Physical, Chemical, and Biological Attributes of Least Disturbed Watersheds in Connecticut

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Project Summary

This report provides a summary of a project titled, *Percent Impervious Cover TMDLs in Connecticut*, that was conducted by the Connecticut DEP (CTDEP), Bureau of Water Protection and Land Reuse, from 2007-2008. The project was funded, in part, by a grant to CTDEP from the US Environmental Protection Agency Section 104 (b) (3) of the Clean Water Act.

The CTDEP has modeled the multiple stressors associated with storm water runoff from impervious cover (IC) and ecological degradation of macroinvertebrates and developed a Total Maximum Daily Load (TMDL) using IC as a surrogate measure. This work expands on our efforts using IC as an important landscape variable by evaluating fish and macroinvertebrate communities and describing watershed attributes from 30 least disturbed watersheds in Connecticut. We used Geographic Information Systems to select watersheds in Connecticut based on land use characteristics (e.g. IC < 4%, Natural Land Cover > 80%), habitat fragmentation (e.g. no dams within a mile upstream, no large dams in watershed upstream), water quantity (e.g. no water diversions), fish stocking records (e.g. no known records of salmonid fry stocking), and stream geomorphology (e.g. watershed size > 1 square mile). These sites are referred to as "least disturbed" in this report. We define least disturbed conditions as the "best available physical, chemical, and biological habitat conditions given today's state of the landscape" (Stoddard et al., 2006).

Summary of Important Findings

- **A total of 30 least disturbed watersheds were selected for this study. These were concentrated in northwest Connecticut (Barkhamsted, Canaan, Harwinton, Sharon, Torrington, Winchester), northeast Connecticut (Ashford, Chaplin, Eastford, Union), and the central valley (Colchester, East Haddam, East Hampton, Haddam, Lyme). East Haddam had the most least disturbed watersheds (four). Ashford, Canaan, and Lyme each contained three least disturbed watersheds. Barkhamsted, East Hampton, and Torrington each contained two least disturbed watersheds. Eleven towns contained one least disturbed watershed.**

- **The percent preserved land contained in the 30 least disturbed watersheds ranged from 0-73%. This analysis highlights potential opportunities for future preservation of some least disturbed watershed in Connecticut. In addition, the GIS analysis used in this study to select the least disturbed watersheds can serve as a template for other studies that are consistent with DEP's Green Plan.**

- **We describe 2 watersheds, Brown Brook and Whiting Brook located in Canaan, Connecticut, that can be considered as candidates for Level 1 Biological Condition Gradient sites. Level 1 sites are the natural or native condition and are described as follows (Gerritsen and Jessup 2007):**

  > **"*Native structural, functional and taxonomic integrity is preserved; ecosystem function is preserved within the range of natural variability*"**

  Level 1 watersheds have previously not been known to exist in Connecticut.

- **Precipitation (about 7 inches below normal) and streamflow in 2007 were below average. Streamflows during the macroinvertebrate index period (September 15 – November 30, 2007) were at near record lows. As a result, macroinvertebrate samples were not collected from 6 of the 30 initial watersheds selected for study.**

- **None of the 24 least disturbed watersheds sampled clearly failed Aquatic Life Use Support (ALUS) goals for macroinvertebrate communities. Only 1 of the watersheds had a macroinvertebrate assessment that was considered to be ambiguous (Hall Meadow Brook, Torrington).**

- **All 30 least disturbed watersheds were sampled for fish. Ninety percent of the sites sampled (27/30) contained wild brook trout populations. Three of these sites, Gardner Book in Ashford, Mott Hill Brook in Glastonbury, and Whiting Brook in Canaan had wild brook trout densities above 1,600 per hectare and would be considered for Class 1 stream flow classification (Bellucci et al., 2007a).**

- **Data from this study will provide insight into fish species composition from least disturbed sites and will assist with the calibration of fish community reference sites and potential development of Biological Condition Gradient for fish in Connecticut.**

- **Water temperature, drainage basin size, and dominant forest type were important variables that influenced fish and macroinvertebrate species distribution in least disturbed watersheds.**

- **Branch Brook in Eastford had unexpectedly high chloride concentrations which should be investigated.**

- **Hall Meadow Brook in Torrington was highlighted for additional stressor identification work because both fish and macroinvertebrate densities were low compared to values from other least disturbed watersheds in Connecticut. Additional work is needed to assess whether low streamflow or other stressors are contributing to the biological communities that are below expectations for least disturbed watersheds.**

- **Results from this study will provide the data necessary to develop estimates of phosphorus export from least disturbed watersheds in Connecticut.**

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Introduction

The negative effect of urbanization on the health of aquatic biota in rivers and streams has been well documented (Coles et al. 2004; Morley and Karr, 2002; Schueler, 1994). The term "urban stream syndrome" (Walsh et al. 2005) has been used to describe the consistent pattern of ecological degradation of streams draining urban lands. Impervious land cover has often been used as a surrogate measure of aggregate negative effects from urbanization on hydrology (Galster et al. 2006; Olivera and Defee 2007; Schuster et al. 2005), geomorphology (Cianfrani et al. 2006), and biological communities (Miltner et al. 2004; Morse et al. 2002; Stanfield and Kilgour, 2006; Wang et al. 2001; Wang and Kanehl 2003). Thus, impervious land cover can provide a useful stressor gradient to measure response of biological communities to assess health of aquatic ecosystems.

Recently, the Connecticut Department of Environmental Protection (CTDEP) has modeled the multiple stressors associated with storm water runoff from impervious cover and ecological degradation of macroinvertebrates within the context of the state's Total Maximum Daily Load (TMDL) Program (Bellucci 2007b). To support this approach, the percent impervious cover in the upstream catchments and scores of macroinvertebrate health were modeled for catchments less than 50 square miles in Connecticut. These data show that once impervious cover in upstream catchments reached approximately 12%, none of the 125 sites analyzed met the state's aquatic life goals set in Connecticut's Water Quality Standards (State of Connecticut 2002).

We believe that IC provides a valuable tool to frame future research and management strategies for Connecticut (**Figure 1**) and this work expands on the Connecticut IC Model by including streams on the low end of IC gradient defined as containing < 4 % IC in the upstream watershed. These are streams that would fall in the "best stream class" and "preservation management strategy" of our conceptual model in Figure 1. We further refined the selection of watersheds and screened watersheds to eliminate other known stressors to aquatic life (e.g. dams, diversions, salmonid fry stocking) and refer to these as "least disturbed watersheds" throughout this report. We define least disturbed watersheds as the "best available physical, chemical, and biological habitat conditions given today's state of the landscape" (Stoddard et al., 2006). We hypothesize that macroinvertebrate communities from these least disturbed watersheds should meet the CTDEP's aquatic life goals. If these watersheds do not meet aquatic life goals, then we can investigate the potential causes through the Stressor Identification (SID) process and develop TMDLs, if necessary.

These data will have several additional benefits beyond their utility within the TMDL Program and related SID programs:

- A description of watershed attributes and locations of least disturbed watersheds can provide an important planning tool to apprise the public and land use planners of these locations for use in local land use decisions.
- A technical recommendation to advance the use of Tiered Aquatic Life Use development in Connecticut (Gerritsen and Jessup, 2007) was to develop a biological condition gradient (BCG) for a second biological assemblage. Data from this study will provide insight into fish community species composition from least disturbed sites to assist with the calibration of fish community reference sites and potential BCG development in Connecticut.
- A second technical recommendation to advance the use of Tiered Aquatic Life Use development in Connecticut (Gerritsen and Jessup, 2007) was to search for macroinvertebrate BCG level 1 sites.

- These data will assist with DEP with efforts to develop minimum streamflow regulations for the state. DEP has developed a methodology which uses wild brook trout densities to strengthen with streamflow classification. Data on wild brook trout densities from many of these streams could qualify the stream for the highest level of protection within the streamflow regulation.
- Nutrient data from least disturbed watersheds in Connecticut will support development of nutrient criteria. DEP has developed a methodology that uses nutrient data from least disturbed watersheds to estimate phosphorus export from forested lands to improve state-wide nutrient criteria.

Methods

Selection of Least Disturbed Watersheds

We used Geographic Information Systems (GIS; ESRI ArcMap 9.2) to select least disturbed watersheds in Connecticut based on land use characteristics, water quantity, habitat fragmentation, fish stocking, and stream geomorphology (**Table 1**). Only watersheds larger than 1 square mile were considered for study. We first screened subregional basins with greater than 80% natural land cover. For those basins, we then applied criteria for percent impervious cover, locations of diversions, locations of dams and reservoirs, and salmonid fry stocking to catchments within those basins **(Table 1)**.

Screening for Natural Land Cover

Percent natural land cover was calculated from 2002 land cover data produced by the University of Connecticut CLEAR (Center for Landuse Education and Research) program. This land cover grouping was derived from 2002 LandSat satellite imagery. Percent natural land cover was an aggregate calculated percentage of deciduous forest, coniferous forest, open water and wetland land cover categories (Gerritsen & Jessup, 2007). We calculated the percent natural land cover for each of the 334 subregional basins defined in Thomas (1972). Connecticut's subregional basins **(Figure 2)** range in size from 0.08 - 176.46 square miles, although 95% are less than 39 square miles (median = 10.45 square miles).

Percent Impervious Cover

Percent developed land cover was calculated from the 2002 UCONN Clear Land Cover dataset. Percent developed represents high-density areas associated with commercial, industrial and residential activities.

IC percent was calculated using the Impervious Surface Analysis Tool (ISAT), an ESRI Arc Map version 9.2. extension. ISAT was developed by the Coastal Services Center at the National Oceanic and Atmospheric Administration (NOAA) in collaboration with the Non-point Education for Municipal (NEMO) Officials program at the University of Connecticut (http://www.csc.noaa.gov/crs/cwq/isat.html). ISAT uses land cover coefficients and human population density to calculate impervious cover for defined polygons, in our case, upstream catchments. We used coefficients developed for Connecticut based on 2002 Connecticut Land Cover data and population density (Prisloe et al. 2002). All IC calculations using ISAT assumed low population density (<500 people/square mile).

Water Quantity

The location of water diversions was estimated using best available data from the CTDEP. The CTDEP diversion database contains the locations of approximately of 2,236 diversions and is maintained by the Inland Water Resources Division. We used GIS to select catchments that did not contain diversions.

Habitat Fragmentation

Dams are ubiquitous in Connecticut's landscape and can contribute to habitat fragmentation. Measures of dam height, length or storage were not unavailable for all locations at the time of analysis. Therefore, we used a CTDEP database containing Hazard Class C dams and a Connecticut Department of Public Health (CTDPH) database containing information on reservoir size to infer the presence of large dams. We screened stream segments using GIS and excluded those with Hazard Class C dams or reservoirs in upstream segments. Hazard Class C dams impound large volumes of water and could be highly hazardous if the dam were breached. Waterbodies listed as reservoirs in the CTDPH database are typically used for public water supply and storage and usually not "run of river". We also used the CTDEP dam location database to eliminate stream reaches that were within 1 mile of a smaller dam.

Biological Information

Brown trout (*Salmo trutta*) fry and Atlantic salmon (*Salmo salar*) fry stocking records were obtained from the CTDEP Fisheries Division. We used GIS to select only watersheds with no known stocking records of brown trout fry and Atlantic salmon fry. We did not exclude streams that were stocked with adult salmonids because our selection criteria dictated small, remote streams which are typically not stocked with adult salmonids. Our assumption was there would be few, if any, adult stocked streams in the pool of choices given our other selection criteria.

Least Disturbed Study Watersheds

A total of 60 watershed catchments met all of the above screening criteria. These 60 watersheds were screened further to determine suitable sampling habitat (e.g. low gradient reaches were eliminated), site accessibility, proximity to fry stocked area, proximity to dams, proximity to other study streams, and watershed size. Thirty of the initial list of 60 streams were eliminated for consideration in this study (**Table 2**). The final list of 30 watersheds was selected for this study **(Table 3, Figure 3)**. The latitude and longitude of each study site were recorded with a Garmin Model 76 Global Position System to process further catchment delineation using GIS. The catchments upstream of each sampling location were delineated using the ArcHydro extension of GIS. Land use attributes for the 30 least disturbed watersheds selected in this study are shown in **Appendix A**.

Biological Communities

Macroinvertebrates

Benthic macroinvertebrate samples were collected September - October, 2007 using an 800 *u*m-mesh kick net. A total of 2 m^2 of riffle habitat was sampled at each location. Samples were preserved in 70% ethyl alcohol and brought back to the laboratory for subsampling. A 200-organism subsample was taken using a random grid design (Plafkin et al, 1989) from each sampling location. Organisms were identified to the lowest practical taxon, generally species.

A macroinvertebrate multimetric index (MMI) score for each site was calculated using the 200 organism subsample at the genus level (Gerritsen and Jessup 2007). The MMI is composed of 7 metrics: Ephemeroptera taxa (scoring adjusted for watershed size), Plecoptera taxa, percent sensitive EPT (scoring adjusted for watershed size), scraper taxa, biological condition gradient (Davies and Jackson 2006) taxa biotic index, and percent dominant genus. The MMI score is the average score of all seven metrics and ranges from 0 -100 with higher values representing least stressed sites. The CTDEP uses the following convention as one of the measures for assessing aquatic life for Clean Water Act 305 (b) reporting and Section 303 (d) impaired water listing - MMI < 44 = fail, MMI range of 45-55 ambiguous, MMI > 56 = pass (E. Pizzuto personal communication[1]). Ecological attributes for the macroinvertebrates collected during this project are presented in **Appendix B**.

A technical recommendation to advance the use of Tiered Aquatic Life Use in Connecticut (Gerritsen and Jessup, 2007) was satisfied by searching for macroinvertebrate Biological Condition Gradient (BCG) level 1 site. The BCG is a conceptual model of ecological community change in flowing waters with increased anthropogenic stressors (Davies and Jackson, 2006). Level 1 sites are the least disturbed of the sites and have been described as "Native structural, functional and taxonomic integrity is preserved; ecosystem function is preserved within the range of natural variability" (Gerritsen and Jessup, 2007). Level 1 watersheds have not been previously identified in Connecticut.

We used the criteria of Gerritsen and Jessup (2007) to determine minimally disturbed level 1 BCG sites. Candidate BCG level 1 sites had < 5 persons per square mile, < 0.5% urban land use , > 90% natural land cover, and < 5 mg/L chloride. We found that data were unavailable to calculate the persons per square mile metric for the least disturbed watershed so we followed the recommendation in Gerritsen and Jessup (2006) and evaluated a percent developed criterion and percent IC as two surrogate measures of human density. We considered candidate Level 1 BCG sites if the percent developed land in the watershed was < 0.50% and the percent IC in the watershed was < 1.5%. Our final screening criteria for potential BCG Level 1 sites was percent developed < 0.50%, percent IC < 1.5% and > 90% natural land cover, and < 5 mg/L chloride.

Cluster analysis (CA) was used to explore macroinvertebrate taxa similarities between sites from each of the 26 least disturbed watersheds. We evaluated only taxa from the orders Ephemeroptera or E taxa (mayflies), Plecoptera or P taxa (stoneflies) and Trichoptera or T taxa (caddisflies). A 24 site by 44 EPT proportional abundance taxa data matrix was used to determine species similarities and establish potential macroinvertebrate site classes using PC ORD Version 5 (MjM Software Design, Gleneden Beach, OR). CA results were displayed as a dendrogram which graphically displays the relationship of sites to each other based on the proportions of taxa present at each site. Sites that span a short distance of the dendrogram (i.e. percent information remaining statistic) have more homogeneous taxa than sites than span a greater distance.

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Indicator species analysis (Dufrene and Legendre, 1997) was used to highlight taxa that were indicative of the macroinvertebrate stream classes defined by CA. Indicator species analysis combines a measure of taxa relative abundance and relative frequency of taxa into an indicator value score ranging from 0% (no indication) -100% (perfect indication). A taxon with perfect indication of 100% would mean that it occurs at all sites in a group and is exclusive to that group (i.e. does not occur in other groups).

We then used box plots to describe environmental variables and land use characteristics between the macroinvertebrate site classes formed from the CA. These box plots highlight some of the variables that may explain the similarities and differences of EPT taxa between macroinvertebrate stream classes. Finally, we used ordination plots from nonmetric multidimensional scaling (NMS) to provide another graphical display of site similarity based on the EPT taxa and overlaid our interpretation of the important environmental gradients of each axis. NMS was performed in PC ORD Version 5 (MjM Software Design, Gleneden Beach, OR). The details and assumptions used for CA, indicator species analysis, and NMS are in **Appendix C**.

Fish

Fish sampling was conducted from June - September 2007 during periods of low streamflow to maximize sampling efficiency. Typically, 150 meters of stream were electrofished using either a back pack unit or a single tow electro fishing unit (Hagstrom et al. 1995). At each location a length-frequency distribution was obtained for all fish collected during a single pass, identifying to species, and measuring total length to nearest centimeter.

The density of wild brook trout (*Salvelinus fontinalis*) has been described as an important factor for streamflow classification in Connecticut (Bellucci et al 2007a). Since wild brook trout are expected components of the fish communities in least disturbed watersheds in Connecticut (Hyatt et al. 1999: Kanno and Vokoun 2008), we can potentially add to the list of watersheds that can be considered for the highest level of protection (i.e. Class 1 Streamflow Classification). We used >1,600 wild brook trout/ha, as recommended in Bellucci et al (2007a), as a threshold for consideration of Class 1 streamflow classification.

An index of biological integrity (IBI) for fish has not been calibrated for use in Connecticut. There are several index candidates (Vermont DEC 2004, Jacobson 1994) each of which is currently being reviewed for accuracy and applicability. The Vermont Cold Water IBI (VT CWIBI) was used for data analysis in this report. Scores are provisional and should not be used for definitive conclusions. Scores for the VT CWIBI are as follows; Excellent cold water fish community = >42, Very Good cold water fish community = 36, Good cold water fish community = 33, Fair cold water fish community = 27, and Poor cold water fish community = < 27. Low scores do not necessarily translate to water quality impairment but could indicate stream temperatures are not appropriate to support a cold water community.

Ecological attributes for each fish species collected for this project are presented in **Appendix D**. Each species is classified by the flowing water requirement necessary to complete its life cycle (Bain and Meixler 2000). Fluvial Specialists (FS) must have flowing water, Fluvial Dependants (FD) must have flowing water during some part of the life cycle, and Macrohabitat Generalists (MG) do not need flowing water.

We duplicated the CA, indicator species analysis, and NMS ordination plots for fish species (n=17) as described above under macroinvertebrates and details of the assumptions used are outlined in **Appendix C**.

Physical/Chemical

Water Chemistry and Temperature

A **s**urface grab sample was collected from mid-depth of mid-channel at least once during spring, summer, and fall. The samples were placed on ice and delivered to the University of Connecticut Center Environmental Science and Engineering lab for analysis. Samples were submitted for general chemistry and nutrient series. Water temperature was measured concurrent with sites visits using a calibrated thermometer.

Results and Discussion

Connecticut's Least Disturbed Watersheds

The final list of least disturbed watersheds in this study contained 30 sites **(Table 3, Figure 3)**. Least disturbed watersheds were concentrated in northwest Connecticut (Barkhamsted, Canaan, Harwinton, Sharon, Torrington, Winchester), northeast Connecticut (Ashford, Chaplin, Eastford, Union), and the central valley (Colchester, East Haddam, East Hampton, Haddam, Lyme). East Haddam had four least disturbed watersheds (**Figure 4**). Ashford, Canaan, and Lyme each contained three least disturbed watersheds. Barkhamsted, East Hampton, and Torrington each contained two least disturbed watersheds. Eleven towns contained one least disturbed watershed.

The percent of protected preserved land in the upstream drainage basin was calculated for the 30 least disturbed sites and ranged from 0-73% (**Table 4**). Protected preserved land included land acquired for permanent protection of natural features in the state to support and sustain natural resource conservation or preservation activities. CTDEP GIS data layers that contained protected open space, municipal preserved/conserved land, and CT DEP property (state forests, parks, and wildlife management areas) were used to estimate the percent of protected preserved land within each basin. The wide range of protected preserved land suggests that there may be opportunities for further preservation in some of these basins at the low end of the percent protected preserved land scale. It is also interesting to note that several watersheds contain preserved water company land. However, a single consolidated geospatial data set of all preserved water company land was unavailable for this analysis. It would be beneficial to assemble a GIS layer with all water company land to include in future analyses. In addition, a finer scale analysis that includes town land records may reveal other opportunities for preservation in these watersheds.

As a part of a *State Initiative for Responsible Growth* issued by Governor M. Jodi Rell under Executive Order 15, CTDEP's Landscape Stewardship program revised the CTDEP Green Plan for guiding land acquisition and protection in CT (State of CT, 2007). This guide was updated "*to better identify sensitive ecological areas and unique features, guide acquisition and preservation efforts, support build-out maps and assessments, and make these and other maps accessible to state agencies, regional planning agencies, local communities and nongovernmental organization through geographic information systems (GIS)"*.

Future goals stated in the Green Plan includes a strategy to "inventory and map significant ecological areas and provide that information as GIS data layers available both internally and to our land protection partners." The basin characteristics for these 30 least disturbed watersheds include many of the desirable qualities for potential land protection projects in the CTDEP Green Plan for guiding land acquisition and protection in Connecticut. Identifying these 30 least disturbed watersheds provides a necessary first step to protecting biologically sensitive areas in the state. Further, decision makers with watersheds in towns identified in this study can use these data to inform local land use planning. The GIS methodology used to identify these sites may be applicable to help identify other ecologically important areas that are consistent with the State's Responsible Growth and Landscape Stewardship Program, as well as local initiatives.

There has been some debate regarding Level 1 BCG Sites in Connecticut and the rest of New England (Snook et al, 2007). One view is that sites that contain "Native structural, functional and taxonomic integrity is preserved; ecosystem function is preserved within the range of natural variability" can not exist based on past land use in Connecticut. Town settlement, farming, forestry, canals, railroads, highways, mining, gristmills, factory mills, and the growth of cities - all have influenced Connecticut's landscape (Bell 1985). The argument would follow that these land use activities are known to have potential long-term effects on lotic biological communities (Harding 1998, Maloney et al., 2008; Wenger et al., 2008) and therefore sites meeting the narrative description of Level 1 BCG sites can not exist.

An alternate view, and one that we support for this analysis, would involve identifying sites that are least disturbed based on Stoddard et al.'s (2007) definition of " the best available physical, chemical, and biological habitat conditions given today's state of the landscape". A previous search for minimally disturbed Level 1 BCG sites as defined by the New England Wadeable Streams (NEWS) Project (Snook et. al, 2007) has not identified sites meeting these criteria in Connecticut. However, these group of sites were selected based on a probabilistic sampling design and not a targeted search for least disturbed sites. We used criteria as described in Gerritsen and Jessup (2007), and found that two least disturbed watersheds in Canaan, Connecticut - Brown Brook (Station ID 2342) and Whiting Brook (Station ID 2310) - met all screening criteria (**Table 5**). We note that these watersheds were further screened to eliminate sites stressors caused by large dams, distance to dams, salmonid fry stocking, and known water withdrawal (e.g. diversions). These 2 site locations and their watersheds can be considered our best candidates for Level 1 BCG sites. Regardless of whether these streams meet Level 1 BCG, they represent "as natural as it gets" conditions based on GIS screening, and this study is an important step to understanding the range of variability of watersheds and their biota that exist in Connecticut. There may be additional candidate sites in Connecticut to investigate and describe (e.g. some of the sites in **Table 2**) and our results suggest that this would be a useful project to pursue.

Streamflow for 2007

Streamflow data and precipitation statistics are presented to provide environmental context for this study. An assessment of streamflows and precipitation during the study year can provide some insight on the potential effect of environmental conditions on the results. This is important to point out since this study was funded for only one year.

According to the National Weather Service, cumulative annual precipitation up to the month of August 2007 approximated the average over the period of record. Lack of precipitation for the remainder of the year resulted in four months (September-December) with relatively low rainfall amounts, which affected streamflows across Connecticut. After the four month dry period, the average rainfall for 2007 was 39.31 inches compared to the long term average of 45.6 recorded at Bradley International Airport, in Windsor Locks, Connecticut.

