16/2014	7/8/2014	10/22/2014
Taxa Richness	23	21	16	29	18	17	22	20	17	31	18	22	26	25	16	27	23	17
EPT Taxa (PTV 0-4)	10	7	6	19	5	7	9	8	8	15	7	10	15	9	7	15	6	7
Beck's Index	17	10	6	27	9	9	9	6	8	21	11	9	26	15	8	23	11	2
Hilsenhoff Biotic Index	2.62	4.91	4.16	3.43	5.22	4.05	4.33	4.93	3.97	3.27	4.85	4.07	3.54	5.02	4.51	2.75	4.42	4.95
Shannon Diversity	2.53	2.36	2.09	2.90	1.81	1.98	2.23	2.17	2.12	2.86	2.27	2.26	2.38	2.13	2.13	2.50	2.31	1.77
Percent Sensitive Individuals (PTV 0-3)	66.2%	7.9%	42.0%	52.2%	8.7%	50.6%	22.9%	11.5%	44.9%	53.6%	16.4%	47.9%	49.5%	17.8%	17.1%	73.0%	23.1%	24.0%
PAIBI SCORE	70.80	46.93	48.43	83.61	39.52	52.44	52.13	45.07	52.74	79.08	47.13	58.65	74.60	53.26	44.81	80.73	51.20	41.02
	NBNC 0.6	NBNC 0.6	NBNC 0.6	NBNC 0.6	NBNC 0.6	NBNC 0.6	NEWT 0.6	NEWT 0.6	NEWT 0.6	NEWT 0.6	NEWT 0.6	NEWT 0.6	WILS 1.5	WILS 1.5	WILS 1.5	WILS 1.5	WILS 1.5	WILS 1.5
	4/24/2013	7/16/2013	10/28/2013	4/16/2014	7/9/2014	10/21/2014	4/24/2013	7/23/2013	10/28/2013	4/22/2014	7/9/2014	10/21/2014	4/10/2013	7/17/2013	10/29/2013	4/16/2014	7/9/2014	10/28/2014
Taxa Richness	21	17	16	21	16	17	21	19	21	26	21	18	34	24	23	24	24	22
EPT Taxa (PTV 0-4)	7	5	6	8	4	4	6	2	7	11	7	6	15	7	11	8	8	9
Beck's Index	3	1	2	6	0	2	6	1	4	7	8	5	13	8	15	7	6	10
Hilsenhoff Biotic Index	4.82	4.83	4.60	5.34	5.31	4.89	4.80	4.96	4.62	4.96	4.90	4.67	4.79	4.91	4.38	3.40	4.45	4.51
Shannon Diversity	2.20	2.07	1.95	1.52	1.87	1.84	1.93	2.16	2.52	2.49	2.30	2.42	2.63	2.27	2.35	1.89	2.39	2.28
Percent Sensitive Individuals (PTV 0-3)	24.2%	11.4%	33.6%	14.0%	7.8%	29.4%	2.6%	1.8%	16.0%	10.3%	10.9%	17.8%	17.4%	5.3%	13.7%	59.9%	16.5%	13.8%
PAIBI SCORE	46.30	38.34	43.33	41.47	33.67	40.00	40.93	35.11	47.40	52.74	46.30	45.11	65.01	46.46	55.78	58.60	50.34	50.66

	CATA 15.0	CATA 15.0	CATA 15.0	CATA 15.0	CATA 15.0	CATA 8.0	CATA 8.0	CATA 8.0	CATA 8.0	CATA 8.0	CATA 8.0	OWEG 2.5	OWEG 2.5	OWEG 2.5	OWEG 2.5	OWEG 2.5	WBOC 5.0	WBOC 5.0	WBOC 5.0	WBOC 5.0	WBOC 5.0	WBOC 5.0
	7/17/2013	10/29/2013	4/22/2014	7/8/2014	10/28/2014	4/10/2013	7/25/2013	10/29/2013	5/8/2014	7/22/2014	10/29/2014	7/18/2013	10/30/2013	5/8/2014	7/22/2014	10/28/2014	4/9/2013	7/24/2013	10/30/2013	4/22/2014	7/14/2014	10/28/2014
Taxa Richness	24	24	28	25	25	24	22	19	25	23	17	22	16	28	20	21	23	20	25	33	26	31
EPT Taxa (PTV0-4)	11	12	13	13	14	13	8	8	13	10	6	8	8	15	9	10	10	8	12	16	15	13