Streamflows followed precipitation patterns and were well below average during the fall of 2007. Data from USGS stream gages (http://waterdata.usgs.gov/ct/nwis/current/?type=flow) showed near record or record daily low streamflows for most of the gages during the fall benthic index period (September 15 – November 30, 2007). For example, for the period from 9/27/07 to 10/08/07, stream flows were very low and exceeded the 95th percentile for the period of record statewide (**Figures 5a – 5c**).

Macroinvertebrates

Macroinvertebrate Multi-metric Index-MMI

Macroinvertebrate communities were sampled from 24 of the 30 least disturbed sites. Six sites were not sampled due to inadequate flow at the site during the fall benthic sampling index period. MMI total scores ranged from a low of 49.8 to a high of 91.4. All of the samples except the Hall Meadow Brook sample(MMI=49.8) clearly met ALUS standards with scores > 55 points. The low streamflows during the 2007 macroinvertebrate sampling season may have affected the metrics and subsequent MMI scores at Hall Meadow Brook more than the other sites in this study for unknown reasons. MMI scores and individual metric scores are presented in **Table 6** and summary statistics in **Figure 6**.

The MMI score (**Figure 7**) and 6 out of 7 MMI metrics were independent of the narrow range of low IC in this study (**Figure 8**). The Plecoptera genera metric decreased across this IC range.

Traditional RBP 3 metrics

Attributes of the macroinvertebrate community including taxa richness, EPT richness, HBI, density, tolerance, density, % dominant taxa, and dominant taxa are presented in **Table 7**. The range of taxa richness was 23 to 45, EPT richness 9 to 22 and HBI 4.55 to 1.76. Twelve different taxa were dominant in at least 1 of the subsamples (**Table 8 & Figure 9**).

Of the traditional RBP 3 metrics calculated and reported, only EPT richness decreased across the narrow impervious cover gradient. The remaining metrics - Taxa richness, HBI, % dominant taxa, and organism density (numbers/m^2) – were independent across this narrow % IC range (**Figure 10**).

The site with the greatest taxa richness (i.e. 45 taxa) was Pendleton Hill Brook in Stonington; the sites with the highest EPT richness were Kettle Brook in Barkhamsted, and Flat Brook in East Hampton each with 22 taxa; lowest HBI was Flat Brook (East Hampton) with a very low value of 1.76; the site with the highest density was Pendleton Hill Brook (2,856/m^2); and the lowest density was Hall Meadow Brook (62/m^2). In general, the densities of organisms were consistently low except for 3 samples with >2,000 /m^2. These metrics are consistent with ecological theory of low abundance but high species diversity in small streams with a change as watershed size and landscape stressors increase (Vannote et al, 1980). It is also possible that low streamflows may have had a negative effect on macroinvertebrate densities that were collected during the 2007 sampling season. Additional monitoring could better define the range of densities from least disturbed watersheds in Connecticut under varied environmental conditions.

Macroinvertebrate Stream Classes in Least Disturbed Watersheds

One hundred sixty-four unique taxa were identified from the 24 least disturbed sites. The 10 most common taxa from all 24 sites are listed in **Table 9** by % of all individuals (N=4,403) and by % of sites (N= 24). A dendrogram of EPT taxa from 24 least disturbed watersheds showed three groups of sites or stream classes (**Figure 11**). Class 1 contained 8 streams, Class 2 had 9 streams, and Class 3 had 7 streams. Beaver Brook (SID 1236) and Chatfield Hollow Brook (SID 2334) were the sites with most similar EPT taxa in Class 1. EPT taxa lists from Powder Brook (SID 2304) and Muddy Brook (SID2308) were the most similar for Class 2 macroinvertebrate streams. The sites with the most similar EPT taxa in Class 3 were Beaver Meadow Brook (SID 2296) and Early Brook (SID 2307).

Isonychia sp., a collector-gatherer mayfly, was the taxa most indicative of least disturbed macroinvertebrate Class 1 (**Table 10**). *Isonychia* had a highly significant (p=0.0001) indicator value of 96.9% showing that it occurred almost exclusively in Class 1 sites and occurred in all Class 1 sites. *Diplectrona sp*, a collector-filtering caddisfly, was the taxa most indicative of Class 2 sites with an 81.1% indicator value (p=0.0002). It is worth noting that the collection of *Diplectrona sp.* from the least disturbed sites in this study represents 30% of its known occurrence in the CTDEP database. *Acroneuria abnormis*, a predatory Perlid stonefly, was the taxa most indicative of Class 3 with a 54.2% indicator value (p=0.0295).

Macroinvertebrate stream classes were not grouped in any noticeable geographic pattern (**Figure 12**) suggesting that variables other than location were more important in describing EPT distribution among macroinvertebrate stream classes. Macroinvertebrate stream Class 1 sites had warmer water temperatures and larger watersheds (stream order and drainage area), but lower percent impervious cover than Class 2 or Class 3 (**Figure 13**). Class 3 watersheds had a higher percentage of deciduous forest and lower percentage of coniferous forest than Class 1 and 2 (**Figure 14**). The forested component of Class 2 watersheds exhibited a similar pattern to Class 1 streams (high percent deciduous, low percent coniferous), although the range of values in both forest types was greater than Class 1 watersheds. The percent forest type of Class 3 watersheds varied the most of any macroinvertebrate stream class. The dominant forest type may have an important role in the type and quality of allochthanous materials in least disturbed watersheds and may therefore be important in food chain dynamics for EPT taxa and perhaps other macroinvertebrate species in these systems.

The NMS ordination plots using EPT taxa formed clusters that were similar to the grouping of macroinvertebrate classes from CA (**Figure 15**). Combining the least disturbed site clusters formed from NMS with the variables highlighted in the box plots suggest that water temperature, watershed size (drainage area, stream order), and dominant forest type may have an important role in determining EPT taxa composition in least disturbed watersheds in Connecticut. It is important to note that the least disturbed sites studied represent a narrow range of the human disturbance gradient (e.g. <4% IC, little development, high percentage of forest), and therefore the results for some of these variables (e.g. percent impervious cover) may be within measurement error. Nevertheless, these environmental and landscape variables show trends worthy of further inquiry and it would be interesting to assess these same variables from watersheds that represent the entire range of the human disturbance gradient.

Fish

A technical recommendation to advance the use of Tiered Aquatic Life Use development in Connecticut (Gerritsen and Jessup, 2007) was to develop biological condition gradient (BCG) for a second biological assemblage. The CTDEP has been collecting fish data to assist with aquatic life assessments for a number of years. Data from this study will provide insight to fish community species composition from least disturbed sites to assist with the calibration of fish community reference sites and potential BCG development in Connecticut.

Fish Species Occurrence

Fish communities were sampled from each of the 30 least disturbed watersheds. 3,955 individuals representing 25 resident and 4 stocked species were collected. Adult stocked brook trout were collected in Knowlton Brook in Ashford. Adult stocked brown trout were collected in Hall Meadow Brook in Torrington and Day Pond Brook in Colchester. Adult stocked rainbow trout (*Oncorynchus mykiss*) were collected in Carse Brook in Sharon. Despite our efforts to eliminate fry stocked Atlantic salmon from our pool of study sites, we collected Atlantic salmon fry from two streams in the Salmon River Basin – Day Pond Brook and Flat Brook; and Burnhams Brook in the Eightmile River Basin.

The ten most common fish species are listed in **Table 11** by percent of all individuals (N=3,955) and by percent of sites (N= 30). Ninety percent of the least disturbed sites (27/30) sampled for this study contained wild brook trout. Brook trout were absent from Beaver Brook in Lyme, Carse Brook in Sharon, and Chatfield Hollow Brook in Madison. Wild brook trout densities ranged from 29 per hectare to 4,902 per hectare (mean 630, s.d. 1003.53). Three sites, Gardner Book in Ashford, Mott Hill Brook in Glastonbury, and Whiting Brook in Canaan had wild brook trout densities above the 1,600 per hectare threshold and could be considered for Class 1 streamflow classification.

Several other notable fish species were collected from least disturbed streams. Burbot (*Lota lota*) is listed as an endangered species in Connecticut (State of CT, 2004) and was collected at one location. A species listed as endangered is any native species documented by biological research and inventory to be in danger or extirpiration throughout all or a significant portion of the state and have no more than five occurrences in the state. Slimy sculpin (*Cottus cognatus*) was collected from Mott Hill Brook (Glastonbury) and is known to exist only in cold, high water quality streams in Connecticut.

The total fish density (individuals per 100 m^2) was independent of the narrow low IC range (**Figure 16**). The site with the highest fish density was Bebbington Brook in Ashford as a result of abundant black nose dace (*Rhinichthys atratulus*). The site with the lowest fish density was Hall Meadow Brook in Torrington. The low fish density coupled with the low macroinvertebrate density and marginal MMI scores is inconsistent with expected conditions from least disturbed sites. Hall Meadow Brook would be a good candidate site for future SID work. The proportion of native to exotic species did not exhibit any noticeable pattern across the narrow % IC range (**Figure 17**). Fish species from least disturbed watersheds were primarily fluvial specialist and fluvial dependants **(Figure 18)**. Both the number of macrohabitat generalist taxa and % of the individuals were minor portions of the samples at most sites

Fish Community Cold Water IBI (provisional)

Fish community CWIBI scores ranged from a low of 12 at four sites (Beaver Brook, Bebbington Brook, Carse Brook, and Stonehouse Brook) to a high of 45 at Mott Hill Brook. (**Table 12**). CWIBI scores appeared to be independent of the narrow low IC range (**Figure 19**). Cold water fish communities were nearly evenly split between good to excellent and poor. This is probably attributed to different temperature regimes and not water quality issues. Specifically 4 sites were Excellent, 4 Very Good, 3 Good, 3 Ambiguous, 3 Fair and 13 Poor (**Figure 20**). The highest scoring sample was from Mott Hill Brook in Glastonbury (45 points). The lowest scoring samples were from Beaver Brook in Lyme, Bebbington Brook in Ashford, Carse Brook in Sharon, and Stonehouse Brook in Chaplin (12 points each). All of the 4 lowest scoring sites appear to be closer to warm water conditions than cold water conditions.

Fish Stream Classes in Least Disturbed Watersheds

A dendrogram of fish taxa from the 30 least disturbed watersheds showed three groups of sites or stream classes (**Figure 21**). Class 1 contained 12 streams, Class 2 had 7 streams, and Class 3 had 11 streams. In general, fish class 1 sites had fewer species per site than the other 2 classes. Although not abundant (**Figure 18**), it is interesting to note that each of the three fish stream classes had macrohabitat generalist indicator species (**Table 13**). This result was unexpected from the least disturbed study watersheds. It may be that the influence of dams is so widespread in Connecticut that their influence on fish communities cannot be eliminated. This is a subject that could be investigated further through a study designed to evaluate dam impacts on fish communities.

Five sites in Class 1 were most similar- Kettle Brook (SID 2301), Whiting Brook (SID 2310), Elbow Brook (SID 2305), Early Brook (SID 2307), and Jakes Brook (SID 2312) all contained wild brook trout and blacknose dace. Wild brook trout and golden shiner (*Notemigonus crysoleucas*) were two fish species indicative of Class 1 streams (**Table 13**). Wild brook trout occurred in all Fish Class 1 streams (indicator value of 53.7%, p=0.0026), but was also ubiquitous in Class 2 and Class 3 streams. Golden shiner occurred exclusively in three Class 1 fish streams and had an indicator value of 41.7% (p=0.0145). On the contrary, Class 2 fish streams had a higher species diversity than any of the three fish classes. Seven species were significant indicators (p<0.05) of Class 2 fish streams. Chain pickerel (*Esox niger*) and tessellated darter (*Etheostoma olmstedi*) both had indicator values of 71% and occurred exclusively in Class 2 streams. Other fish class 2 streams were fallfish (*Semotilus corporalis*), bluegill (*Lepomis macrochirus*), common shiner (*Luxilus cornutus*) and white sucker (*Catostomus commersoni*).

The sites with the most similar fish species in Class 3 were Day Pond Brook (SID 2304) and Brown Brook (SID 2342). Species diversity from Class 3 fish site generally fell between Class 1 and Class 2. The only significant indicator species was creek chub (*Semotilus atromaculatus*), which had an indicator species value of 36.4% (p=0.0372).

Fish species stream classes were not grouped in any noticeable geographic pattern (**Figure 22**) suggesting that variables other than location were more important in describing fish species distribution among least disturbed watersheds. Fish Class 2 streams had warmer water temperatures and larger watersheds (stream order and drainage area) than fish Class 1 or fish class 3 (**Figure 23**). The IC increased slightly from fish class 1 to fish class 2 to fish class3. Fish class 2 and fish class 3 watersheds were mostly comprised of deciduous forest while fish class 1 were more variable (**Figure 24)**. These same variables that showed differences with the macroinvertebrate analysis- water temperature, watershed size (drainage area, stream order), and dominant forest type – also were important in defining stream fish classes.

The NMS ordination plots using fish species formed groupings that were similar to the clusters of fish stream classes from CA (**Figure 25**). The NMS plot highlighted the important indicator species by plotting species within clusters of sites for each of the three fish classes. For example, wild brook trout (WBK) and golden shiner (GS), two of the significant indicator species in Class 1 showed an affinity to be grouped with Class 1 sites in the ordination plot. Similarly, creek chub (CR) plotted with an affinity towards Class 3 sites. Class 2 sites were the most speciose, with the same species highlighted by indicators species analysis (e.g. chain pickerel (CP), fallfish (FF), tessellated darter (TD), largemouth bass (LM), bluegill (BG), common shiner (CS), and white sucker (WS)) plotting near the Class 2 cluster. The important environmental gradients for least disturbed sites fish sites were similar to those noted in the classification of least disturbed sites by EPT taxa. However, like the caveat mentioned with the EPT taxa, the narrow range of sites in this study (i.e. only least disturbed sites) must be interpreted with caution. But like the EPT analysis, the environmental variables depicted graphically in box plots and highlighted with the NMS ordination plots for fish classes show trends worthy of further inquiry. This is especially true since the same few variables –water temperature, watershed size, and dominant forest type- were highlighted in both using EPT macroinvertebrate taxa and fish species.

Chemical/Physical

Grab Chemistry

Grab chemistry samples were collected at least once per season at all sites except Pendleton Hill Brook which was sampled weekly (**Table 14**).

Non-Nutrients: Summary statistics by chemical parameter are presented in **Table 15** and in box plots in **Figure 26**, and scatter plots in **Figure 27**. Alkalinity (**Figure 28**), hardness (**Figure 29**) and total solids (**Figure 30**) values varied greatly across sites.

Chloride, a good indicator of human disturbance, had a narrow range with the exception of the Branch Brook site in Eastford (**Figure 31**). The highest chloride value of 70 ppm at Branch Brook in September 2007 was collected during very low streamflow conditions when the stream was probably 100% groundwater. Land use activities in the vicinity of the sampling location may have contributed to high levels of chloride to the groundwater. The source of chloride at this location should be investigated further.

Brown Brook, Flat Brook and Whiting Brook (all three located in Canaan, CT) all had the highest and most varied alkalinities and hardness values (**Figures 28-29**) resulting from calcareous surficial geology.

Nutrients:

Management of anthropogenic sources of nitrogen and phosphorus are of great interest in Connecticut. Connecticut's TMDL for nitrogen in Long Island Sound represents a major effort to reduce nitrogen loads in order to achieve dissolved oxygen standards in Long Island Sound. CT DEP is also in the process of developing state-wide freshwater phosphorus criteria. Data from least disturbed sites is being used to estimate the export of phosphorus from areas with minimal human influence. Estimating the export of phosphorus from least disturbed sites will help to provide goals for minimally disturbed watersheds in Connecticut and can be used as a benchmark so that the export of phosphorus does not increase in those basins.

Summary statistics for nitrogen and phosphorus are presented in **Table 16** and in box plots in **Figure 32.** All nitrogen values are below 1.0 mg/l and most TP values were below 0.04 mg/l. Nitrogen series data follow expected patterns with ammonia values at or near detection limits in most every sample. Total nitrogen and its larger constituents varied by 0.5 ppm across 2007. All of the nitrogen series were independent across this narrow range of IC (**Figure 33**).

Summary statistics by station show Bebbington Brook, Cedar Pond Brook, and Stickney Hill Brook had the highest median total nitrogen values while Day Pond Brook, Muddy Brook, and Roaring Brook had the lowest (**Figure 34**). Bebbington Brook also had the highest and greatest range of total phosphorous data while almost all other sites had very low value and narrow range. Phosphorous series data were independent across this narrow range of IC (**Figure 35**).

Water temperatures were generally < 20 degrees C during site visits May-September, 2007 (**Table 17**). Water temperature values were independent of IC across this narrow range (**Figure 36**).

Project Summary

This study provides an important step to understanding the watershed characteristics and biota from least disturbed watersheds in Connecticut. Least disturbed watersheds were concentrated in three geographic clusters -northwest Connecticut, northeast Connecticut and the central valley. Four least disturbed watersheds were located in East Haddam. Ashford, Canaan, and Lyme each contained three least disturbed watersheds. Barkhamsted, East Hampton, and Torrington each contained two least disturbed watersheds. Eleven towns contained one least disturbed watershed.

This study expands on earlier work conducted by DEP (Bellucci 2007, Bellucci et al. 2008) by exploring streams that fall into the “best” stream class and “preservation” management class of our conceptual model (**Figure 1**). Most streams that were sampled for the least disturbed watershed project had MMI scores within the range of expected values (**Figure 37**), which increases our confidence in our conceptual model. The one exception, Hall Meadow Brook in Torrington, requires further investigation to determine the potential causes of low MMI scores and poor fish community.

This work also provides a framework for approximating biological conditions with land use change. For example, current conditions can be mapped (**Figure 38**), and any land use change that would increase the impervious cover in watershed could degrade the macroinvertebrate community (as measured by MMI) in predictable pattern absent sufficient pollution controls. The linear equation to estimate MMI score from this relationship of 180 sampling sites (**Figure 37**) in Connecticut is MMI = 74.87 - 3.135 Percent IC upstream of site (R^2 = 52.8%). As a general guideline, a 2% increase in IC results in a 6 point decrease in MMI value. This relationship between a stressor variable such as percent impervious cover and MMI scores continues to be of interest to DEP and more work is planned to explore additional stressor relationships that may explain more of the variance in MMI scores.

Finally, it is important to note that although we tried to identify catchments that had negligible anthropogenic effects on water quality, there still may have been human factors that influenced the biota in some of our study streams. This is in part due to scale of our analysis and the fixed nature of GIS data captured at the set time intervals. For example, we used state-wide data layers at 30 meter resolution that effectively capture the overall differences in watersheds at this scale, but may misinterpret some watershed factors on a finer scale. Further, the data used in these analyses represent a snapshot of the available information at the time of analysis and may not always reflect the most current conditions. For example, the most current land cover data at the time of analysis was a 2002 land cover dataset at a 30-meter resolution, although we sampled the least disturbed watershed in 2007.

Our results may also reflect our incomplete knowledge of how certain factors affect fish and macroinvertebrate species. For example, although we excluded watersheds with large dams and sampled at least one mile downstream of small dams, macrohabitat generalist fish species were unexpectedly found to be indicator species in all three fish stream classes (**Table 13**). This may reflect an unavoidable influence of past land use such as mill dams on aquatic biology in Connecticut. An interesting follow-up study would be to evaluate the effect of dams on changes in macroinvertebrate and fish species composition, particularly because dams are so ubiquitous in Connecticut streams and it is difficult to eliminate their potential effect in any drainage basin.

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Figures and Tables

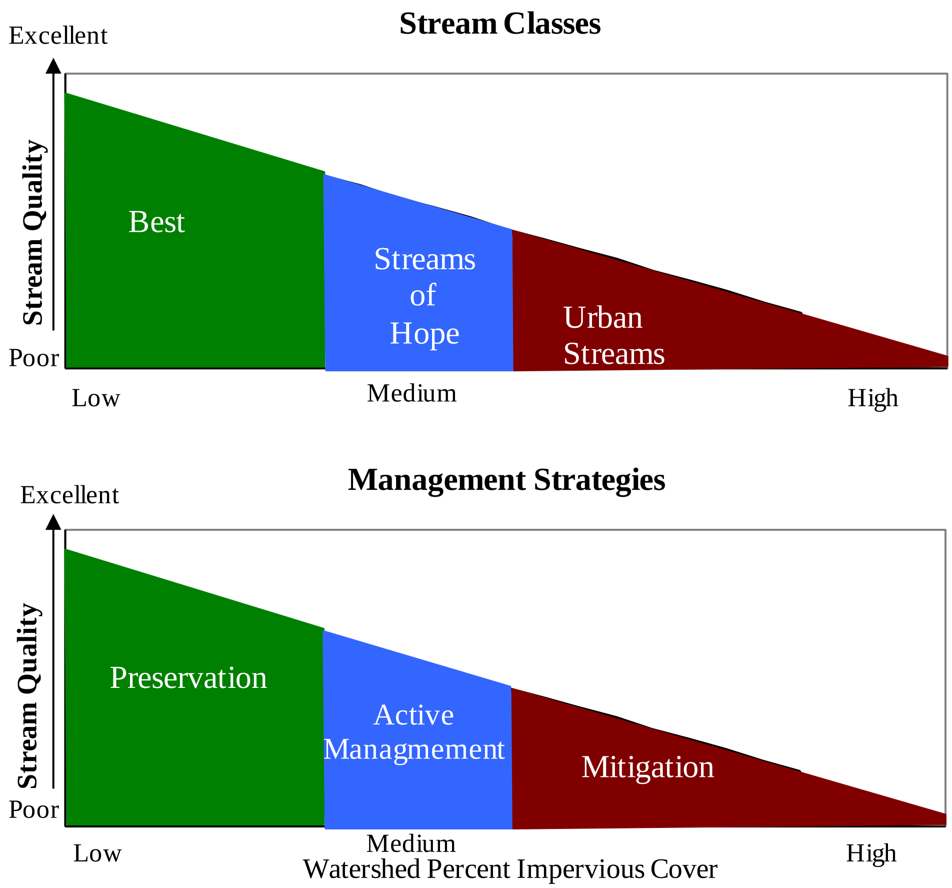


Figure 1. Conceptual model of the effect of impervious cover on stream quality. Watershed percent impervious cover is used to identify stream classes (top) and potential management strategies (bottom).

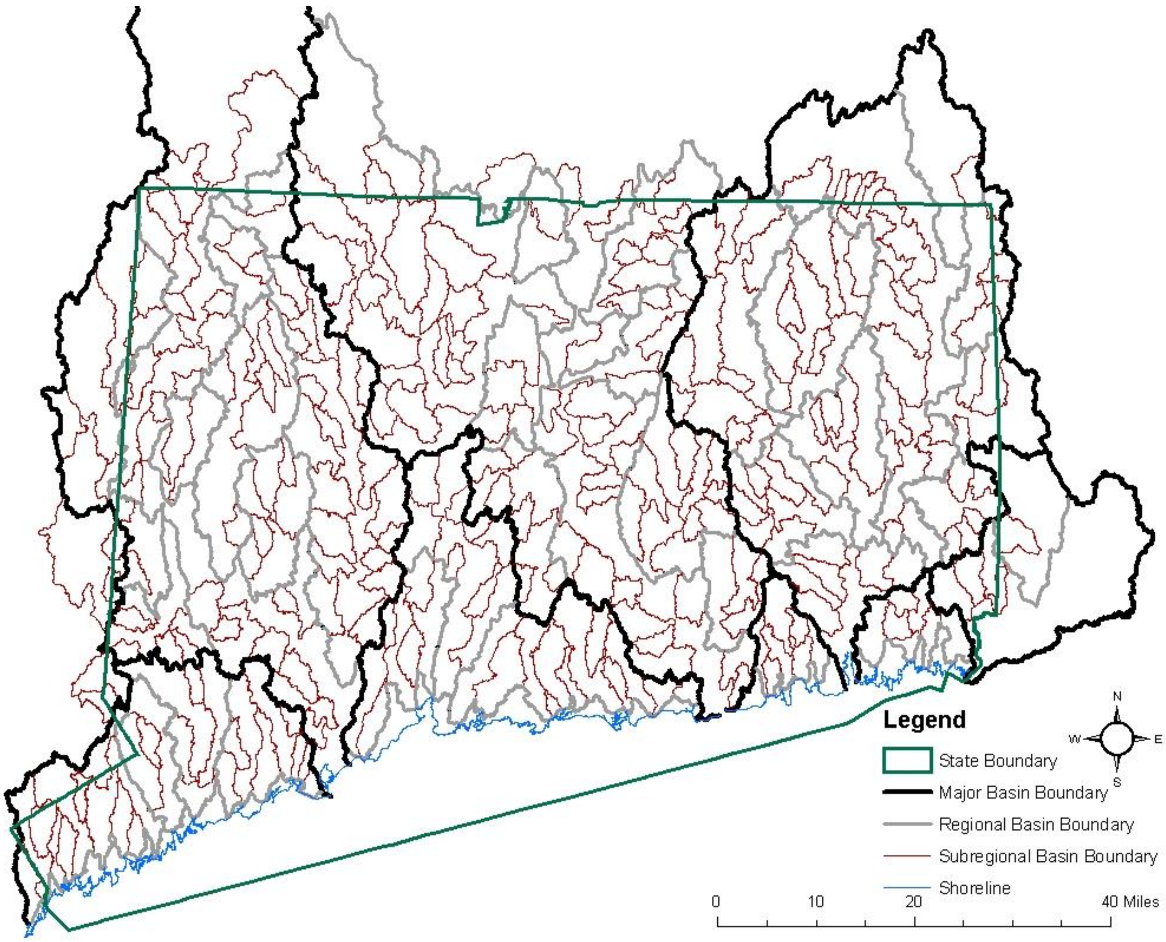


Figure 2. Subregional basins in Connecticut.

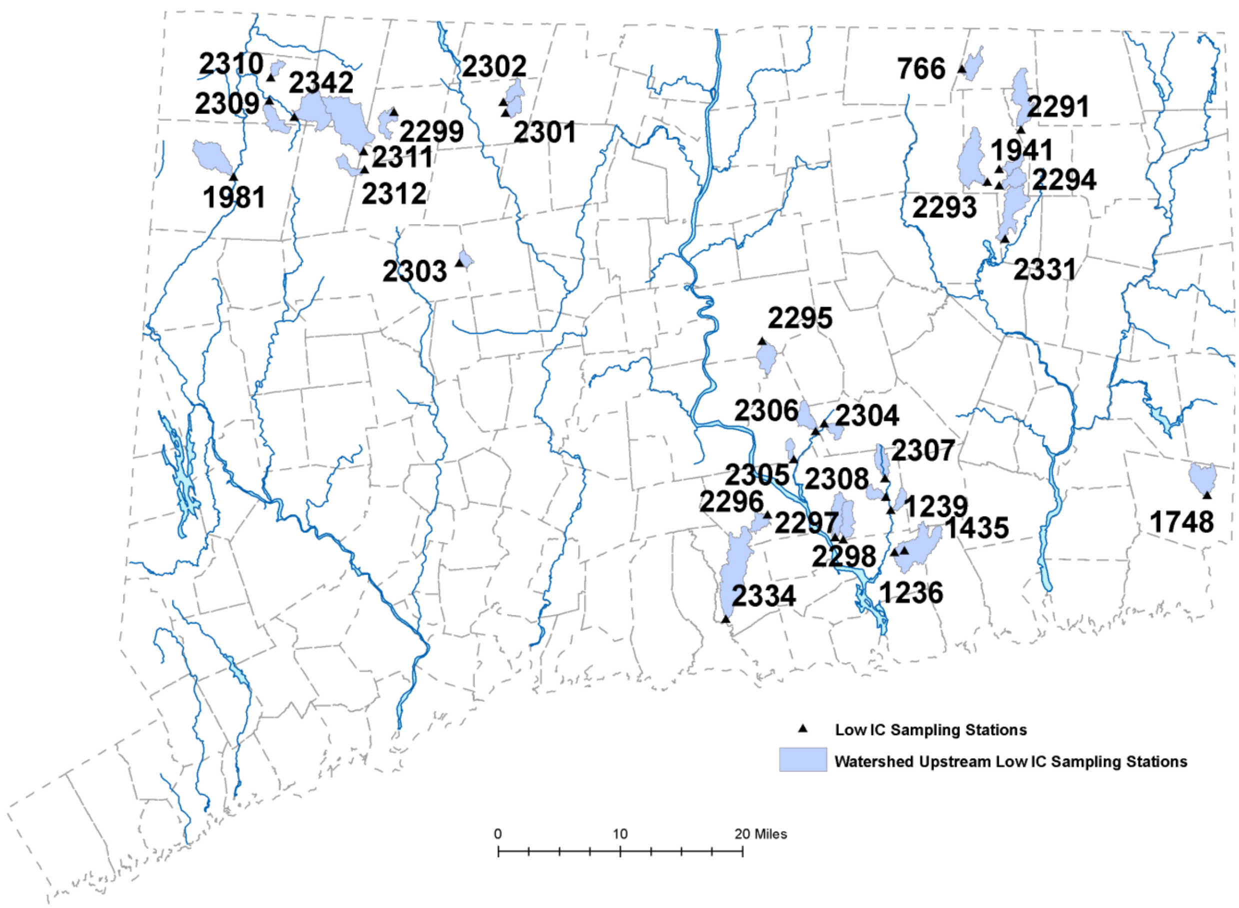


Figure 3. Location of the 30 study watersheds selected for data collection as part of the least disturbed watershed project.

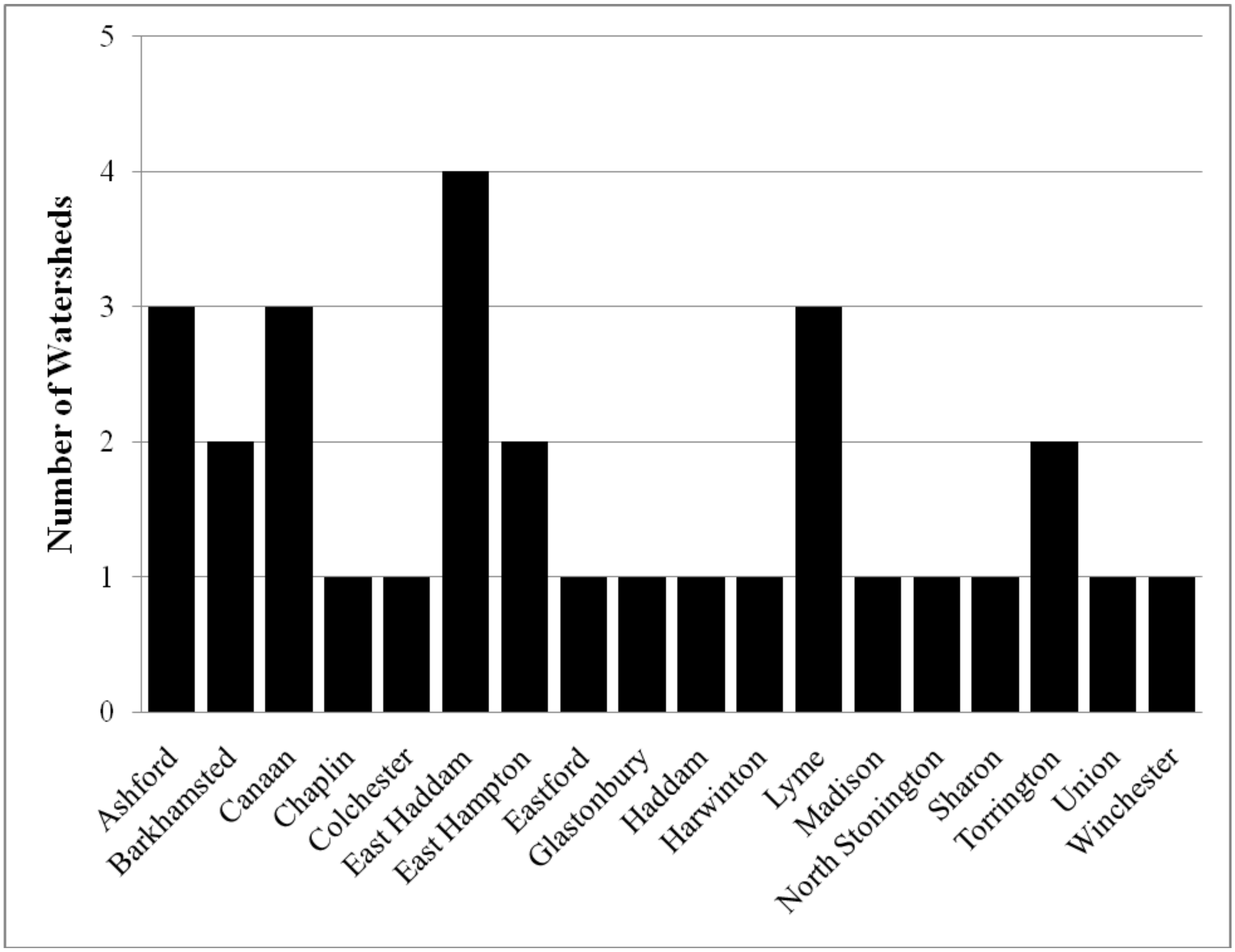
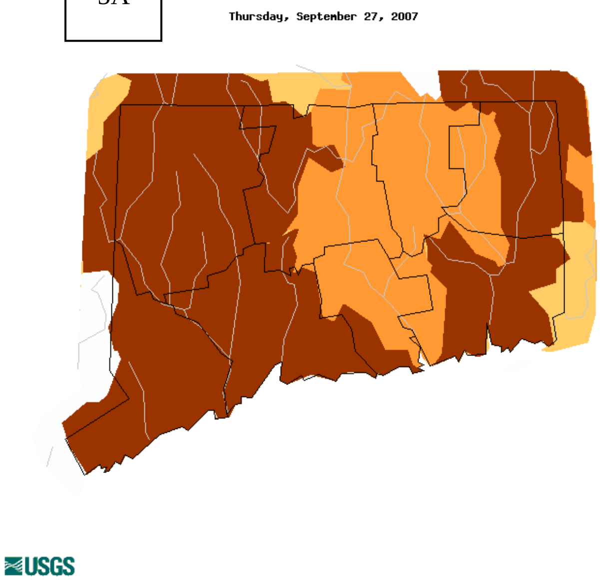


Figure 4. Location of the 30 least disturbed watersheds in this study listed alphabetically by town.

5A



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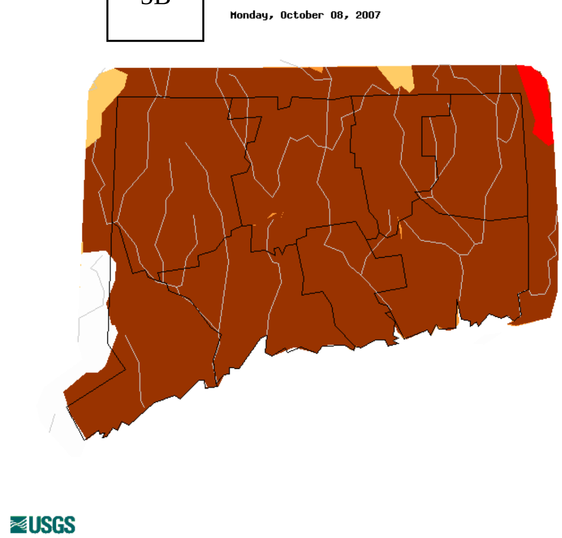

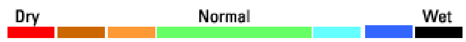

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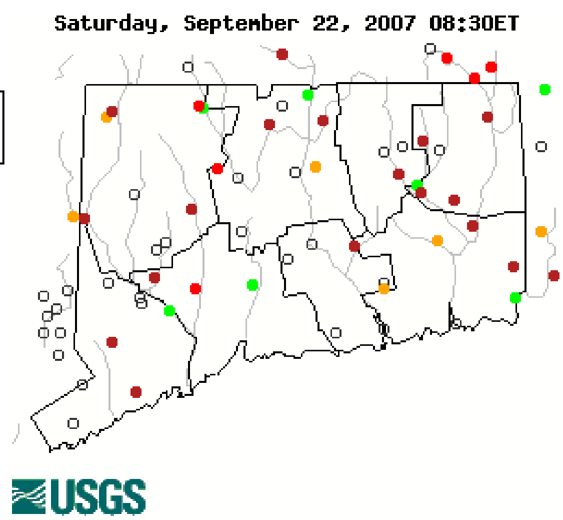
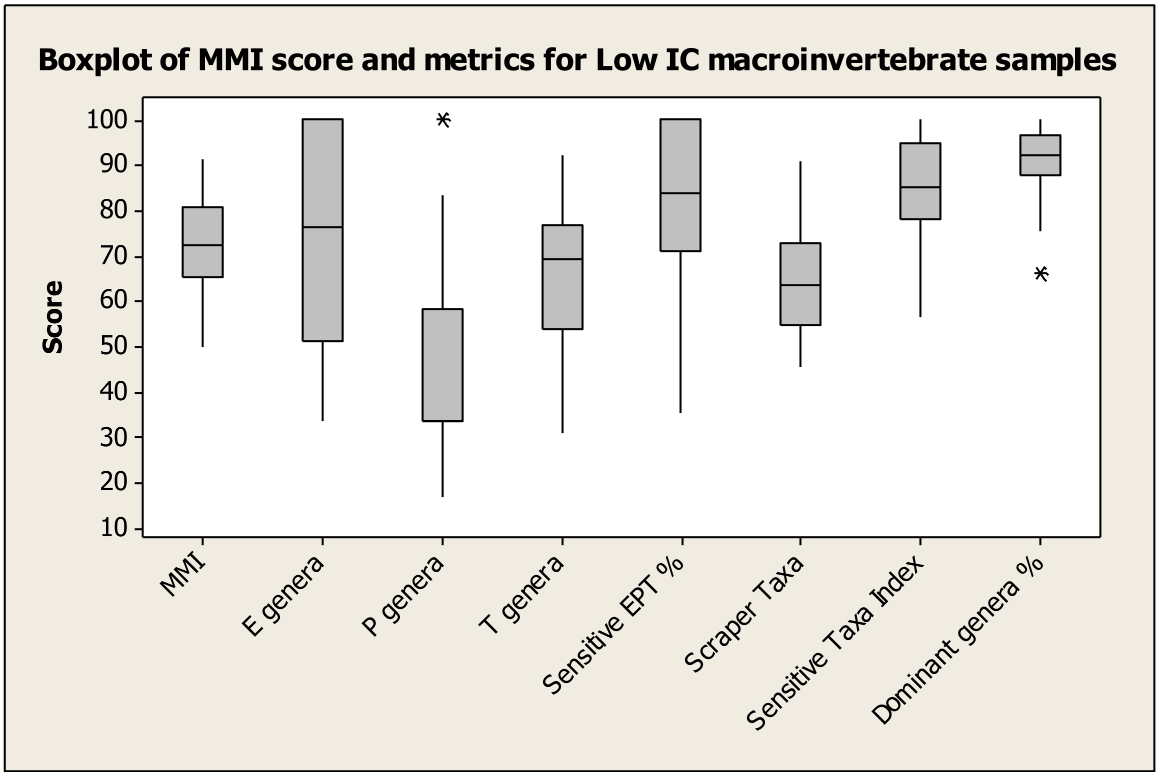


Figures 5a, 5b and 5c. Stream flow conditions across the period of record for USGS stream gaging stations. The dark brown represents flows greater than the dry streamflow conditions where 95% of the time flows were greater than what was currently observed. Figures from USGS website http://waterdata.usgs.gov/ct/nwis/current/?type=flow



Variable	Mean	Min	25th	Median	75th	Max	Range
MMI	72	50	65	73	81	91	42
E genera	75	34	51	76	100	100	67
P genera	45	17	33	33	58	100	83
T genera	64	31	54	69	77	92	62
%Sensitive EPT	82	35	71	84	100	100	65
Scraper Taxa	65	45	55	64	73	91	45
Sensitive Taxa Index	85	57	78	85	95	100	43
% Dominant genera	91	66	88	92	97	100	34

Figure 6. MMI value and MMI metric scores for each of the 25 macroinvertebrate samples collected during fall 2007 in support of the least disturbed watershed project. Macroinvertebrate samples were not collected at Stickney Hill Brook, Branch Brook, Bebbington Brook, Powder Brook, Whiting Brook, and Roaring Brook due to inadequate flow.

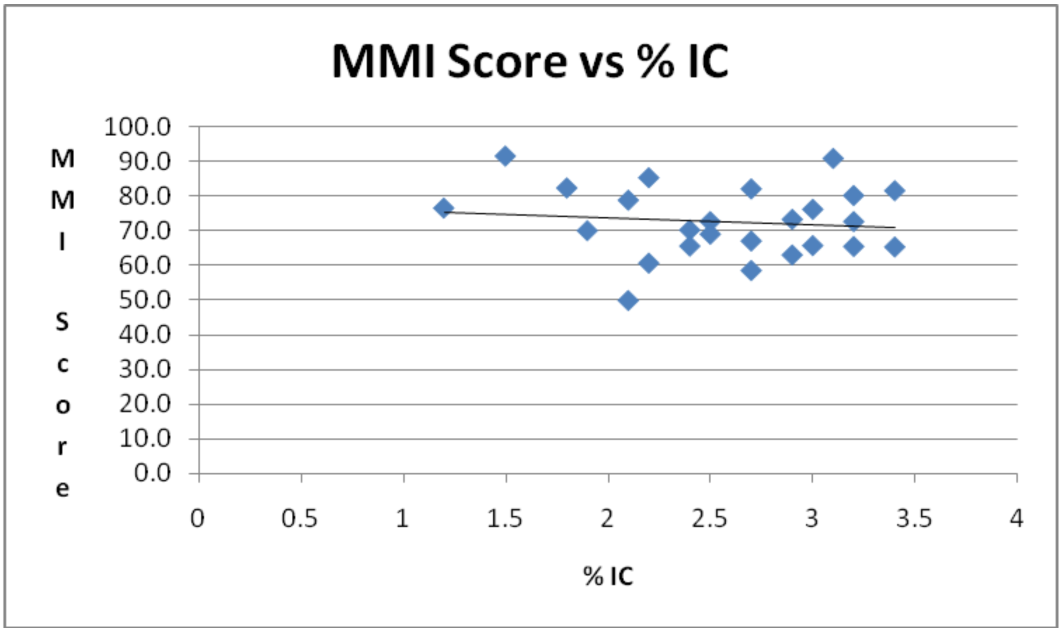
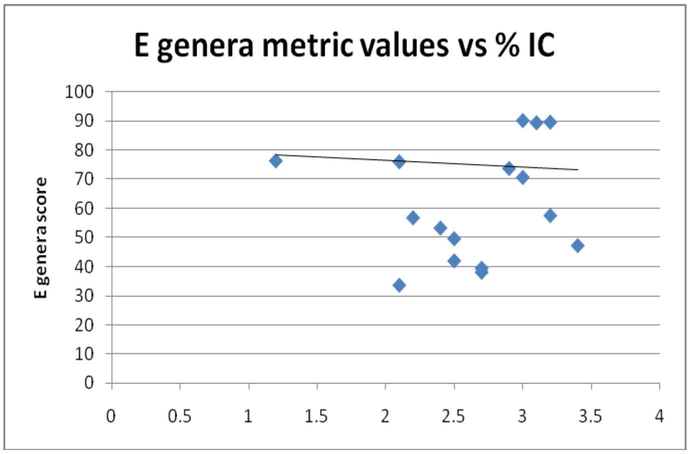
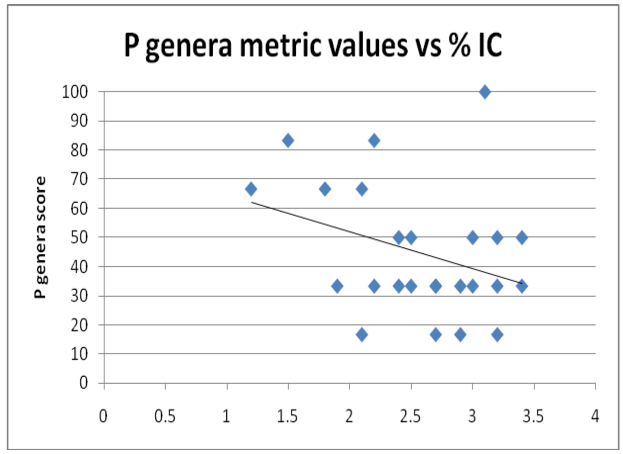
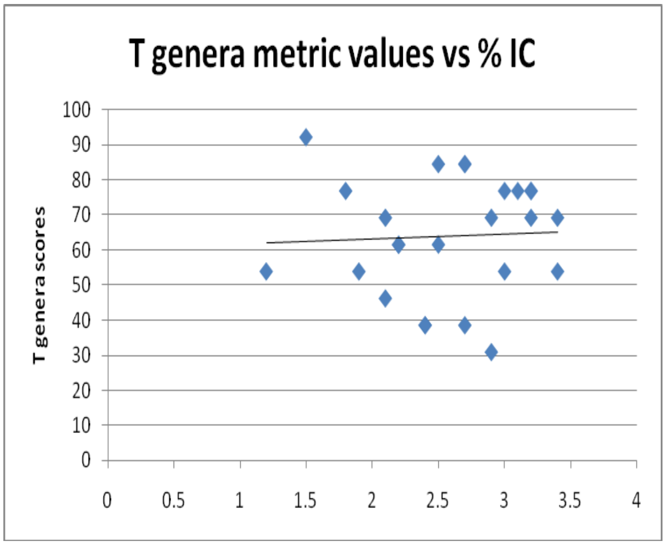
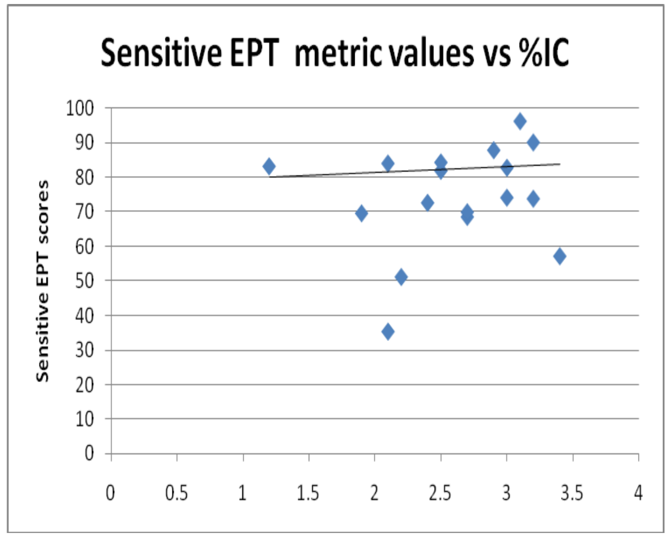


Figure 7. MMI total score versus % impervious cover upstream of sample locations for the least disturbed watershed project. Macroinvertebrate samples were not collected at Stickney Hill Brook, Branch Brook, Bebbington Brook, Powder Brook, Whiting Brook, and Roaring Brook due to inadequate flow.