Beck's Index	14	17	17	16	21	19	4	7	17	6	3	11	9	18	12	17	11	11	15	25	21	16
Hilsenhoff Biotic Index	3.95	3.80	3.61	4.34	3.69	3.90	4.76	4.16	4.34	4.64	5.59	4.45	4.02	4.57	3.76	3.95	5.18	4.38	4.13	3.79	4.44	4.20
Shannon Diversity	2.56	2.61	2.25	2.62	2.55	2.32	2.42	2.23	2.00	2.32	1.04	2.30	1.86	2.19	1.82	2.37	1.76	2.40	2.48	2.99	2.45	2.69
Percent Sensitive Individuals (PTV0-3)	36.6%	38.2%	41.7%	23.3%	38.6%	38.4%	18.1%	41.2%	38.8%	20.0%	8.8%	20.4%	49.6%	25.6%	57.4%	39.3%	12.0%	18.3%	30.5%	41.0%	15.5%	25.1%
PA IBI SCORE	73.53	77.90	80.36	73.77	83.59	78.58	54.39	61.16	74.80	58.68	36.48	60.30	61.34	76.50	69.12	72.74	55.95	59.45	73.47	91.80	77.01	78.22
	CATA 1.0	CATA 1.0	CATA 1.0	CATA 1.0	CATA 1.0	EBOC 5.0	EBOC 5.0	EBOC 5.0	EBOC 5.0	EBOC 5.0	EBOC 5.0	CAYT 3.7	CAYT 3.7	CAYT 3.7	CAYT 3.7	CAYT 3.7						
	7/17/2013	10/30/2013	5/8/2014	7/22/2014	10/28/2014	4/9/2013	7/17/2013	11/4/2013	4/22/2014	7/22/2014	10/29/2014	7/16/2013	10/29/2013	5/8/2014	7/21/2014	10/22/2014						
Taxa Richness	24	23	29	28	20	25	22	16	25	23	23	16	25	22	19	26						
EPT Taxa (PTV0-4)	8	9	11	11	9	19	10	8	14	11	11	5	11	12	5	11						
Beck's Index	9	8	4	9	10	23	13	11	21	14	13	8	14	13	10	15						
Hilsenhoff Biotic Index	4.59	4.09	5.13	4.54	3.81	3.18	4.27	4.07	3.69	4.53	3.81	4.26	4.00	3.69	4.33	3.68						
Shannon Diversity	2.31	2.37	2.37	2.70	2.37	2.57	2.13	2.10	2.50	2.38	2.56	2.10	2.54	2.45	2.27	2.55						
Percent Sensitive Individuals (PTV0-3)	16.8%	37.3%	16.7%	26.7%	41.6%	56.4%	41.4%	40.4%	43.9%	25.9%	40.4%	16.0%	39.1%	50.7%	23.4%	51.8%						
PA IBI SCORE	58.67	65.09	59.75	68.80	66.71	92.19	68.58	61.79	84.61	67.90	73.53	49.87	74.44	76.23	55.65	79.75						
	OWEG 1.0	OWEG 1.0	OWEG 1.0	OWEG 1.0	OWEG 1.0	CAYT 18.0	CAYT 18.0	CAYT 18.0	CAYT 18.0	CAYT 18.0	CAYT 18.0	CAYT 8.7	CAYT 8.7	CAYT 8.7	CAYT 8.7	CAYT 8.7						
	7/25/2013	10/30/2013	5/8/2014	7/8/2014	10/29/2014	4/10/2013	7/17/2013	10/28/2013	5/8/2014	7/21/2014	10/22/2014	8/13/2013	10/29/2013	5/8/2014	7/21/2014	10/22/2014						
Taxa Richness	20	13	20	19	21	18	19	17	30	27	23	19	18	22	23	20						
EPT Taxa (PTV0-4)	11	6	11	10	13	5	6	8	16	14	15	8	7	11	10	8						
Beck's Index	7	4	11	6	13	9	10	13	20	22	23	12	8	16	13	11						
Hilsenhoff Biotic Index	4.56	3.77	4.52	4.06	3.54	4.48	4.36	3.94	3.62	4.72	4.25	4.29	4.20	3.67	4.69	4.08						
Shannon Diversity	2.41	1.81	1.91	2.14	2.37	2.24	2.12	2.19	2.80	2.23	2.34	2.18	2.30	2.55	2.29	2.49						