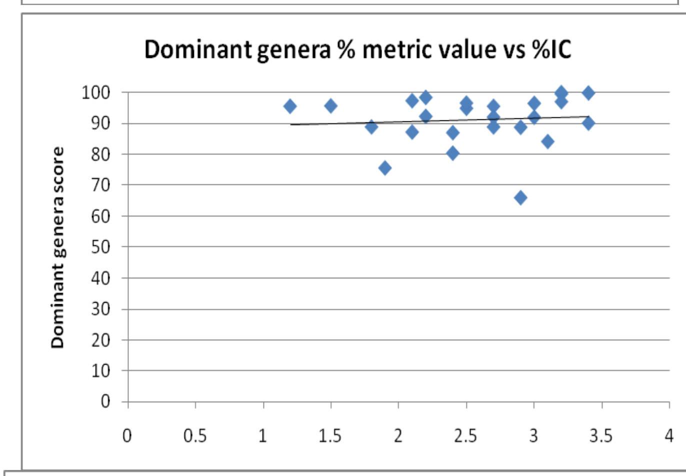
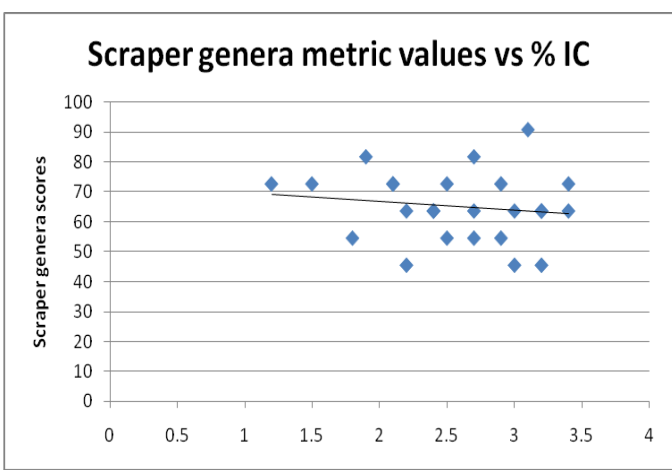
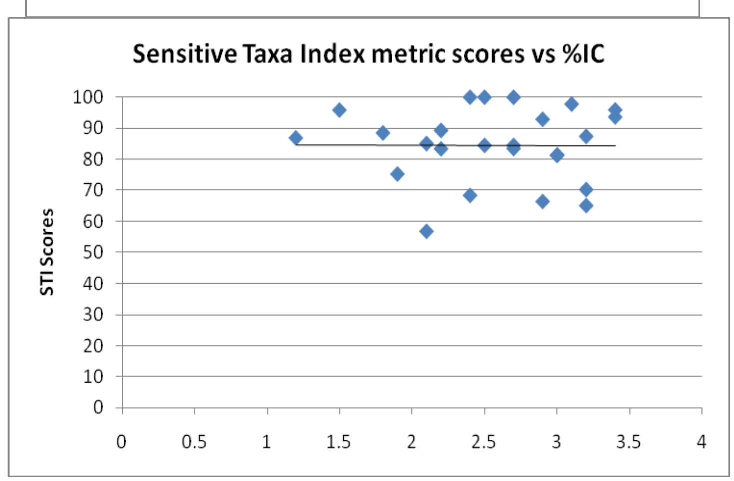


Figure 8. Scatter plots of the 7 individual metric scores that make-up the MMI versus % impervious cover upstream of sample location for the least disturbed watershed project.





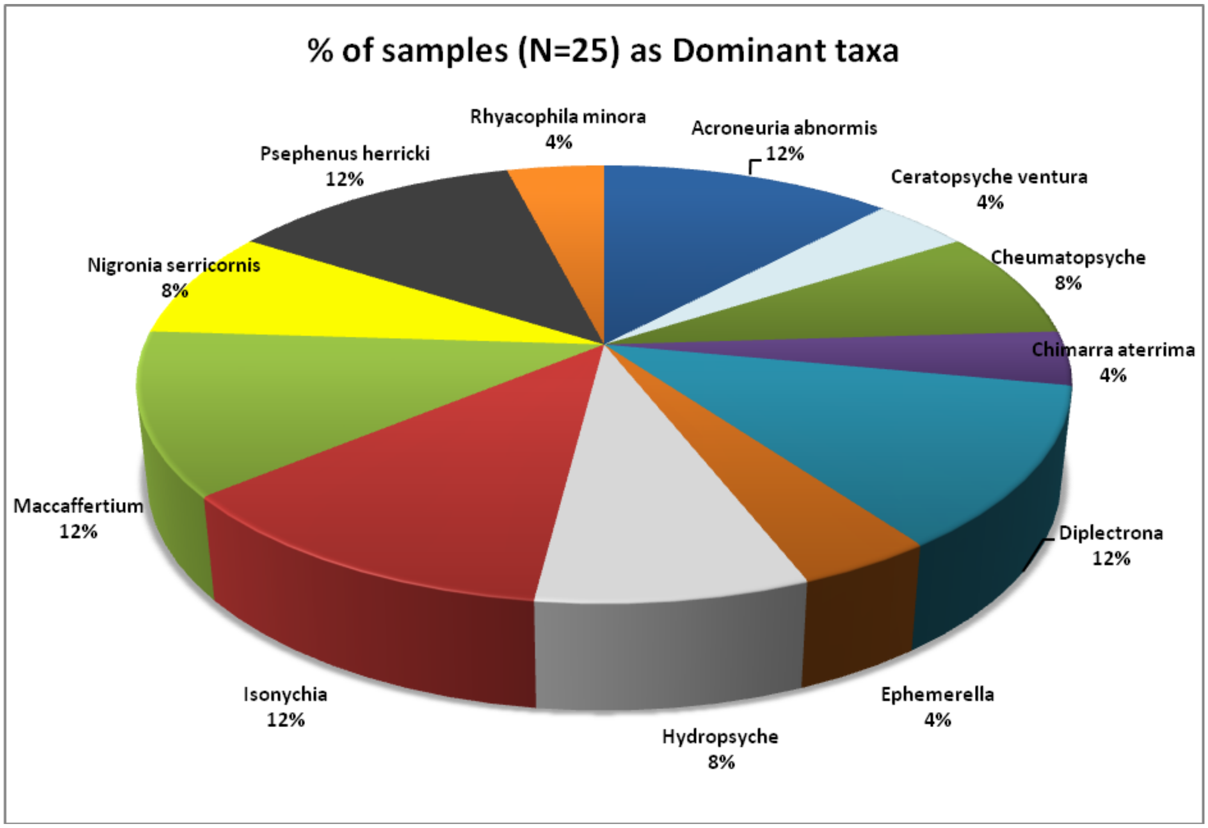


Figure 9. Dominant taxa from sites sampled for the least disturbed watershed project. Macroinvertebrate samples were not collected at Stickney Hill Brook, Branch Brook, Bebbington Brook, Powder Brook, Whiting Brook, and Roaring Brook due to inadequate flow.

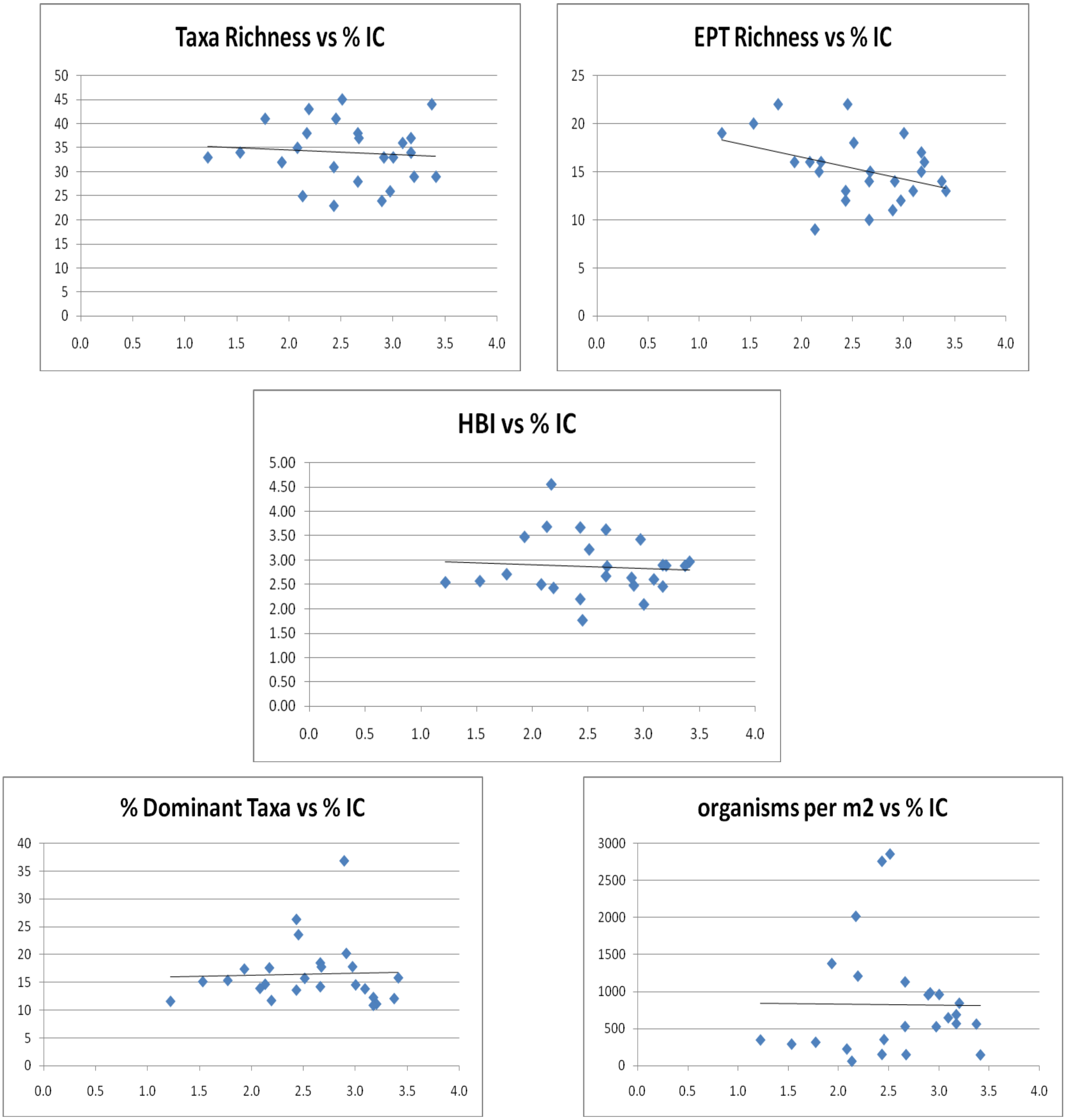


Figure 10. Select traditional RBP 3 metrics versus % IC for data collected to support the least disturbed watershed project. Macroinvertebrate samples were not collected at Stickney Hill Brook, Branch Brook, Bebbington Brook, Powder Brook, Whiting Brook, and Roaring Brook due to inadequate flow.

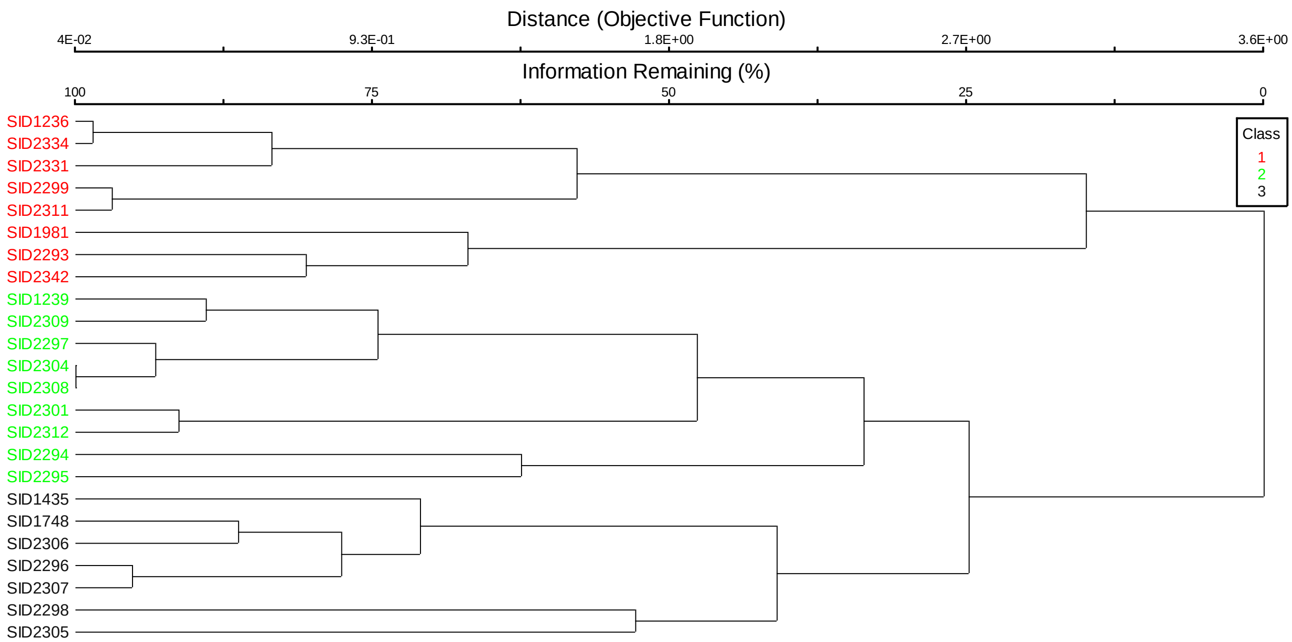


Figure 11. Dendrogram forming three macroinvertebrate stream classes- class 1 (red sites), class 2 (green sites), and class 3 (black sites). Refer to Table 3 for more information on Station IDs (e. g. SID 1236 is Beaver Brook).

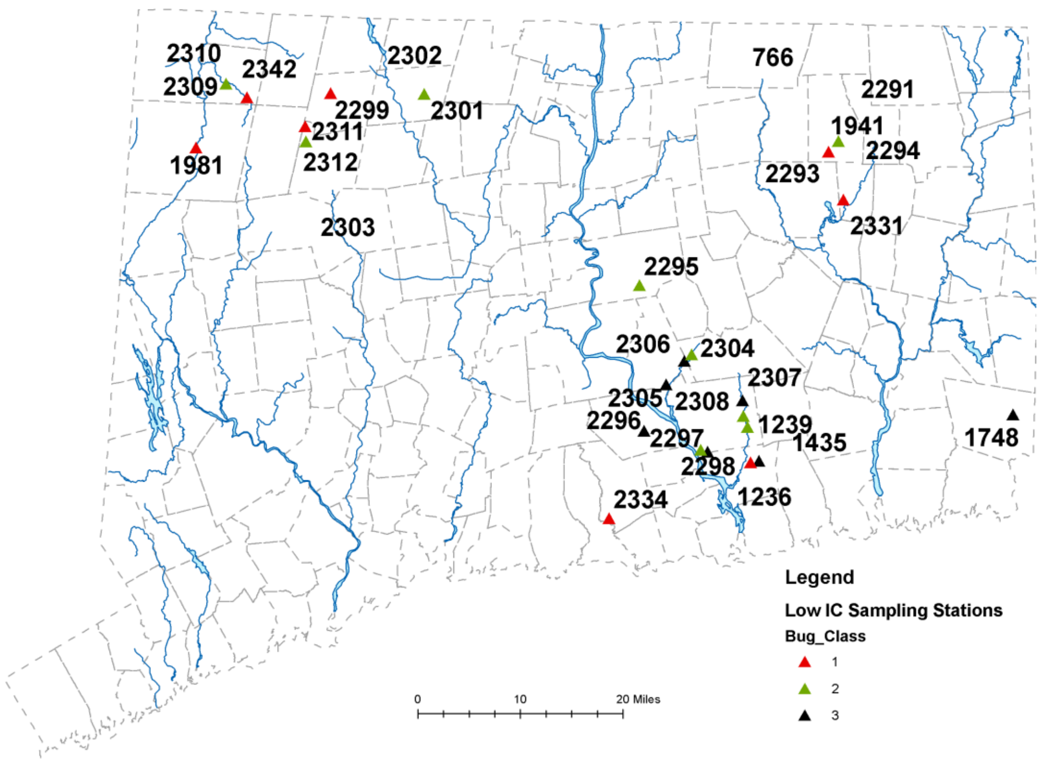


Figure 12. Map of macroinvertebrate stream classes (1-red, 2-green, 3=black) defined using cluster analysis. Refer to Table 3 for more information on Station IDs (e. g. SID 1236 is Beaver Brook).

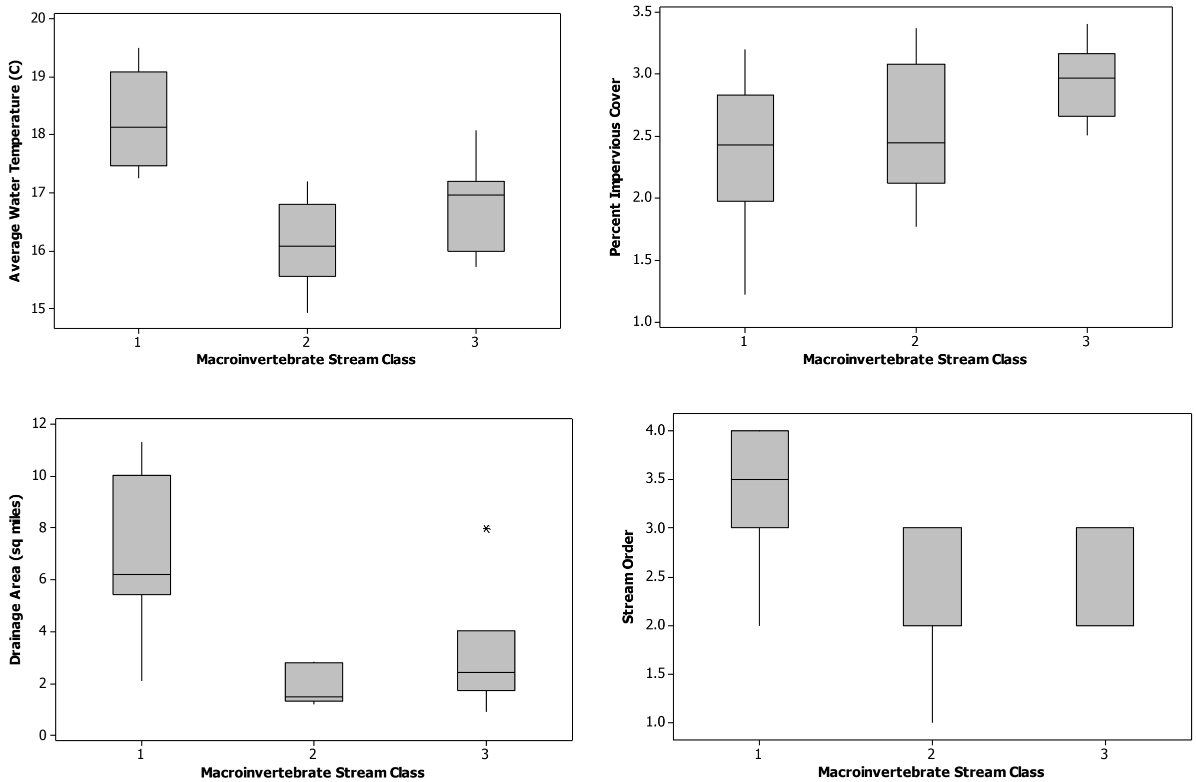


Figure 13. Average water temperature, percent impervious cover drainage area, and stream order for least disturbed watersheds containing three macroinvertebrate stream classes defined using cluster analysis.

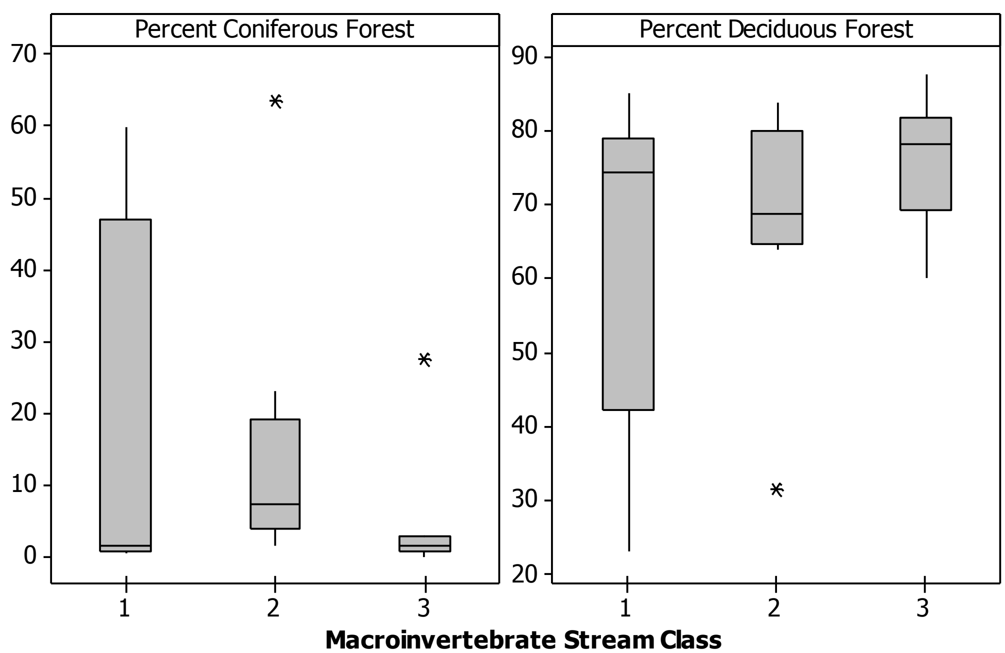


Figure 14. Percent deciduous and coniferous forest for least disturbed watershed containing three macroinvertebrate stream classes defined using cluster analysis.

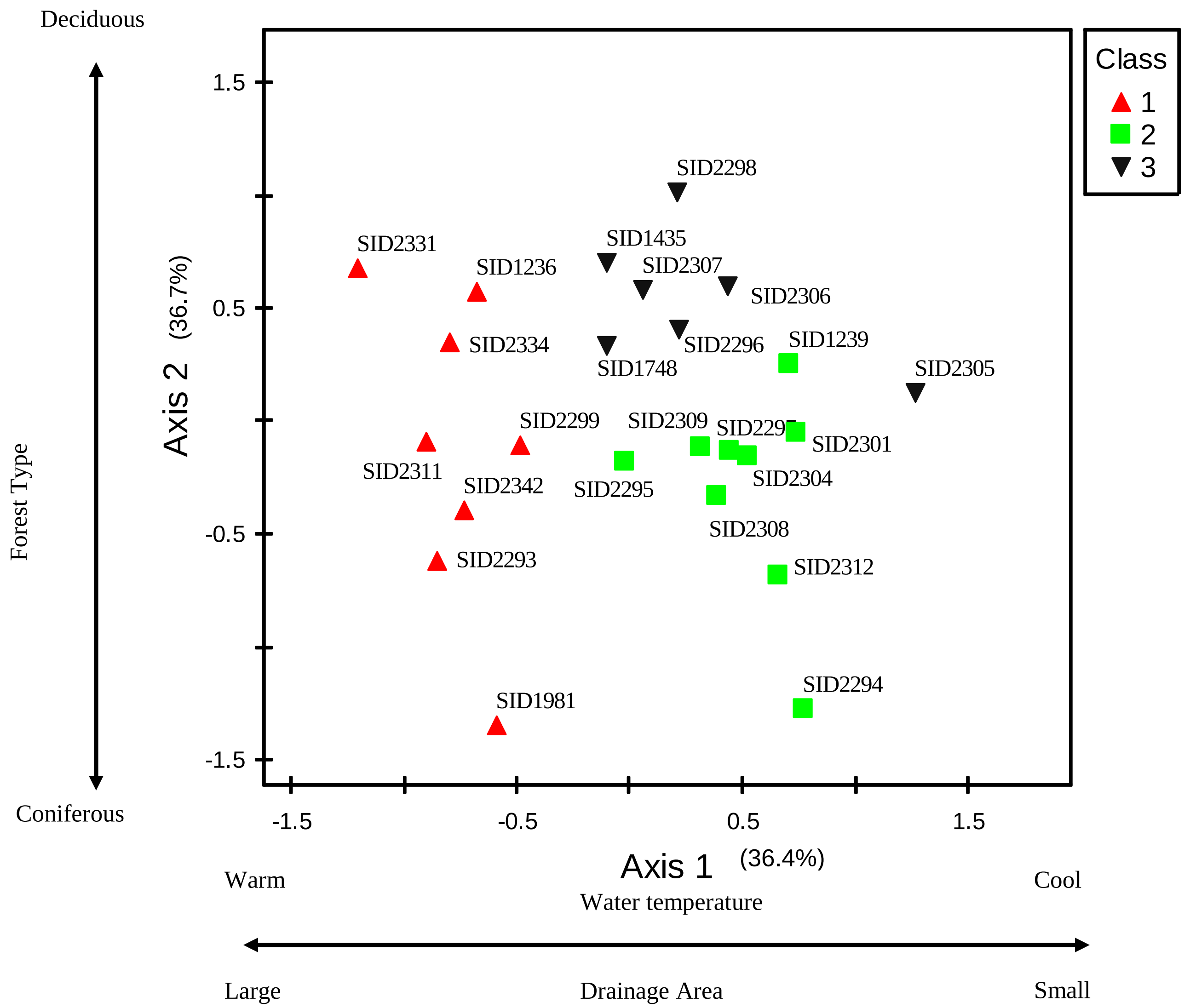


Figure 15. Nonmetric multidimensional scaling ordination of EPT taxa from 24 stations. Refer to Table 3 for more information on Station IDs (e. g. SID 1236 is Beaver Brook).