Percent Sensitive Individuals (PTV0-3)	19.5%	57.4%	31.3%	39.3%	58.7%	9.0%	11.7%	21.7%	37.0%	17.2%	24.2%	16.3%	20.8%	42.5%	12.6%	35.9%						
PA IBI SCORE	59.50	56.08	62.65	61.75	78.69	50.23	52.83	60.04	88.82	75.74	78.12	58.12	55.57	76.04	61.89	65.12						

APPENDIX C
Fish Assemblage Raw Data

Genus and Species	Common name	Post Creek 0.6	Newton Creek 0.6	Cayuta Creek 24.5	Cayuta Creek 8.7	Wynkoop Creek 1.5	Catatonk Creek 15.0	Pipe Creek 0.5	Owego Creek 1.0	East Branch Owego Creek 15.6	West Branch Owego Creek 5.0	Castle Creek 0.9	Osborne Creek 0.1
Date Sampled		**7/18/2013**	**7/23/2013**	**9/25/2013**	**9/9/2013**	**7/23/2013**	**8/13/2013**	**7/18/2013**	**9/26/2013**	**7/24/2013**	**7/24/2013**	**7/24/2013**	**7/24/2013**
Catostomus commersoni	white sucker	27	20	4	23	17	25	50	10	141	10	0	25
Erimyzon oblongus	creek chubsucker	0	1	0	0	0	0	0	0	0	0	0	0
Hypentelium nigricans	northern hog sucker	2	0	0	1	0	0	0	5	0	2	0	0
Ambloplites rupestris	rock bass	0	23	15	2	1	7	1	2	0	5	0	0
Lepomis auritus	redbreast sunfish	0	9	0	0	0	0	1	0	0	0	0	0
Lepomis cyanellus	green sunfish	0	9	0	4	0	0	2	2	0	0	0	0
Lepomis gibbosus	pumpkinseed	0	1	1	0	0	1	0	2	11	0	0	2
Lepomis macrochirus	bluegill	0	1	0	2	0	0	8	0	0	1	0	2
Micropterus dolomieu	smallmouth bass	1	1	0	7	0	4	1	30	0	1	0	5
Micropterus salmoides	largemouth bass	0	2	0	0	0	0	17	0	0	4	0	5
Cottus bairdi	mottled sculpin	0	0	137	0	0	0	0	112	386	302	55	9
Cottus spp.	sculpin species	48	2	0	83	60	189	7	0	0	0	0	0
Campostoma anomalum	central stoneroller	240	4	4	447	104	66	70	78	78	26	63	730
Clinostomus elongatus	redside dace	0	0	0	0	0	0	0	0	0	0	0	0
Cyprinella spiloptera	spotfin shiner	3	2	0	12	0	0	23	60	0	0	0	0
Exoglossum maxillingua	cutlips minnow	133	0	166	45	29	142	12	11	199	277	36	57
Luxilus cornutus	common shiner	244	0	57	4	14	7	1	4	207	0	15	8
Margariscus margarita	pearl dace	0	0	3	0	0	0	0	0	97	0	0	0
Nocomis biguttatus	horneyhead chub	0	0	0	0	0	0	0	0	0	0	0	0
Nocomis micropogon	river chub	100	0	0	4	0	0	0	1	0	0	0	0
Notemigonus chrysolelucas	golden shiner	0	0	0	0	0	0	2	0	1	0	0	0
Notropis hudsonius	spottail shiner	0	0	0	0	0	0	0	0	3	0	0	0
Notropis rubellus	roseyface shiner	0	0	0	7	0	0	0	7	0	0	0	0
Notropis volucellus	mimic shiner	7	11	0	17	13	0	46	235	0	0	0	0
Pimephales notatus	bluntnose minnow	3	33	13	7	14	11	91	82	116	4	0	15
Pimephales promelas	fathead minnow	0	0	0	0	2	0	2	0	3	1	0	0