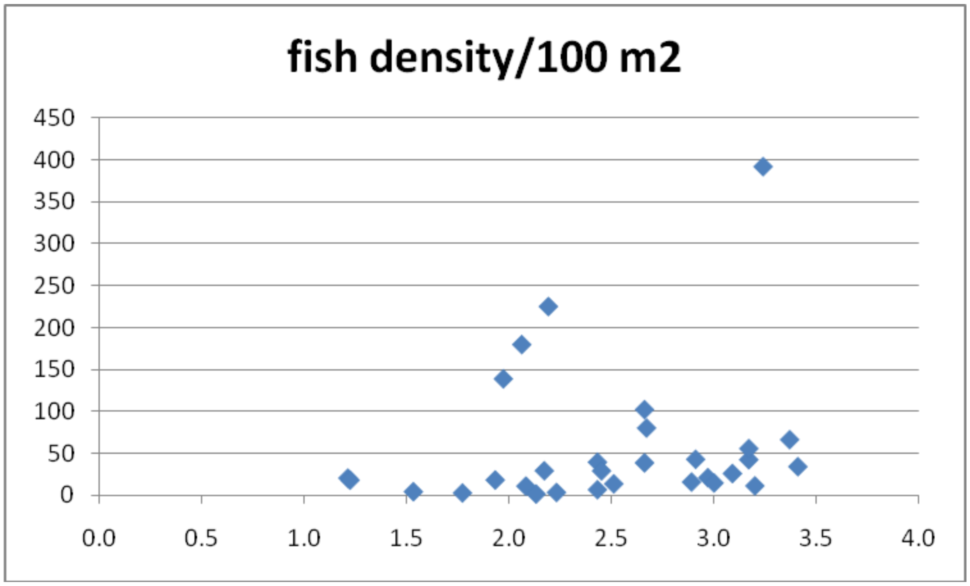


Figure 16. Density of fish versus % impervious cover upstream of sample location for data collected at part of the least disturbed watershed project.

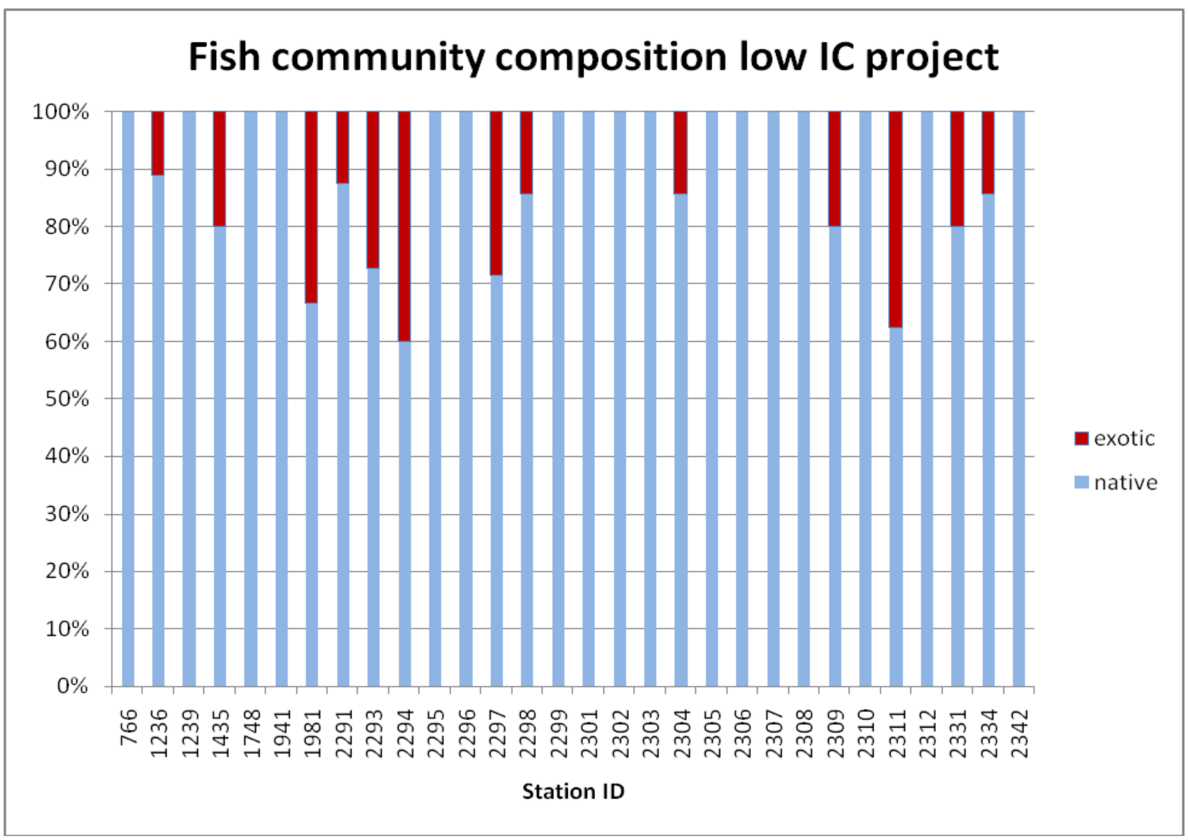
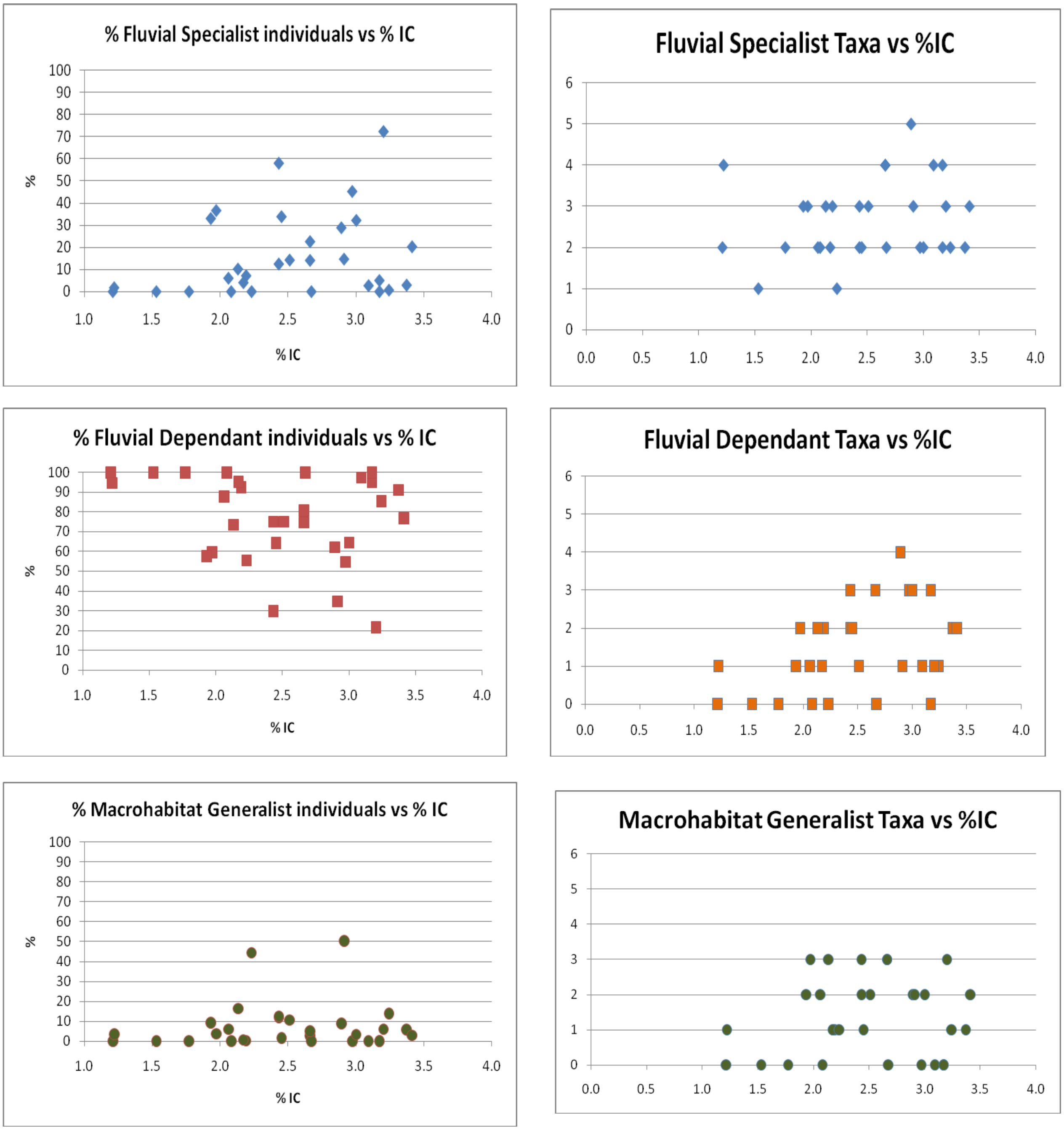


Figure 17. Proportion of native and exotic species per sample for data collected at part of the least disturbed watershed project. Station ID's are further explained in Table 1.



Figures 18. Scatter plots of fish species flow guild attributes. The left are % of individuals vs. % IC and the right are number of taxa vs. % IC for data collected at part of the least disturbed watershed project.

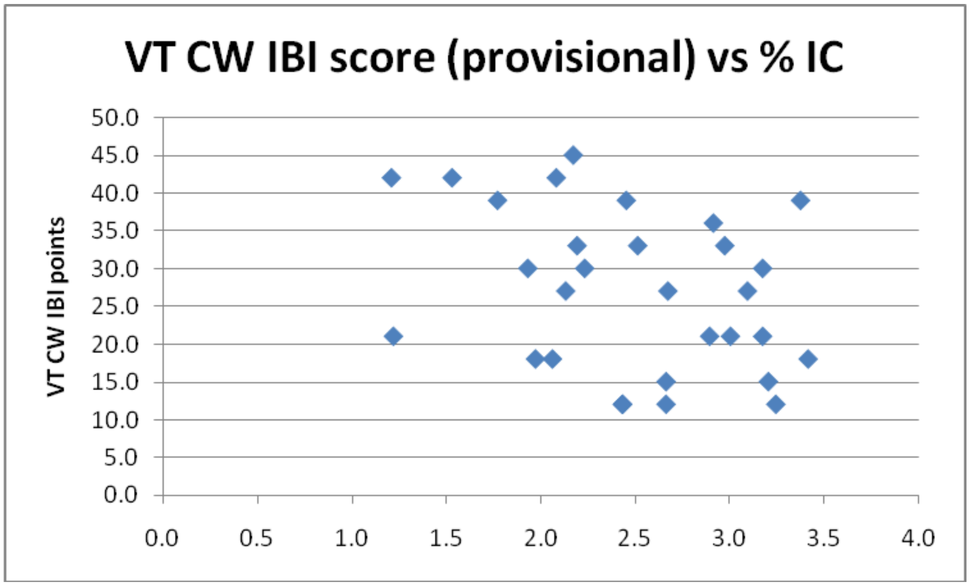


Figure 19. Scatter plot of Vermont Cold Water Index of Biotic Intergrity (VT CWIBI) scores versus percent impervious cover upstream of sample location for fish community data collected at part of the least disturbed watershed project.

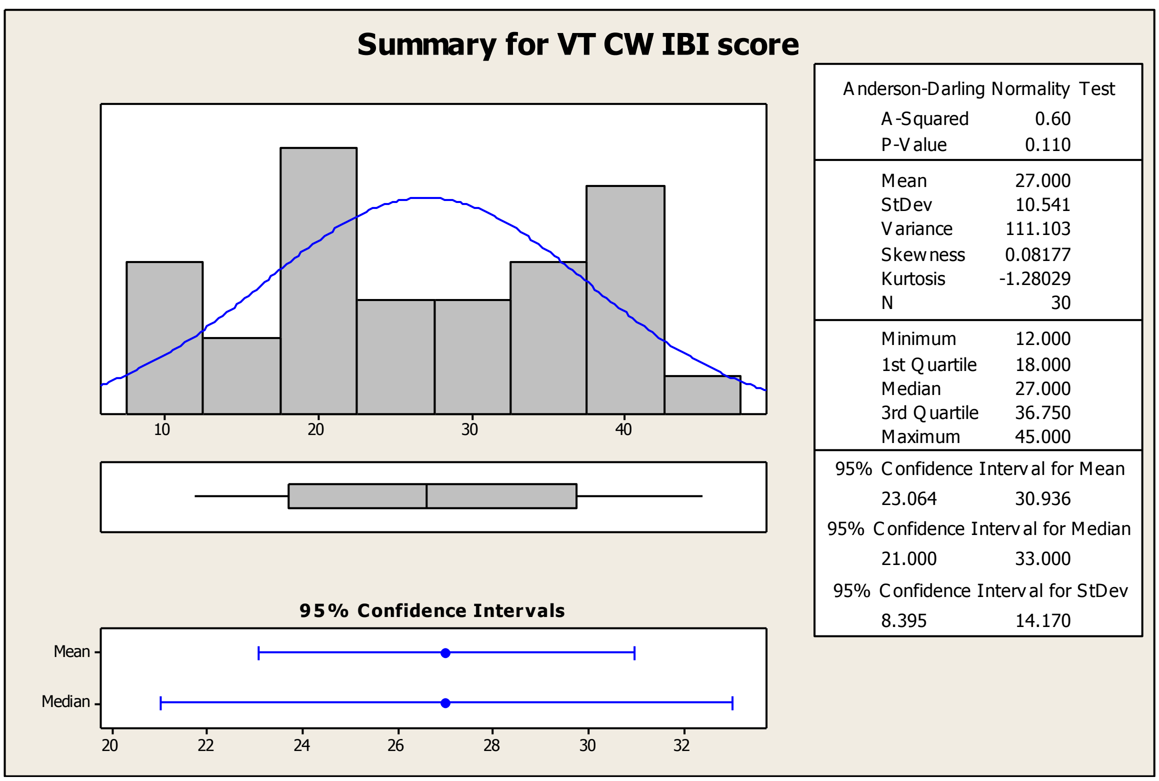


Figure 20. Distribution of Vermont Cold Water Index of Biotic Intergrity (VT CWIBI) scores for fish community data collected at part of the least disturbed watershed project.

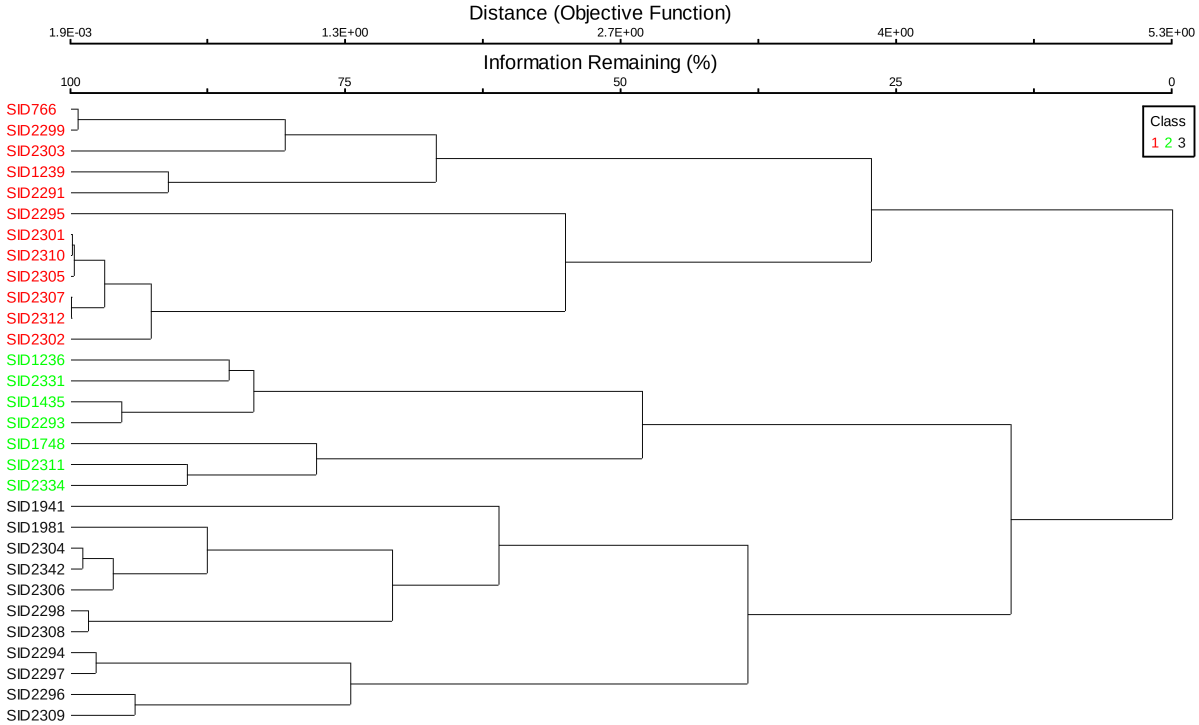


Figure 21. Dendrogram forming three fish stream classes- class 1 (red sites), class 2 (green sites), and class 3 (black sites). Refer to Table 3 for more information on Station IDs (e. g. SID 1236 is Beaver Brook).

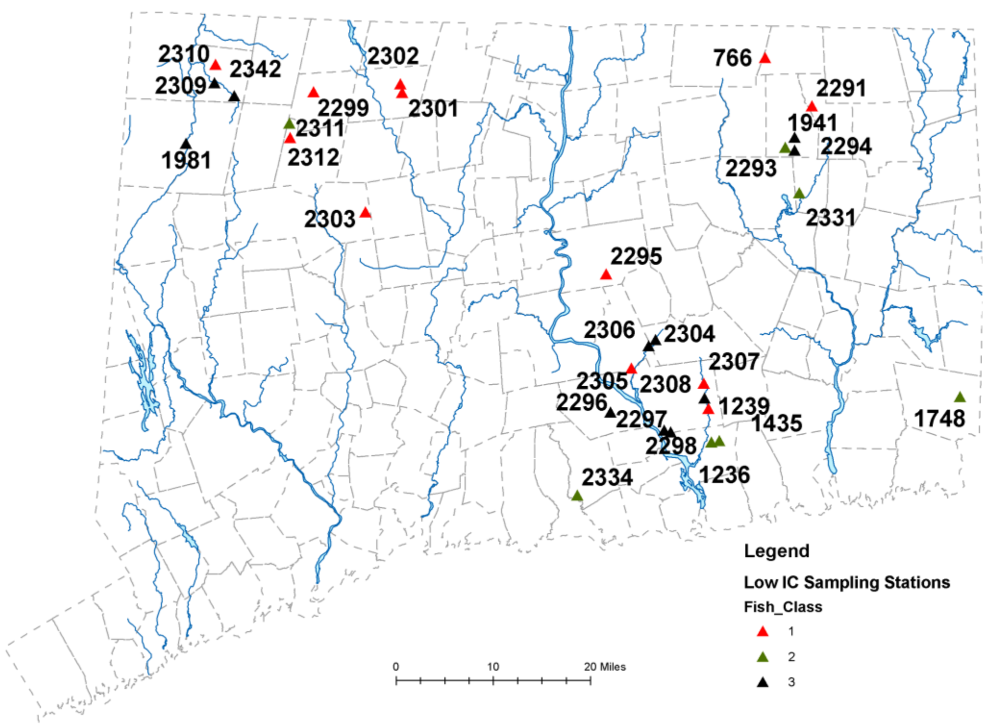


Figure 22. Map of fish stream classes (1-red, 2-green, 3=black) defined using cluster analysis. Refer to Table 3 for more information on Station IDs (e. g. SID 1236 is Beaver Brook).

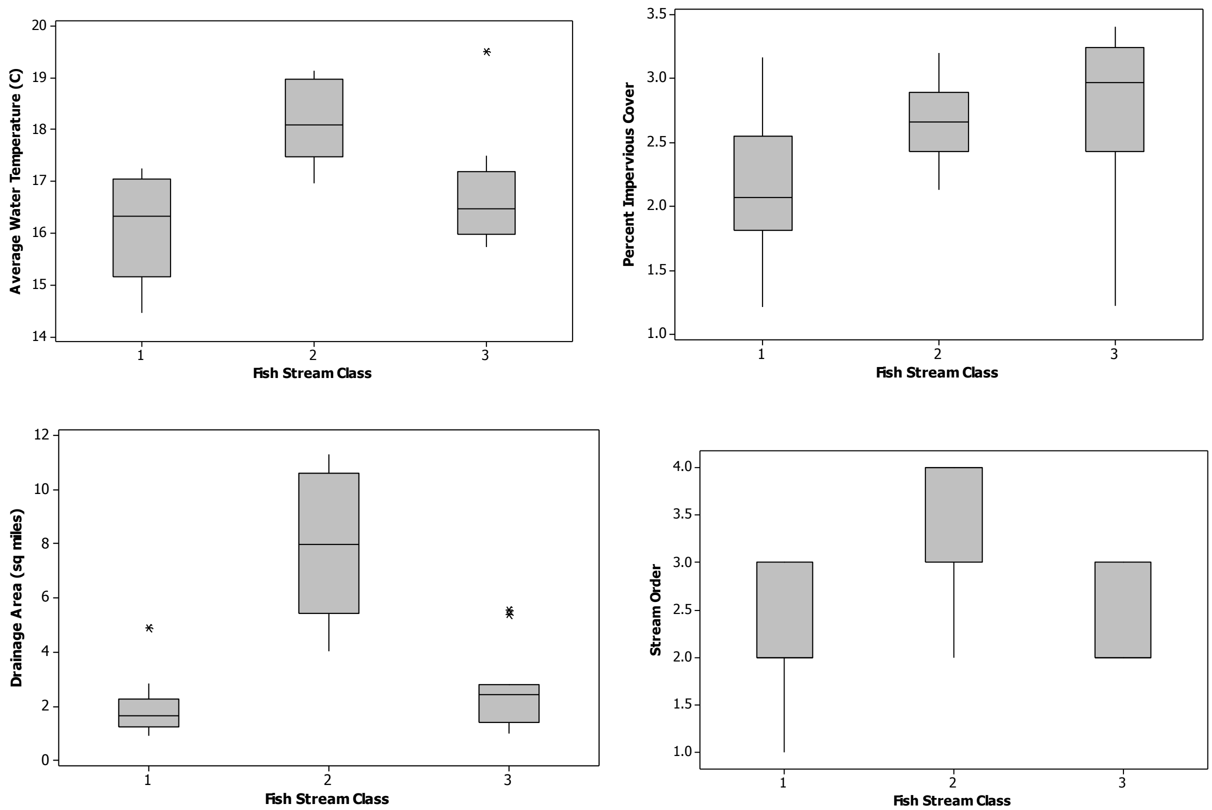


Figure 23. Average water temperature, percent impervious cover drainage area, and stream order for least disturbed watersheds containing three fish stream classes defined using cluster analysis.