Rhinichthys atratulus	blacknose dace	331	1	146	211	349	74	60	0	317	39	300	589
Rhinichthys cataractae	longnose dace	216	103	5	99	31	41	30	65	11	32	81	150
Semotilus atromaculatus	creek chub	0	1	69	18	125	29	10	0	229	6	31	31
Semotilus corporalis	fallfish	0	0	0	4	0	0	0	14	0	0	0	0
Esox niger	chain pickerel	0	0	0	4	0	0	0	0	0	0	0	0
Fundulus diaphanus	banded killifish	0	0	0	0	0	0	1	0	0	0	0	0
Culea inconstans	brook stickleback	0	0	0	0	0	0	0	0	55	0	0	0
Ameiurus natalis	yellow bullhead	0	7	0	0	0	0	2	0	0	0	0	0
Noturus insignis	margined madtom	72	13	3	14	16	25	2	11	0	72	0	15
Etheostoma blennioides	greenside darter	113	79	9	38	7	15	11	54	4	126	0	1
Etheostoma flabellare	fantail darter	0	3	0	0	83	0	0	0	0	0	0	0
Etheostoma olmstedi	tessellated darter	20	84	50	57	30	48	18	41	37	46	11	26
Etheostoma zonale	banded darter	33	37	1	94	0	0	0	26	7	13	0	0
Percina peltata	shield darter	0	0	0	1	0	0	0	14	0	0	0	0
Salmo trutta	brown trout (wild)	0	1	6	0	0	1	0	0	10	0	0	1

Genus and Species	Common name	Catatonk Creek 1.0	Newtown Creek 12.0	West Branch Owego Creek 13.0	East Branch Owego Creek 5.0	North Branch Newtown Creek 0.6	Cayuta Creek 18.0	Wilseyville Creek 1.5	Owego Creek 2.5
Date Sampled		**9/17/2014**	**7/15/2014**	**7/14/2014**	**9/17/2014**	**9/18/2014**	**9/18/2014**	**7/14/2014**	**9/17/2014**
Catostomus commersoni	white sucker	149	1	7	13	4	9	9	331
Erimyzon oblongus	creek chubsucker	0	0	0	0	0	0	0	0
Hypentelium nigricans	northern hog sucker	15	0	0	6	3	1	0	52
Ambloplites rupestris	rock bass	0	0	0	0	0	0	2	9
Lepomis auritus	redbreast sunfish	1	0	0	0	0	0	0	0
Lepomis cyanellus	green sunfish	0	0	0	0	0	2	0	0
Lepomis gibbosus	pumpkinseed	0	0	1	0	0	0	2	0
Lepomis macrochirus	bluegill	0	0	0	0	0	0	0	0
Micropterus dolomieu	smallmouth bass	59	0	0	7	0	0	0	88
Micropterus salmoides	largemouth bass	8	0	0	0	3	0	0	1
Cottus bairdi	mottled sculpin	0	0	0	0	0	0	0	0
Cottus spp.	sculpin species	6	82	198	279	2	255	79	201
Campostoma anomalum	central stoneroller	95	8	0	123	158	7	15	75
Clinostomus elongatus	redside dace	1	0	3	0	0	0	0	2
Cyprinella spiloptera	spotfin shiner	1	0	0	0	0	0	0	6
Exoglossum maxillingua	cutlips minnow	54	18	87	57	47	25	40	64
Luxilus cornutus	common shiner	9	1	3	0	14	30	1	2
Margariscus margarita	pearl dace	0	0	11	0	0	0	0	0
Nocomis biguttatus	horneyhead chub	0	0	0	0	0	0	0	0
Nocomis micropogon	river chub	8	0	0	0	0	0	0	0