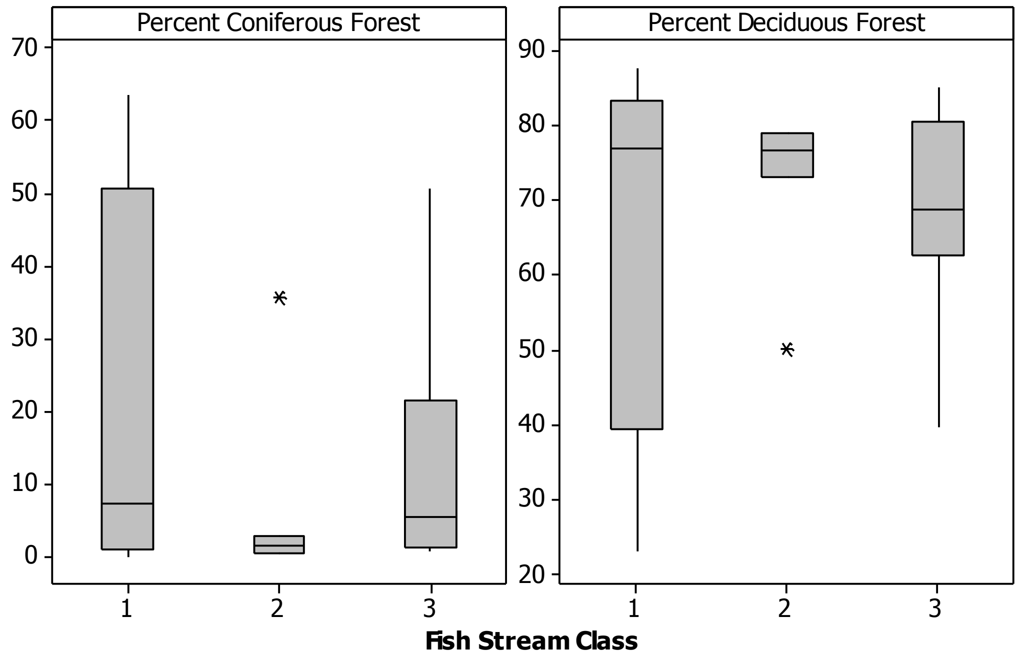


Figure 24. Percent deciduous and coniferous forest for least disturbed watershed containing three fish stream classes defined using cluster analysis.

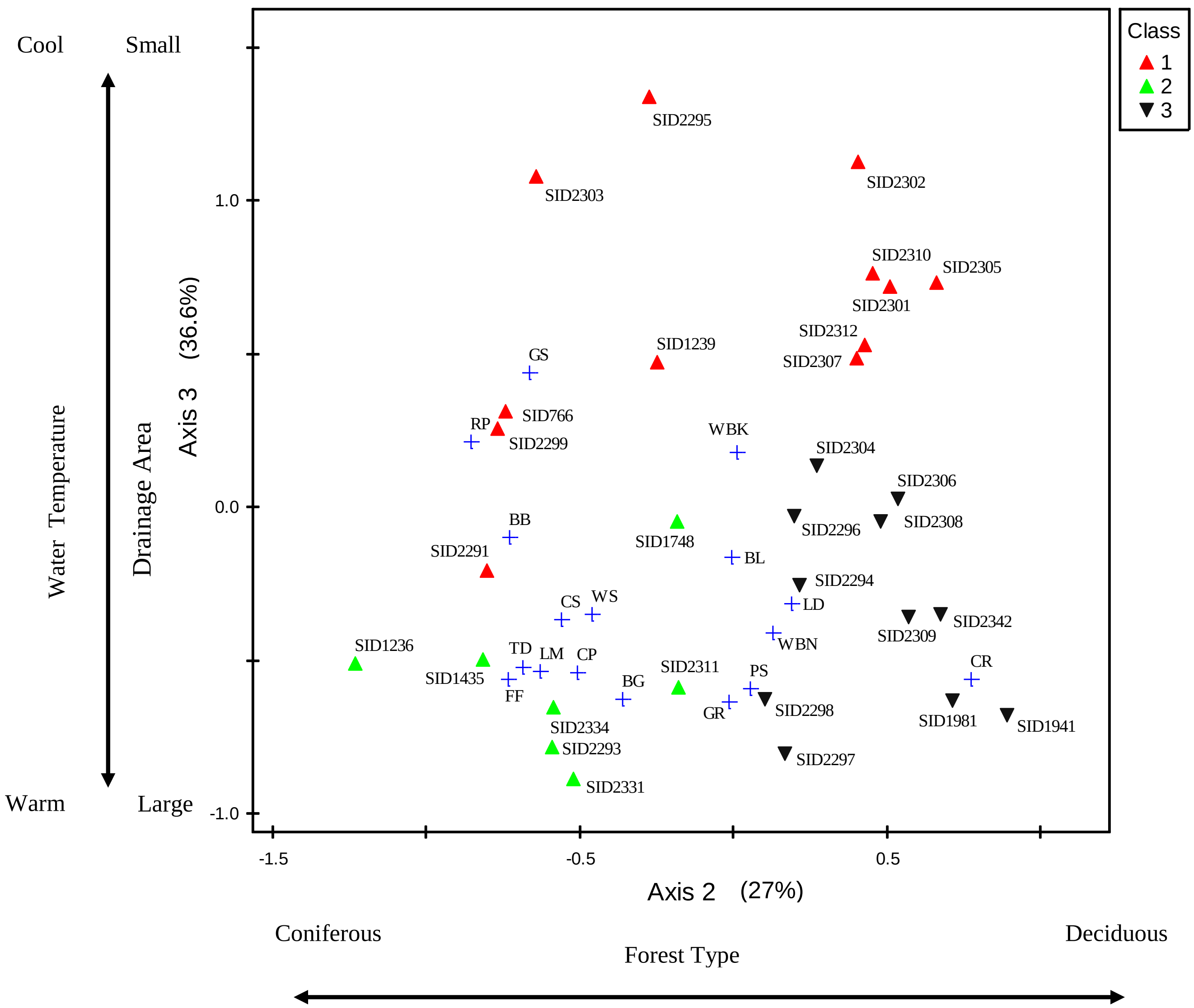


Figure 25. Nonmetric multidimensional scaling ordination of fish species from 30 stations. Refer to Table 3 for more information on Station IDs (e. g. SID 1236 is Beaver Brook). Fish species codes can be found in Appendix D.

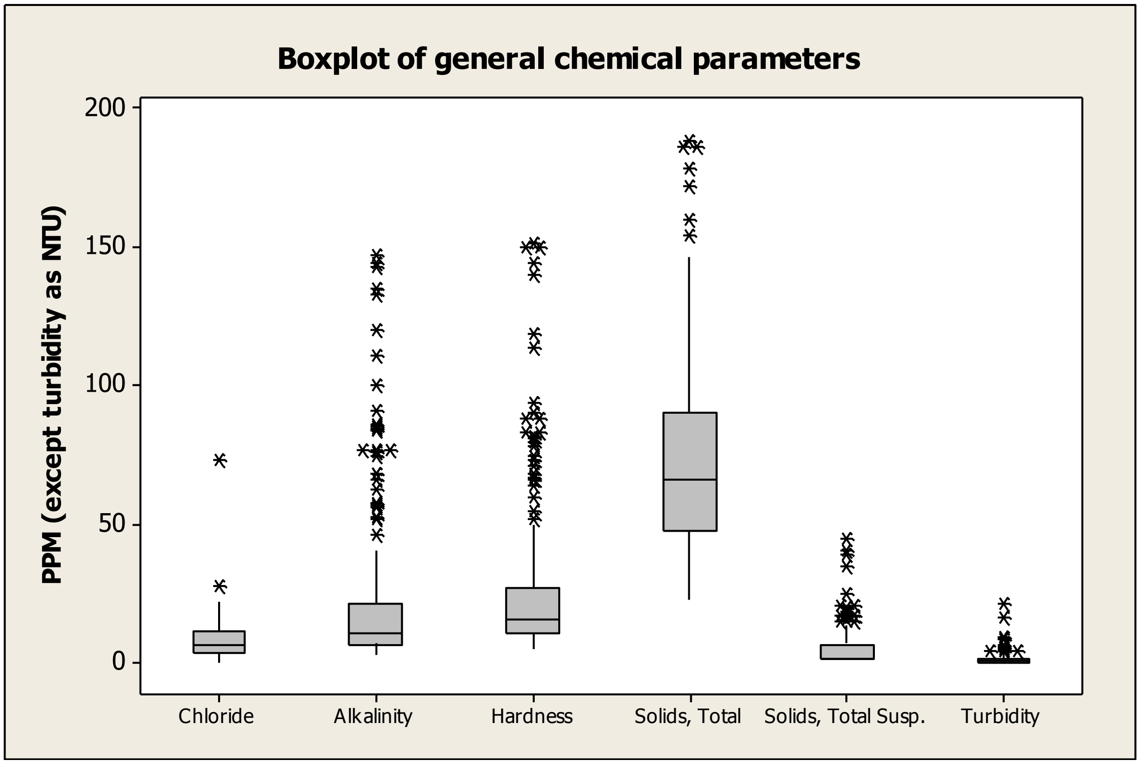
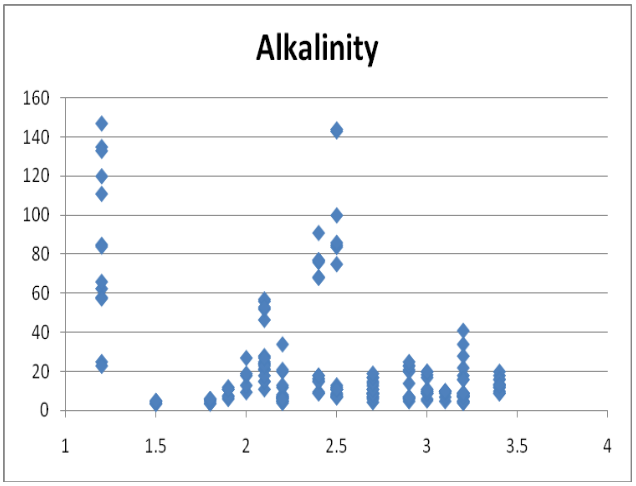
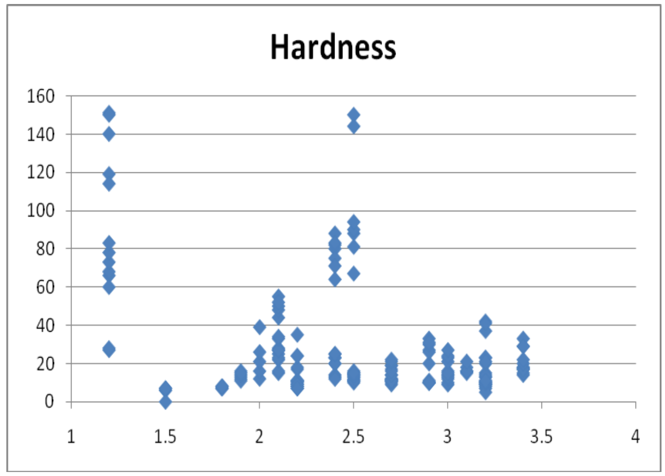
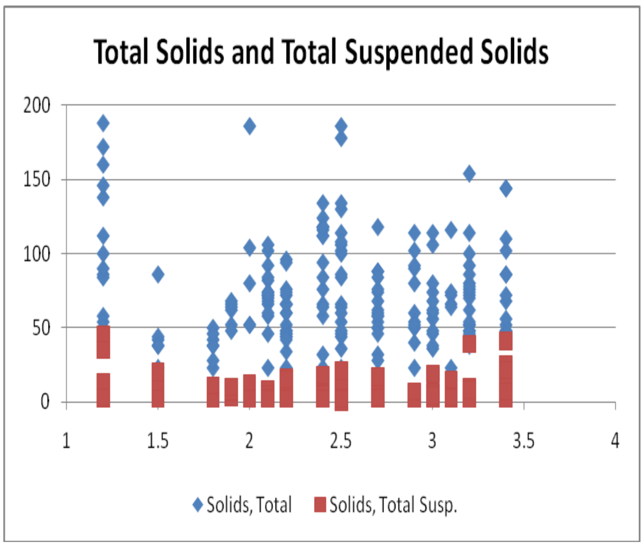
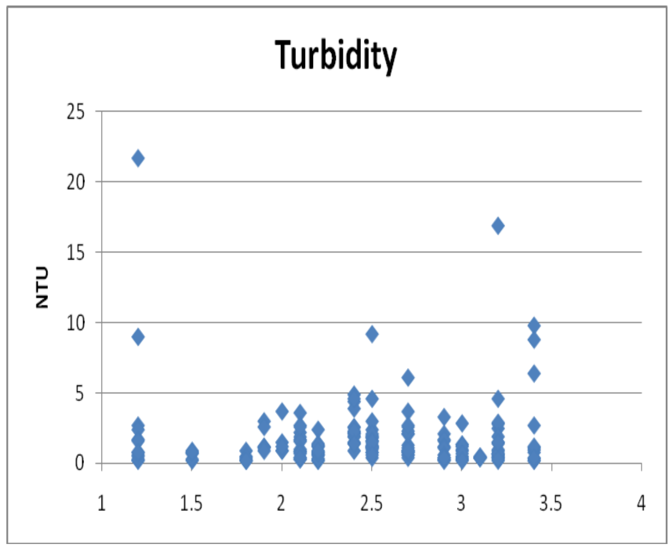


Figure 26. Box plot of general chemical parameters.









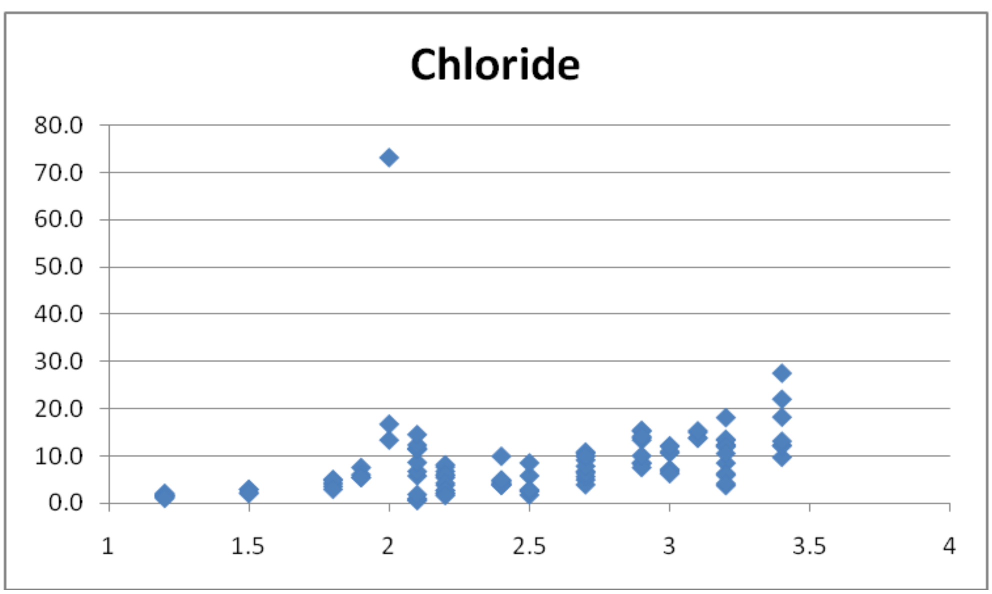


Figure 27. Scatter plots of general chemical parameters versus % IC. Results are in ppm (mg/l) except turbidity (NTUs)

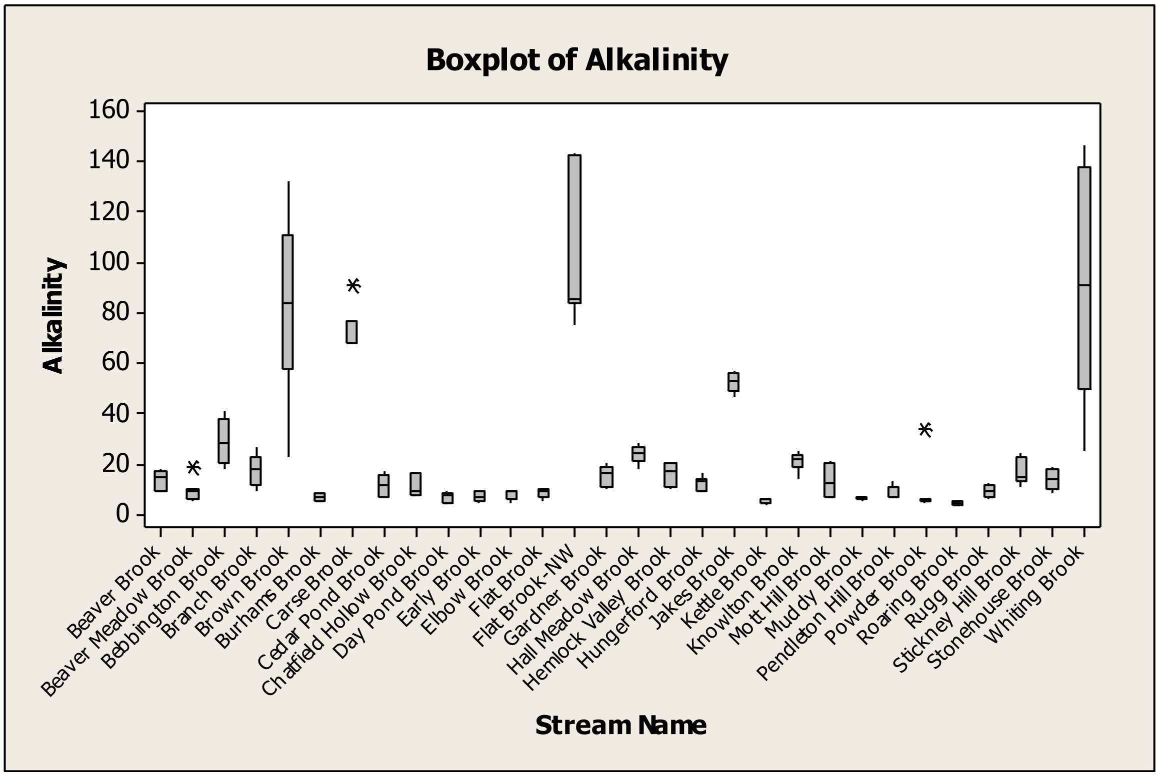


Figure 28. Box plot of alkalinity (ppm) by the least disturbed watershed site location.

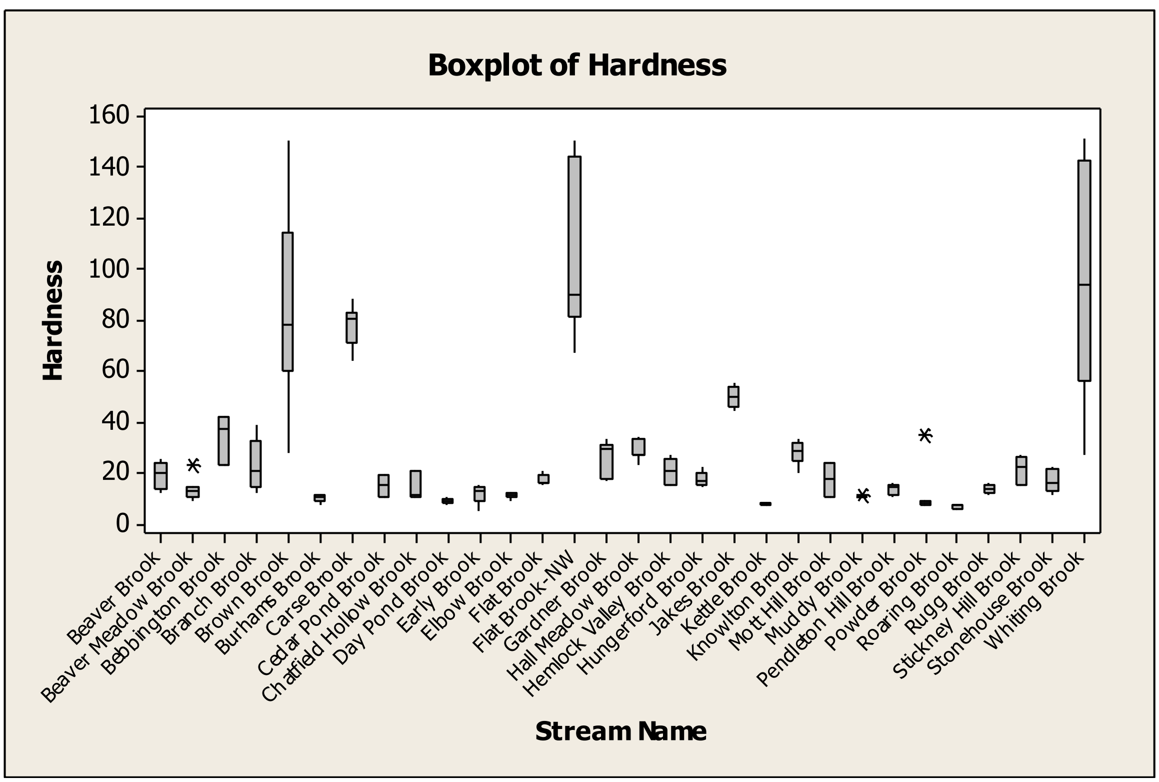


Figure 29. Box plot of hardness (ppm) by the least disturbed watershed site location.

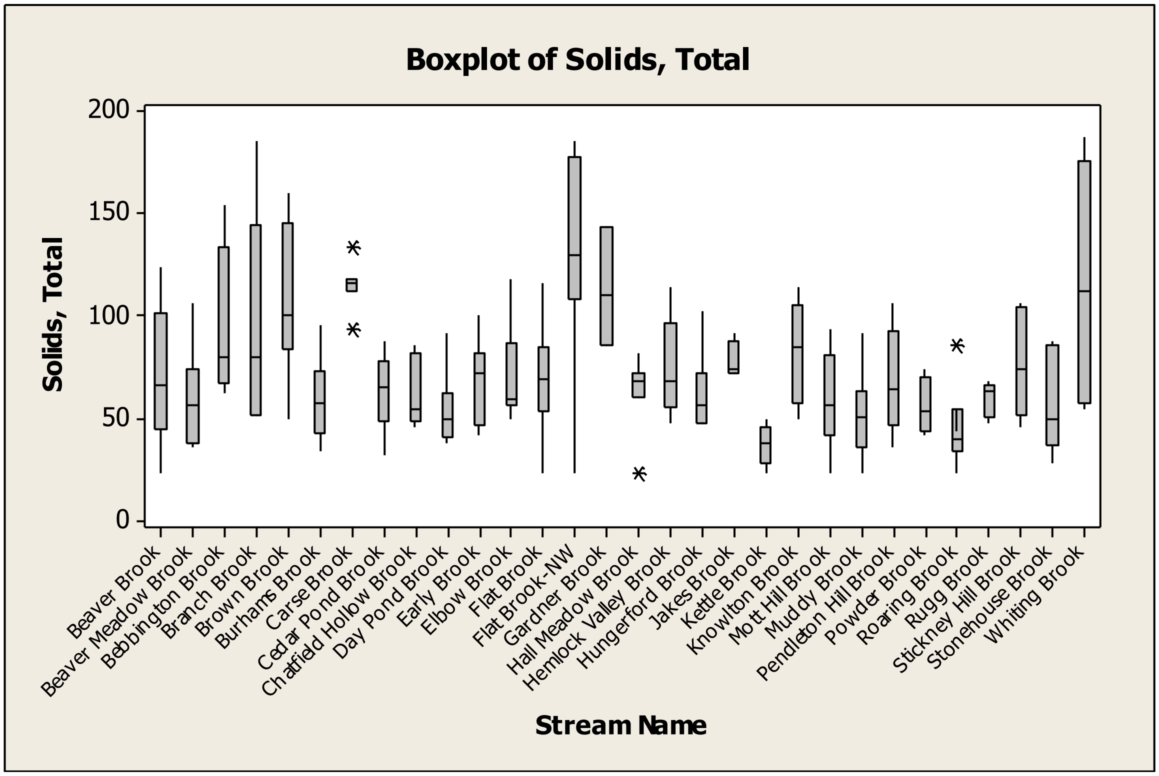


Figure 30. Box plot of total solids (ppm) by least disturbed watershed site location.

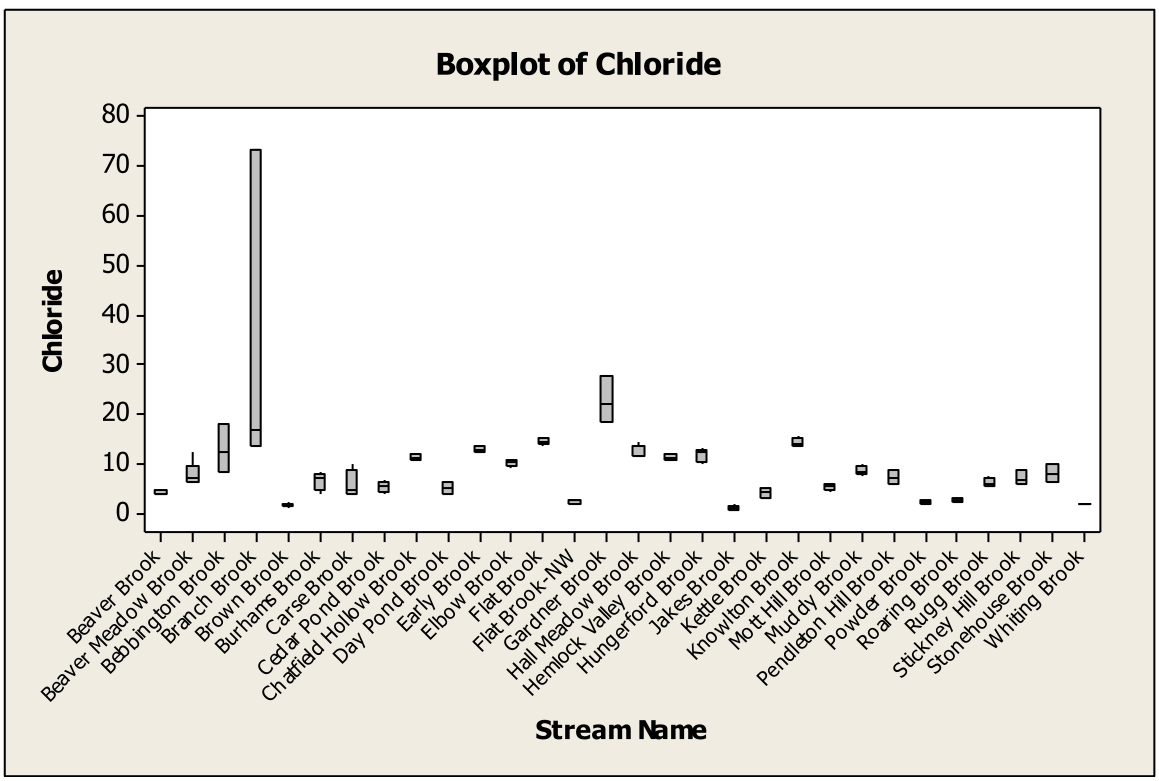
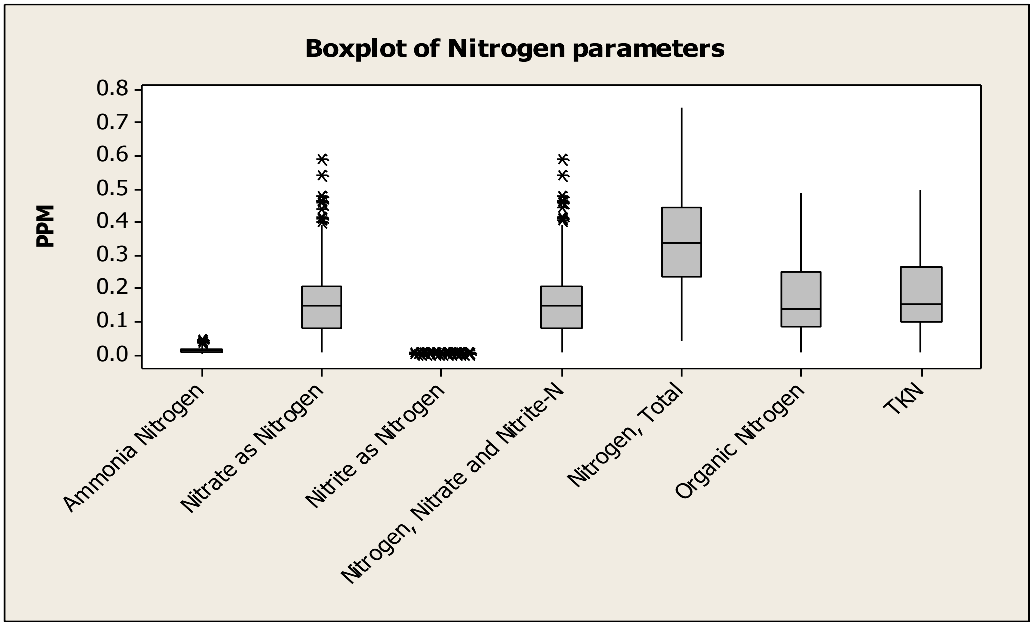


Figure 31. Box plot of chloride (ppm) by least disturbed site location.



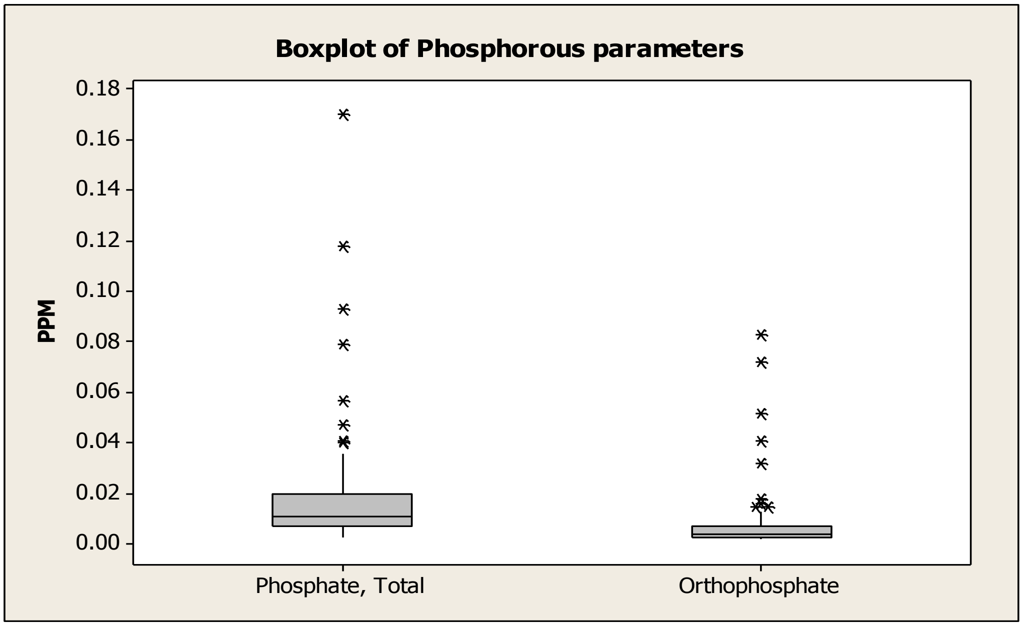


Figure 32. Box plots of Nitrogen (top) and Phosphorous (bottom) from parameters from 30 least disturbed watersheds.

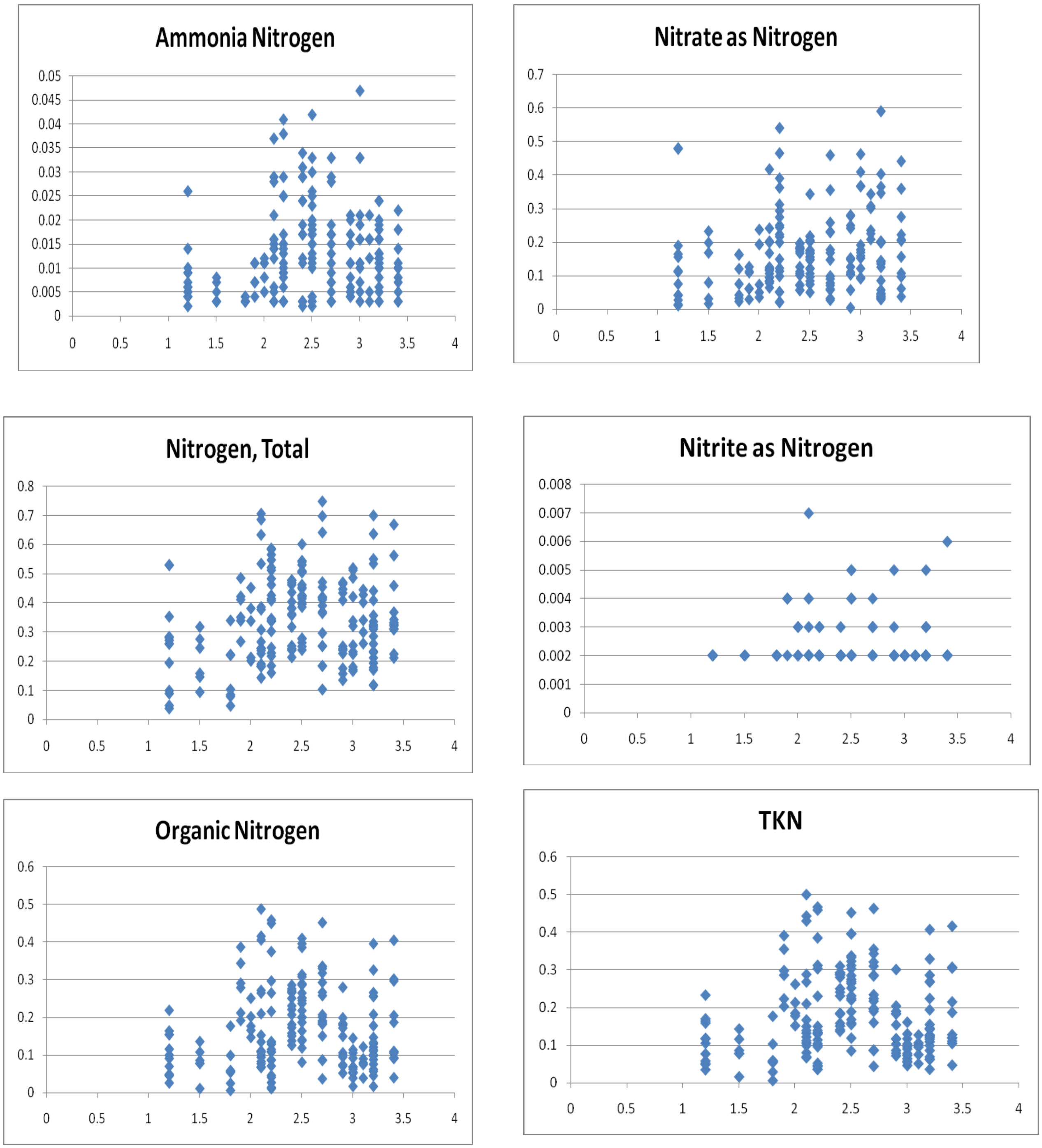


Figure 33. Scatter plot of Nitrogen series vs. % IC for samples collected in support of the least disturbed watershed project. All units represented on the Y-axis are ppm (mg/l).

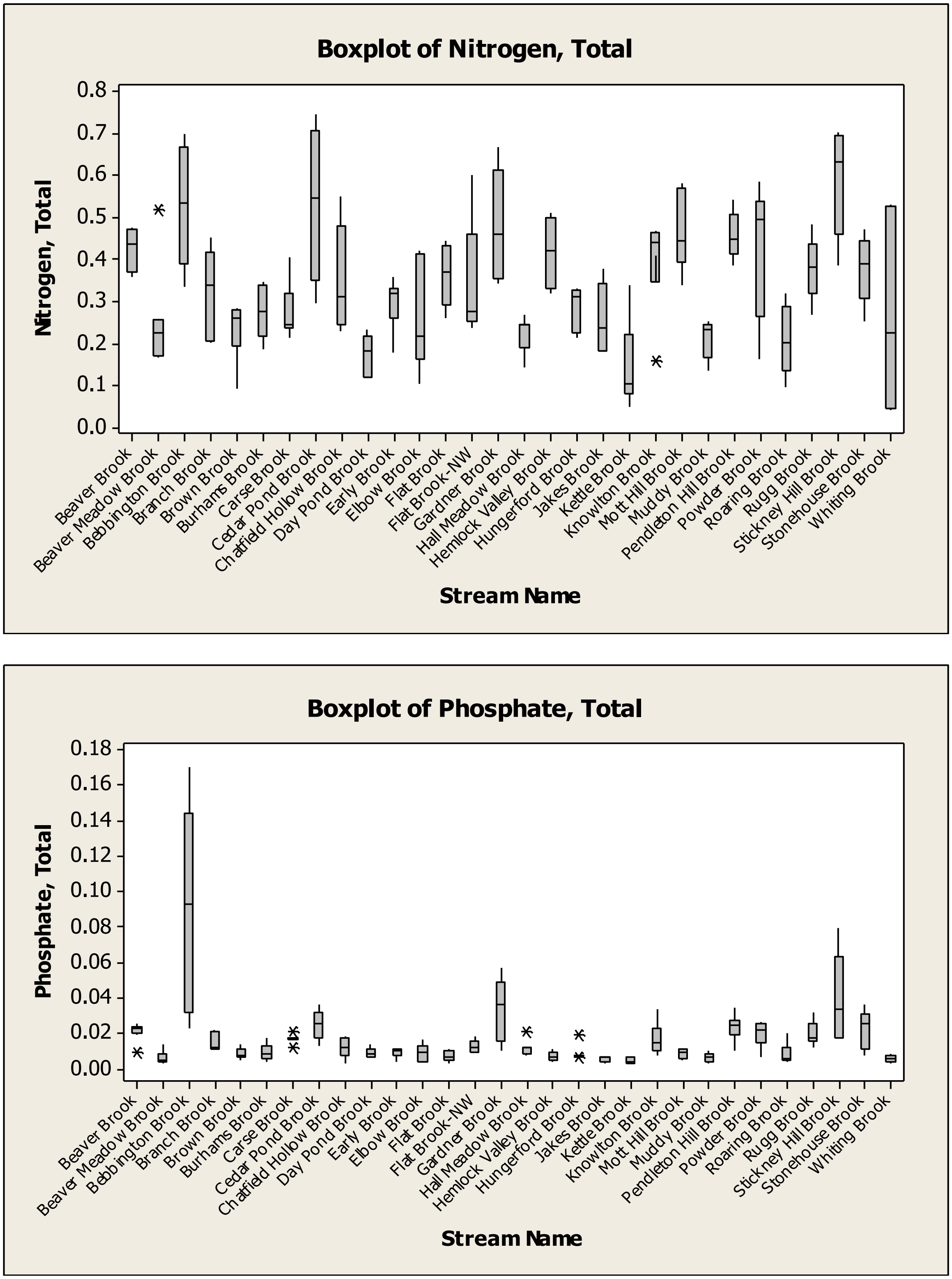
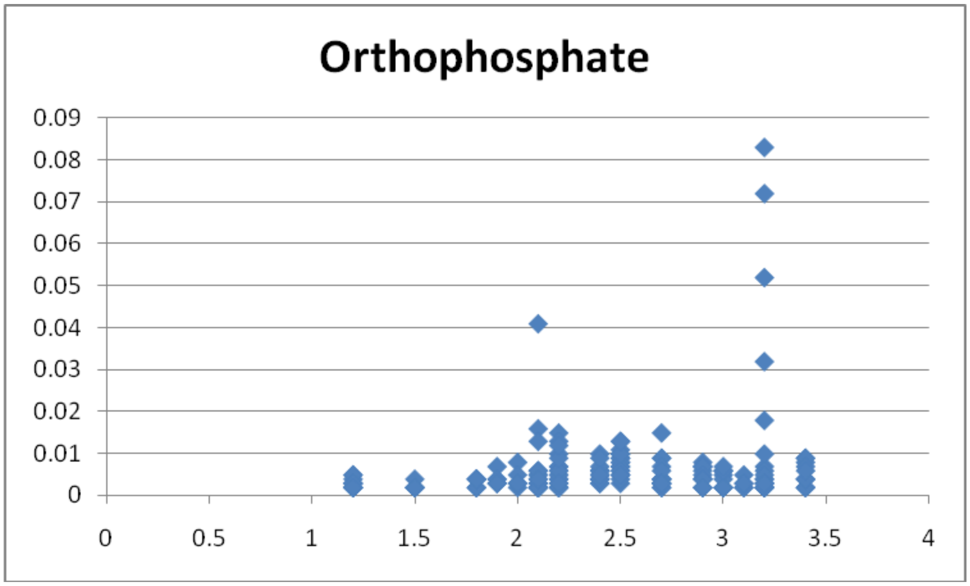


Figure 34. Box plots of Total Nitrogen (top) and Phosphorous (bottom) at each of the 30 least disturbed watersheds. All units represented on the Y-axis are ppm (mg/l).



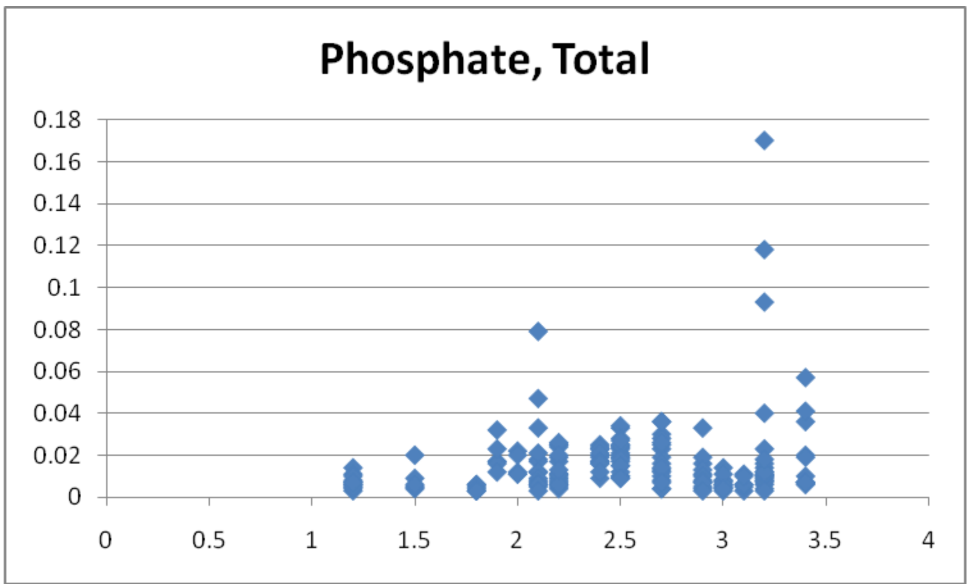


Figure 35. Scatter plot of Phosphorous series vs. % IC from samples collected in support of the least disturbed watershed project. All units represented on the Y-axis are ppm (mg/l).

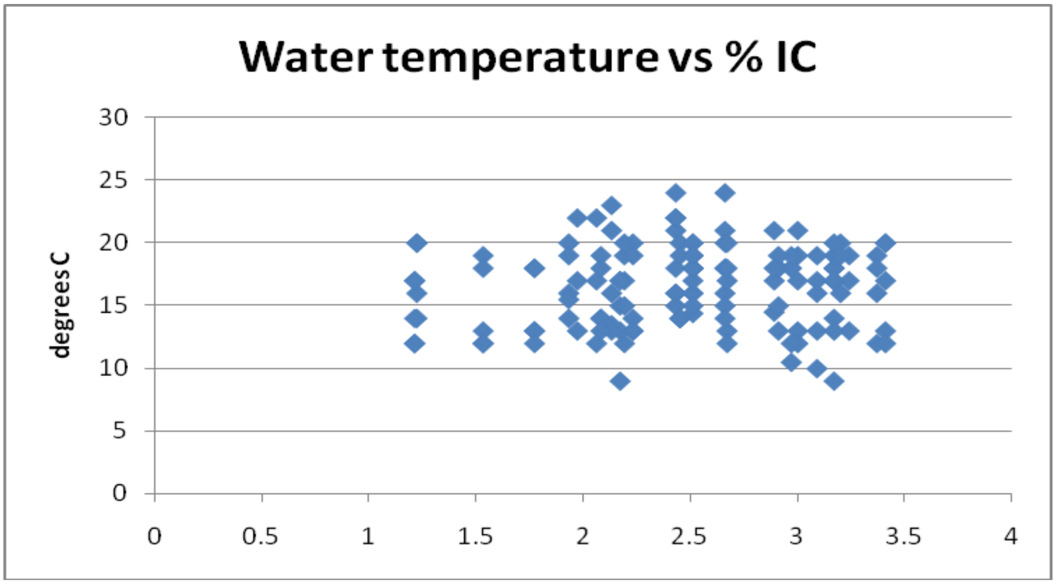


Figure 36. Water temperature data vs % IC from samples collected in support of the least disturbed watershed project.

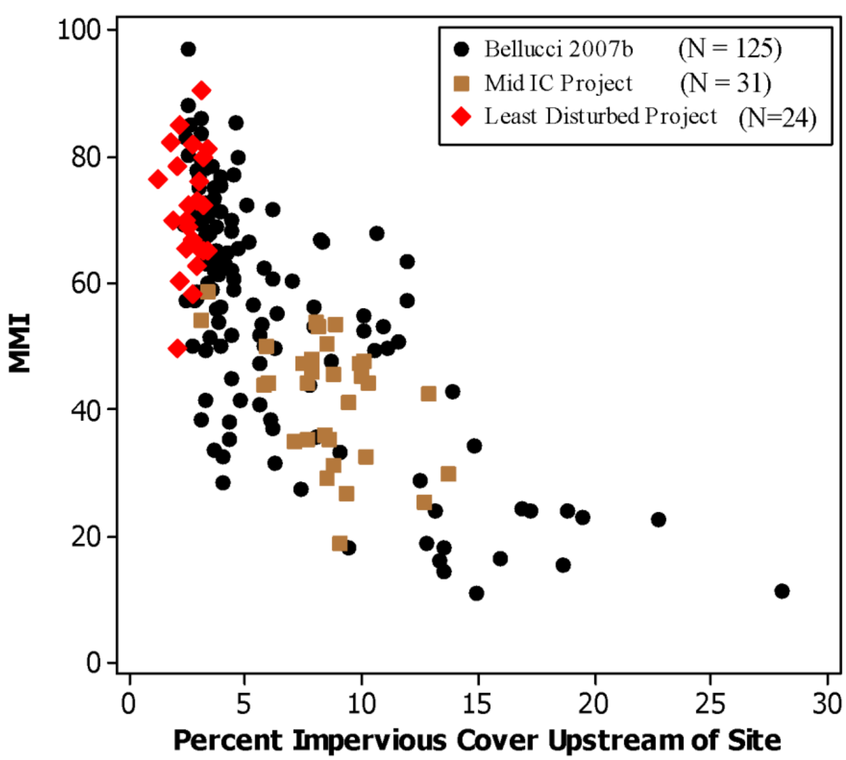


Figure 37. Scatter plot of percent impervious cover and macroinvertebrate multimetric index (MMI) from three CTDEP projects – Bellucci 2007b, Mid IC Project (Bellucci et al. 2008) and least disturbed watershed project. The linear relationship using a least squares regression was MMI = 74.87 - 3.135 Percent IC (R^2 = 52.8%).