Notemigonus chrysolelucas	golden shiner	0	0	0	0	0	0	0	0
Notropis hudsonius	spottail shiner	0	0	0	0	0	0	0	0
Notropis rubellus	roseyface shiner	0	0	0	1	0	0	0	16
Notropis volucellus	mimic shiner	50	0	0	0	0	0	0	263
Pimephales notatus	bluntnose minnow	18	0	4	0	20	4	0	45
Pimephales promelas	fathead minnow	0	0	4	0	0	0	1	0
Rhinichthys atratulus	blacknose dace	2	215	41	424	180	65	42	22
Rhinichthys cataractae	longnose dace	52	60	11	22	30	87	68	56
Semotilus atromaculatus	creek chub	1	60	78	1	14	26	15	7
Semotilus corporalis	fallfish	81	0	0	0	0	0	0	101
Esox niger	chain pickerel	0	0	0	0	0	0	0	0
Fundulus diaphanus	banded killifish	0	0	0	0	0	0	0	0
Culea inconstans	brook stickleback	0	0	0	0	0	0	0	0
Ameiurus natalis	yellow bullhead	1	0	0	0	1	0	0	0
Noturus insignis	margined madtom	11	3	0	22	1	1	14	7
Etheostoma blennioides	greenside darter	105	0	0	56	1	5	3	81
Etheostoma flabellare	fantail darter	0	28	0	0	70	0	0	0
Etheostoma olmstedi	tessellated darter	105	0	19	16	5	5	28	76
Etheostoma zonale	banded darter	39	0	0	59	0	5	0	54
Percina peltata	shield darter	10	0	0	0	0	0	0	9
Salmo trutta	brown trout (wild)	0	0	4	0	0	7	0	0

APPENDIX D
Fish Community Metrics

	Post Creek 0.6	Newton Creek 0.6	Cayuta Creek 24.5	Cayuta Creek 8.7	Wynkoop Creek 1.5	Catatonk Creek 15.0	Pipe Creek 0.5	Owego Creek 1.0	East Branch Owego Creek 15.6	West Branch Owego Creek 5.0
Date sampled	**7/18/2013**	**7/23/2013**	**9/25.2013**	**9/9/2013**	**7/23/2013**	**8/13/2013**	**7/18/2013**	**9/26/2013**	**7/24/2013**	**7/24/2013**
Density/Abundance Metrics										
Richness	17	24	17	25	16	16	24	22	19	18
Abundance	1593	448	689	1205	895	685	468	866	1912	967
Density (fish/m2)	1.77	0.28	0.70	0.72	0.60	0.46	0.35	0.20	0.97	0.37
CPUE (indiv/s)	0.32	0.11	0.26	0.32	0.27	0.19	0.17	0.24	0.40	0.24
CPUE (indiv/min)	19.42	6.73	15.56	19.29	16.35	11.23	10.32	14.24	23.97	14.16
Biomass (kg/ha)	58.90	16.40	36.80	23.90	11.40	21.80	6.10	5.00	24.50	17.00
Relative Abundance, by Family										
% Catostomidae	1.82	4.69	0.58	1.99	1.90	3.65	10.68	1.73	7.37	1.24
% Centrarchidae	0.06	10.27	2.32	1.24	0.11	1.75	6.41	4.16	0.58	1.14
% Cottidae	3.01	0.45	19.88	6.89	6.70	27.59	1.50	12.93	20.19	31.23
% Cyprinidae	80.16	34.60	67.20	72.61	76.09	54.01	74.15	64.32	65.95	39.81
% Fundulidae	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.00
% Gasterosteidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.88	0.00
% Ictaluridae	4.52	4.46	0.44	1.16	1.79	3.65	0.85	1.27	0.00	7.45
% Percidae	10.42	45.31	8.71	15.77	13.41	9.20	6.20	15.59	2.51	19.13
% Salmonidae	0.00	0.22	0.87	0.00	0.00	0.15	0.00	0.00	0.52	0.00
Origin Metrics										
Native Taxa Richness	13	15	13	18	12	12	16	16	14	11
% Native Individuals	90.33	63.39	95.50	86.39	97.43	96.06	81.20	59.70	95.87	84.38
Introduced Taxa Richness	4	9	4	7	4	4	8	6	5	7
% Introduced Individuals	9.67	36.61	4.50	13.61	2.57	3.94	18.80	40.30	4.13	15.62
Benthic Metrics										
Benthic Taxa Richness	7	9	6	8	6	5	6	8	5	7
% Benthic Individuals	19.77	54.91	29.61	25.81	23.80	44.09	19.23	31.52	30.07	59.05
Darter, sculpin, madtom Richness	5	6	5	6	5	4	4	6	4	5
% Darters,sculpins,madtoms	17.95	48.66	29.03	23.82	21.90	40.44	8.12	29.79	22.70	57.81
Community Tolerance										
Tolerant Taxa Richness	4	9	6	7	5	6	9	5	7	7
% Tolerant Individuals	23.92	33.93	41.07	26.72	59.78	27.45	55.13	15.82	44.56	11.38
Intolerant Taxa Richness	10	7	7	12	6	6	8	12	7	7
% Intolerant Individuals	68.49	37.95	54.14	67.05	28.38	68.61	31.20	46.30	46.60	74.87
Spawning Metrics										
Lithophilic Richness	8	7	9	11	7	7	6	11	8	7
% Lithophilic Individuals	51.91	20.09	57.04	58.76	34.41	63.80	30.13	31.99	58.84	65.67
Trophic Guilds										
Top Predator Richness	1	3	1	2	0	2	2	1	1	2
% Top Predators	0.06	0.89	0.87	0.91	0.00	0.73	3.85	3.46	0.52	0.52
Generalist Feeder Richness	1	5	3	5	3	3	5	4	2	3
% Generalist Feeders	1.69	13.84	12.77	4.23	15.98	8.91	13.68	3.23	19.35	2.17
Invertivore Richness	5	6	5	7	3	4	6	7	5	5
% Invertivores	14.44	22.77	32.37	11.45	8.38	31.53	13.68	15.82	18.15	41.16
Insectivore Richness	3	4	3	4	3	2	2	4	3	3
% Insectivores	12.18	27.01	21.34	17.93	16.76	29.78	3.85	23.79	20.76	45.60
Omnivore Richness	5	4	4	5	5	4	7	4	6	4
% Omnivores	56.12	32.14	32.08	26.97	45.81	19.42	40.17	17.55	34.26	7.86

	Catatonk Creek 1.0	Newtown Creek 12.0	West Branch Owego Creek 13.0	East Branch Owego Creek 5.0	North Branch Newtown Creek 0.6	Cayuta Creek 18.0	Wilseyvile Creek 1.5	Owego Creek 2.5	Castle Creek 0.9	Osborne Creek 0.1
Date Sampled	**9/17/2014**	**7/15/2015**	**7/14/2014**	**9/17/2014**	**9/18/2014**	**9/18/2014**	**7/14/2014**	**9/17/2014**	**7/24/2013**	**7/24/2013**
Density/Abundance Metrics										
Richness	24	10	14	14	16	16	14	23	8	17
Abundance	881	476	471	1086	553	534	319	1568	592	1671
Density (fish/m2)	0.35	0.51	0.29	0.93	0.56	0.37	0.34	0.40	0.51	0.75
CPUE (indiv/s)	0.34	0.19	0.16	0.33	0.19	0.20	0.11	0.35	0.20	0.39
CPUE (indiv/min)	20.18	11.29	9.65	19.56	11.64	11.92	6.50	21.02	12.07	23.30
Biomass (kg/ha)									8.00	9.70
Relative Abundance, by Family										
% Catostomidae	18.62	0.21	1.49	1.75	1.27	1.87	2.82	24.43	0.00	1.50
% Centrarchidae	7.72	0.00	0.21	0.64	0.54	0.37	1.25	6.25	0.00	0.84
% Cottidae	0.68	17.23	42.04	25.69	0.36	47.75	24.76	12.82	9.29	0.54
% Cyprinidae	42.22	76.05	51.38	57.83	83.73	45.69	57.05	42.03	88.85	94.55
% Ictaluridae	1.36	0.63	0.00	2.03	0.36	0.19	4.39	0.45	0.00	0.90
% Percidae	29.40	5.88	4.03	12.06	13.74	2.81	9.72	14.03	1.86	1.62
% Salmonidae	0.00	0.00	0.85	0.00	0.00	1.31	0.00	0.00	0.00	0.06
Origin Metrics										
Native Taxa Richness	19	10	12	11	14	12	11	17	8	12
% Native Individuals	70.37	100.00	98.30	88.77	99.28	96.44	98.12	68.37	100.00	99.16
Introduced Taxa Richness	5	0	2	3	2	4	3	6	0	5
% Introduced Individuals	29.63	0.00	1.70	11.23	0.72	3.56	1.88	31.63	0.00	0.84
Benthic Metrics										
Benthic Taxa Richness	9	4	3	7	8	7	5	8	2	5
% Benthic Individuals	50.06	23.95	47.56	41.53	15.73	52.62	41.69	51.72	11.15	4.55
Darter, sculpin, madtom Richness	6	3	2	5	5	5	4	6	2	4
% Darters,sculpins,madtoms	31.33	23.74	46.07	39.78	14.29	50.75	38.87	27.30	11.15	3.05
Community Tolerance										
Tolerant Taxa Richness	6	3	6	4	6	6	5	6	3	8
% Tolerant Individuals	32.12	57.98	31.85	41.80	40.87	20.79	30.09	30.74	57.77	41.59
Intolerant Taxa Richness	14	6	5	7	7	8	6	12	5	6
% Intolerant Individuals	43.47	36.13	64.12	52.30	46.11	76.97	68.03	40.11	42.23	57.99
Spawning Metrics										
Lithophilic Richness	11	6	7	6	7	8	6	11	4	6
% Lithophilic Individuals	53.01	28.99	66.45	49.45	53.89	63.48	45.77	57.40	28.55	49.67
Trophic Guilds										
Top Predator Richness	2	0	1	1	1	1	0	2	0	3
% Top Predators	7.60	0.00	0.85	0.64	0.54	1.31	0.00	5.68	0.00	0.66
Generalist Feeder Richness	4	2	2	2	2	3	3	4	1	2
% Generalist Feeders	26.33	12.82	18.05	1.29	3.25	6.93	8.15	28.57	5.24	3.35
Invertivore Richness	6	2	5	5	4	4	4	7	2	5
% Invertivores	21.23	4.41	25.69	9.39	10.13	5.99	26.33	14.22	7.94	6.10
Insectivore Richness	4	2	1	3	3	3	2	4	1	2
% Insectivores	18.16	23.11	42.04	36.28	13.20	49.63	25.71	22.00	9.29	0.60
Omnivore Richness	6	3	5	2	5	4	4	4	3	4
% Omnivores	10.22	57.98	13.38	41.07	44.30	34.83	35.11	7.97	66.89	45.60