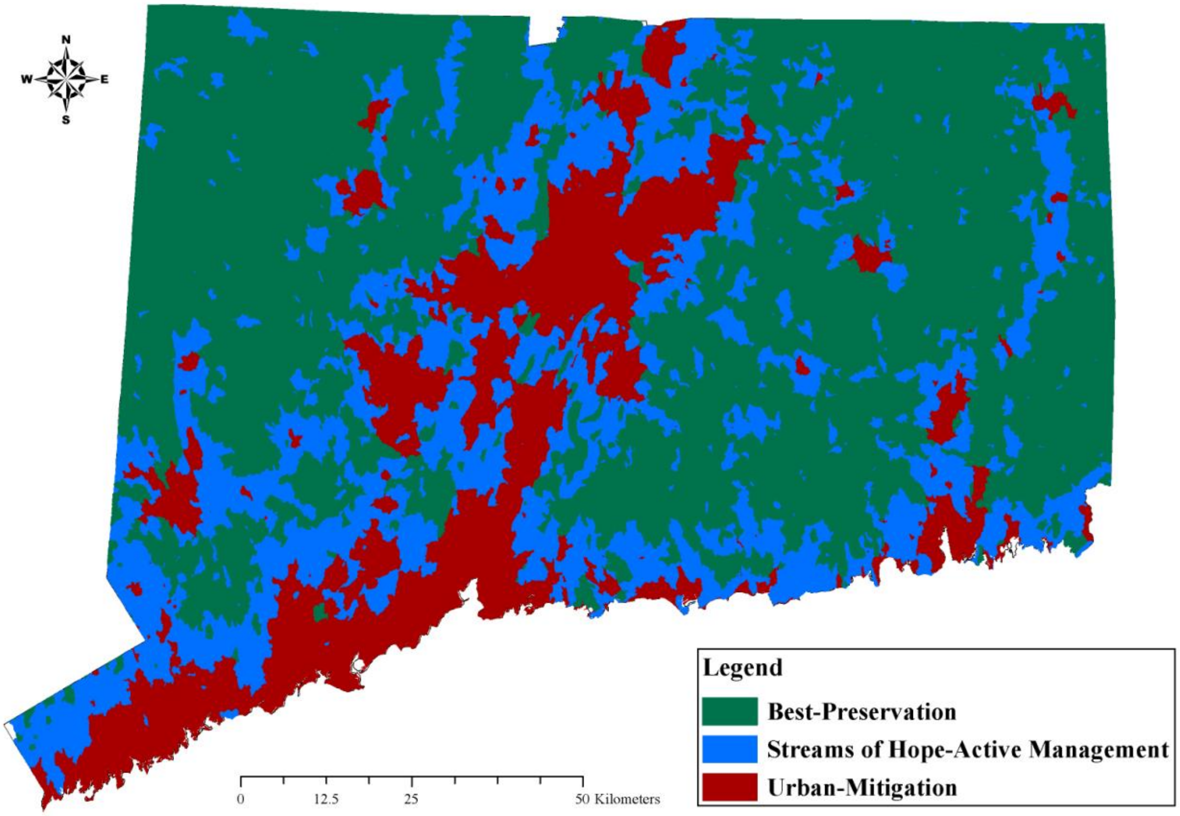


Figure 38. Map of Connecticut showing stream classes and management classes based on the conceptual model in Figure 1. Categories were based on using percent impervious cover calculated using the Impervious Surface Analysis Tool from 2002 Land Cover data and the relationship with macroinvertebrate multimetric index scores. Best-preservation is 0-4.99% impervious cover, streams of hope-active mitigation is 5-11.99% impervious cover and urban-mitigation is >12% impervious cover.

Table 1. Parameters and criteria used to select least disturbed watersheds for this study.

Parameter	Criteria
Land use	
Impervious Cover	< 4%
Natural Land Cover	> 80%
Developed Land	< 10%
Water Quantity	
Diversions	None
Habitat Fragmentation	
Reservoirs / Large Class C Dams	None
Sample Site Distance Below a dam (included all dams in database)	Site located > 0.5 mile downstream from dam
Biological	
Streams Stocked with Salmonid Fry	No known stocking
Geomorphology	
Watershed Size	> 1 Square Mile

Table 2. List of 30 streams that were considered for the project, but excluded after field check and additional GIS verification.

Subregional Basin Number	Stream Name	Town(s)	Reason(s) for Exclusion
2203	Willys Meadow Brook	Waterford	Too small, poor access
3101	Aborn Brook	Ellington	Low gradient, too small
3101	Diamond Ledge Brook	Stafford	Too small
3104	Keene Brook	Willington	Poor access
3203	Buell Brook	Eastford	Sampled Branch Bk instead
3203	Lead Mine Brook	Ashford	Ph D study site
3203	Stones Brook	Eastford	Too small
3204	East Branch Stonehouse Brook	Chaplin	Low gradient
3206	East Branch Mount Hope River	Ashford	Poor access
3603	Denison Brook	Voluntown	WPLR Study Site
4008	Dark Hollow Brook	Glastonbury	Dam proximity
4011	Buck Brook	Portland	Request for access denied
4015	Mill Creek	Haddam	Dam proximity
4015	Pole Bridge Brook	Haddam	Dam proximity, too small
4015	Turkey Hill Brook	Haddam	Dam proximity, too small
4304	Wright Brook	Hartland	Too small
4304	North Brook	Colebrook	Dam proximity, Crosses state border
4319	Bissell Brook	Granby, Simsbury	Request for access denied
4501	Cemetery Brook	Tolland	Low gradient
4501	Martins Brook	Stafford, Ellington, Tolland	Low gradient
4800	Falls Brook	Lyme	Low gradient
4800	Hedge Brook	East Haddam	Too small
4800	Lake Hayward Brook	East Haddam	Dam proximity
6010	Baldwin Brook	Cornwall	Town landfill and garage
6010	Bloody Brook	Cornwall	Near salmonid stocking area
6010	Tanner Brook	Cornwall	Too small, low gradient
6015	Pond Mountain Brook	Kent	Near salmonid stocking area
6200	Bradford Brook	Cornwall	Low gradient
6201	North Branch Brown Brook	Canaan	Sampled Brown Bk
6202	Deming Brook	Canaan	Sampled Brown Bk

Table 3. Attributes of the 30 watersheds sampled as part of the least disturbed watershed study.

Station ID	Stream	proximity	landmark	%IC	Basin id	Municipality	YLat	XLong	Total Acres	IC acres
1236	Beaver Brook	Downstream	bridge at 55-123 Beaver Brook Road	**2.4**	4803	Lyme	41.4100	-72.3289	789.0	18.9
2296	Beaver Meadow Brook	US	commuter lot exit 8 off Rt 9	**3.0**	4015-02	Haddam	41.4553	-72.5288	1387.3	54.6
1941	Bebbington Brook	adjacent to Bicknell Road	at Hastings Memorial Forest (Joshuas Trust) sign	**3.2**	3206-10	Ashford	41.8447	-72.1593	1504.9	48.7
2291	Branch Brook	Upstream Westford Road	at mouth	**2.0**	3203-10	Eastford	41.9108	-72.1245	3130.6	61.9
2342	Brown Brook	at	Route 63	**1.2**	6201	Canaan	41.9267	-73.2799	3567.3	43.8
1239	Burhams Brook	at	Mouth	**2.2**	4800	East Haddam	41.4603	-72.3343	764.7	16.6
1981	Carse Brook	between	route 7 and mouth	**2.4**	6009	Sharon	41.8552	-73.3755	3459.2	83.8
1435	Cedar Pond Brook		US of route 156 near 134 Beaver Brook road	**2.7**	4803	Lyme	41.4119	-72.3128	4554.8	111.1
2334	Chatfield Hollow Brook	at	Mouth on River Road	**3.2**	5105	Madison	41.3314	-72.5950	7215.2	229.7
2304	Day Pond Brook	at	mouth	**3.2**	4700-02	Colchester	41.5623	-72.4338	847.8	26.9
2307	Early Brook	at	Haywardville Road	**3.2**	4800-01	East Haddam	41.4978	-72.3435	1489.3	48.3
2305	Elbow Brook	at	Route 196 and Wopowaug Road	**2.7**	4700-09	East Hampton	41.5211	-72.4869	727.3	19.8
2309	Flat Brook	at	Lower Barrack Road	**2.5**	6200-05	Canaan	41.9459	-73.3200	1951.0	49.1
2306	Flat Brook	at	Route 16	**3.1**	4700-	East Hampton	41.5544	-72.4523	1631.0	50.4
2294	Gardner Brook	Upstream	Route 89 and adjacent Slade Rd	**3.4**	3206-09	Ashford	41.8643	-72.1598	899.1	30.5
2311	Hall Meadow Brook	at	park access road bridge	**2.1**	6901	Torrington	41.8861	-73.1689	7650.0	170.6

Station ID	Stream	proximity	landmark	%IC	Basin id	Municipality	YLat	XLong	Total Acres	IC acres
2297	Hemlock Valley Brook	at	Bone Mill Road	**3.0**	4016-11	East Haddam	41.4283	-72.4226	1909.4	58.7
2298	Hungerford Brook	parallel to Old Town Street	at mouth	**3.4**	4016-10	Lyme	41.4255	-72.4094	1719.1	58.9
2312	Jakes Brook	at	Route 272	**2.1**	6902-02	Torrington	41.8646	-73.1679	1293.2	28.4
2301	Kettle Brook	MDC east access road	at mouth	**1.8**	4308-13	Barkhamsted	41.9324	-72.9442	956.0	17.1
2293	Knowlton Brook	Between	Cushman Rd and confluence with Squaw Hollow Brook	**2.9**	3205-01	Ashford	41.8492	-72.1783	4387.1	126.8
2295	Mott Hill Brook	off Hunt Ridge Drive	at Private Drive for houses # 107-109	**2.2**	4008-03	Glastonbury	41.6615	-72.5365	1814.2	39.3
2308	Muddy Brook	at	Hopyard Road	**2.9**	4800-06	East Haddam	41.4756	-72.3420	860.3	24.9
1748	Pendleton Hill Brook	Upstream Grindstone Hill Road	Near Clarks Falls	**2.5**	1001-02	North Stonington	41.4748	-71.8342	3356.9	93.1
2303	Powder Brook	at old road crossing	access across from Locust Road off Route 72	**2.2**	4313	Harwinton	41.7541	-73.0170	1129.3	29.4
2302	Roaring Brook	MDC east access road	at mouth	**1.5**	4308-11	Barkhamsted	41.9454	-72.9475	1052.3	16.5
2299	Rugg Brook	US first road crossing from reservoir	at #224 Old Waterbury Turnpike	**1.9**	4302-04	Winchester	41.9328	-73.1214	1592.4	31.8
766	Stickney Hill Brook	upstream	Brown road	**2.1**	3104	Union	41.9833	-72.2179	3755.3	113.1
2331	Stonehouse Brook	off old trail	downstream Palmer Road	**2.7**	3204	Chaplin	41.7812	-72.1509	4045.9	110.8
2310	Whiting Brook	at	Under Mountain Road	**1.2**	6200-06	Canaan	41.9730	-73.3178	1213.2	23.1

Table 4. Estimated protected preserved areas in the upstream drainage basin for each least disturbed site.

STATION ID	Waterbody Name	Total Watershed Area (sqmi)	Area Not Preserved (sqmi)	Preserved Area (sqmi)	Percent Area Preserved	Percent Area Not Preserved	Watershed Area May Be Completely or Partially in Water Company Land
2291	Branch Brook	4.89	1.30	3.59	73.44%	26.56%	
2296	Beaver Meadow Brook	1.74	0.47	1.26	72.71%	27.29%	
2304	Day Pond Brook	1.32	0.47	0.85	64.50%	35.50%	
2310	Whiting Brook	0.93	0.34	0.59	63.60%	36.40%	
2302	Roaring Brook	1.64	0.62	1.02	62.08%	37.92%	YES
2295	Mott Hill Brook	2.82	1.23	1.59	56.48%	43.52%	
1239	Burhams Brook	1.18	0.58	0.60	50.63%	49.37%	
2309	Flat Brook	2.79	1.41	1.37	49.33%	50.67%	
1981	Carse Brook	5.40	3.06	2.34	43.29%	56.71%	
1748	Pendleton Hill Brook	4.02	2.52	1.50	37.34%	62.66%	
1236	Beaver Brook	7.99	5.57	2.42	30.30%	69.70%	
766	Stickney Hill Brook	2.28	1.68	0.61	26.55%	73.45%	
2334	Chatfield Hollow Brook	11.29	8.34	2.95	26.09%	73.91%	
2331	Stonehouse Brook	5.44	4.06	1.38	25.43%	74.57%	
1435	Cedar Pond Brook	2.43	1.89	0.54	22.18%	77.82%	
2308	Muddy Brook	1.34	1.05	0.29	21.65%	78.35%	
2305	Elbow Brook	0.90	0.71	0.19	21.61%	78.39%	
2307	Early Brook	2.24	1.89	0.35	15.80%	84.20%	
2297	Hemlock Valley Brook	2.79	2.47	0.32	11.62%	88.38%	
2306	Flat Brook	2.44	2.16	0.28	11.33%	88.67%	
2293	Knowlton Brook	6.84	6.13	0.71	10.42%	89.58%	
2311	Hall Meadow Brook	10.60	9.58	1.02	9.59%	90.41%	YES
1941	Bebbington Brook	2.18	2.08	0.10	4.40%	95.60%	

STATION ID	Waterbody Name	Total Watershed Area (sqmi)	Area Not Preserved (sqmi)	Preserved Area (sqmi)	Percent Area Preserved	Percent Area Not Preserved	Watershed Area May Be Completely or Partially in Water Company Land
2301	Kettle Brook	1.49	1.43	0.05	3.48%	96.52%	YES
2294	Gardner Brook	1.41	1.38	0.03	2.15%	97.85%	
2342	Brown Brook	5.57	5.48	0.08	1.50%	98.50%	
2303	Powder Brook	0.97	0.97	0.00	0.00%	100.00%	YES
2312	Jakes Brook	1.62	1.62	0.00	0.00%	100.00%	YES
2299	Rugg Brook	2.09	2.09	0.00	0.00%	100.00%	YES
2298	Hungerford Brook	2.67	2.67	0.00	0.00%	100.00%	

Table 5. Two streams in the least disturbed project that meet screening criteria for Level 1 Biological Condition Gradient Level sites. N= 4 for chloride samples.

Station ID	Stream Name	Average Chloride (mg/L)	% Developed	% Natural Land Cover	% Impervious Cover
2342	Brown Brook	1.56	0.47	99	1.2
2310	Whiting Brook	1.76	0.18	99	1.2

Table 6. Macroinvertebrate MMI value and individual metric values for each of the 25 sites sampled during fall 2007 in support of the least disturbed watershed project. The MMI value is calculated as the arithmetic mean of the 7 individual MMI metric values. Macroinvertebrate samples were not collected at Stickney Hill Brook, Branch Brook, Bebbington Brook, Powder Brook, Whiting Brook, and Roaring Brook due to inadequate flow.

Station ID	Date	% IC	MMI	E genera taxa	P genera taxa	T genera taxa	Sensitive EPT %	SCR genera Taxa	Sensitive Taxa Index	Dominant Genera %
1236	9/24/2007	2.4	70.1	100	33	38	100	64	68	87
1239	9/25/2007	2.2	85.2	100	83	62	100	64	89	98
1435	9/25/2007	2.7	66.9	38	17	85	68	82	83	96
1748	9/25/2007	2.5	72.5	42	50	85	82	55	100	95
1981	9/19/2007	2.4	65.5	53	50	38	73	64	100	80
2293	9/28/2007	2.9	62.9	74	17	31	88	73	93	66
2294	9/28/2007	3.4	81.4	100	50	54	100	73	94	100
2295	9/19/2007	2.2	60.5	57	33	62	51	45	83	92
2296	9/19/2007	3	65.6	71	33	54	83	45	81	92
2297	9/18/2007	3	76.1	90	50	77	74	64	81	97
2298	9/18/2007	3.4	65.2	47	33	69	57	64	96	90
2299	9/21/2007	1.9	69.9	100	33	54	70	82	75	76
2301	9/21/2007	1.8	82.2	100	67	77	100	55	88	89
2302	9/21/2007	1.5	91.4	100	83	92	100	73	96	96
2304	9/19/2007	3.2	80.1	100	50	77	100	64	70	100
2305	9/19/2007	2.7	82.0	100	33	85	100	64	100	92
2306	9/19/2007	2.5	68.9	49	33	62	84	73	84	97
2307	9/25/2007	3.2	72.6	90	17	77	74	64	87	100
2308	9/25/2007	2.9	73.2	100	33	69	100	55	66	89
2309	9/21/2007	3.1	90.8	89	100	77	96	91	98	84
2311	9/24/2007	2.1	49.8	34	17	46	35	73	57	87
2312	9/24/2007	2.1	78.7	76	67	69	84	73	85	97
2331	9/21/2007	2.7	58.4	39	33	38	70	55	84	89
2334	10/2/2007	3.2	65.4	57	33	69	90	45	65	97
2342	10/9/2007	1.2	76.4	76	67	54	83	73	87	96

Table 7. Select traditional RBP3 metrics for data collected during fall 2007 in support of the least disturbed watershed project.

Station ID	Stream Name	% IC	date	organisms per m2	Taxa Richness	EPT Taxa	HBI	% Dominant taxa	dominant taxa
1236	Beaver Brook	2.4	9/24/2007	2758	31	13	3.66	14	*Hydropsyche*
2296	Beaver Meadow Brook	3.0	9/19/2007	527	26	12	3.42	18	*Maccaffertium*
2342	Brown Brook	1.2	10/9/2007	348	33	19	2.54	12	*Isonychia*
1239	Burhams Brook	2.2	9/25/2007	1210	43	16	2.42	12	*Rhyacophila minora*
1981	Carse Brook	2.4	9/19/2007	154	23	12	2.19	26	*Isonychia*
1435	Cedar Pond Brook	2.7	9/25/2007	1131	38	14	2.66	14	*Acroneuria abnormis*
2334	Chatfield Hollow Brook	3.2	10/2/2007	844	29	16	2.88	11	*Ephemerella*
2304	Day Pond Brook	3.2	9/19/2007	690	37	17	2.45	12	*Diplectrona*
2307	Early Brook	3.2	9/25/2007	568	34	15	2.89	11	*Psephenus herricki*
2305	Elbow Brook	2.7	9/19/2007	150	37	15	2.87	18	*Nigronia serricornis*
2306	Flat Brook	3.1	9/19/2007	647	36	13	2.60	14	*Acroneuria abnormis*
2309	Flat Brook	2.5	9/21/2007	354	41	22	1.76	24	*Acroneuria abnormis*
2294	Gardner Brook	3.4	9/28/2007	563	44	14	2.88	12	*Psephenus herricki*
2311	Hall Meadow Brook	2.1	9/24/2007	62	25	9	3.68	15	*Nigronia serricornis*
2297	Hemlock Valley Brook	3.0	9/18/2007	961	33	19	2.08	15	*Diplectrona*
2298	Hungerford Brook	3.4	9/18/2007	147	29	13	2.96	16	*Cheumatopsyche*
2312	Jakes Brook	2.1	9/24/2007	226	35	16	2.49	14	*Psephenus herricki*
2301	Kettle Brook	1.8	9/21/2007	317	41	22	2.70	15	*Maccaffertium*
2293	Knowlton Brook	2.9	9/28/2007	957	24	11	2.63	37	*Isonychia*
2295	Mott Hill Brook	2.2	9/19/2007	2016	38	15	4.55	18	*Cheumatopsyche*
2308	Muddy Brook	2.9	9/25/2007	985	33	14	2.47	20	*Diplectrona*
1748	Pendleton Hill Brook	2.5	9/25/2007	2856	45	18	3.21	16	*Maccaffertium*
2302	Roaring Brook	1.5	9/21/2007	293	34	20	2.56	15	*Ceratopsyche ventura*
2299	Rugg Brook	1.9	9/21/2007	1379	32	16	3.47	17	*Hydropsyche*
2331	Stonehouse Brook	2.7	9/21/2007	529	28	10	3.62	19	*Chimarra aterrima*

Table 8. Dominant macroinvertebrate taxa statistics for samples collected to support the least disturbed watershed project. Macroinvertebrate samples were not collected at Stickney Hill Brook, Branch Brook, Bebbington Brook, Powder Brook, Whiting Brook, and Roaring Brook due to inadequate flow.

Taxa	Sites	Percent (n=25)
Acroneuria abnormis	3	12
Ceratopsyche ventura	1	4
Cheumatopsyche	2	8
Chimarra aterrima	1	4
Diplectrona	3	12
Ephemerella	1	4
Hydropsyche	2	8
Isonychia	3	12
Maccaffertium	3	12
Nigronia serricornis	2	8
Psephenus herricki	3	12
Rhyacophila minora	1	4

Table 9. Top 10 macroinvertebrate taxa as % of individuals identified (N=4,403) and as % of sites present (N=25) for samples collected during fall 2007 in support of the least disturbed watershed project. Macroinvertebrate samples were not collected at Stickney Hill Brook, Branch Brook, Bebbington Brook, Powder Brook, Whiting Brook, and Roaring Brook due to inadequate flow.

Taxa	% of individuals identified		Taxa	% of sites sampled
Acroneuria abnormis	6		*Nigronia serricornis*	96
Cheumatopsyche	6		*Dolophilodes*	88
Maccaffertium	5		*Maccaffertium*	88
Nigronia serricornis	5		*Cheumatopsyche*	84
Psephenus herricki	5		*Promoresia tardella*	84
Diplectrona	5		*Tipula*	84
Dolophilodes	5		*Stenelmis*	80
Promoresia tardella	4		*Acroneuria abnormis*	76
Hydropsyche	4		*Diplectrona*	76
Isonychia	4		*Hexatoma, Hydropsyche, Psephenus herricki*	72

Table 10. Top four macroinvertebrate taxa indicative of each least disturbed stream class identified using indicator species analysis. Stream classes were determined using cluster analysis and NMS ordination plots. p values <0.05 were considered statistically significant.

Macroinvertebrate Stream Class	Taxa	Functional Feeding Group	Indicator Value (percent)	p value
1	*Isonychia sp.*	Collector-Gatherer	96.9	0.0001
1	*Paragnetina media*	Predator	55.7	0.0094
1	*Maccaffertium modestum group*	Scraper	47.7	0.0482
1	*Chimarra aterrima*	Collector-Filterer	46.4	0.0356
2	*Diplectrona sp.*	Collector-Filterer	81.1	0.0002
2	*Ceratopsyche ventura*	Collector-Filterer	75.2	0.0007
2	*Tallperla sp.*	Shreder	61.5	0.0059
2	*Rhyacophila minora*	Predator	53.6	0.0211
3	*Acroneuria abnormis*	Predator	54.2	0.0295
3	*Brachycentrus Appalachia*	Collector-Filterer	42.9	0.0193
3	*Rhyacophila fuscula*	Predator	35.9	0.0462
3	*Oecetis persimilis*	Predator	37.9	0.0462

Table 11. Top 9* fish species as % of total individuals identified (N=3,955) and top 10 fish species as % of sites present (N=30). Fish community data collected at part of the least disturbed watershed project.

species abbrev	Genus species	% of Individuals	Species abbrev	Genus species	% of Sites
BL	*Rhinichthys atratulus*	47	WBK	*Salvelinus fontinalis*	90
WBK	*Salvelinus fontinalis*	14	BL	*Rhinichthys atratulus*	87
AE	*Anguilla rostrata*	6	WS	*Catostomus commersoni*	40
CS	*Luxilus cornutus*	6	AE	*Anguilla rostrata*	40
FF	*Semotilus corporalis*	6	LD	*Rhinichthys cataractae*	30
WS	*Catostomus commersoni*	4	CS	*Luxilus cornutus*	27
SA	*Salmo salar hatcheryis*	3	FF	*Semotilus corporalis*	23
YP	*Perca flavescens*	3	BG	*Lepomis macrochirus*	20
LD	*Rhinichthys cataractae*	3	LM	*Micropterus salmoides*	20
*			GS	*Notemigonus crysoleucas*	17

***8 species tied at 1 %**

Table 12. Fish community Vermont Cold Water IBI (provisional) and component metric scores for each of the fish community samples collected in support of the least disturbed watershed project. Abbreviations in the table are CW= Coldwater, GF= generalist feeder, TC= top carnivore, WBK= wild brook trout.

Station ID	Stream Name	basin id	sample id	% IC	Mi2	VT CW IBI score	Intolerant Species	% CW stenotherms	% GF	% TC	WBK/100m2	WBK age classes
766	Stickney Hill Brook	3104	11224	2.1	2.3	**18.0**	4.5	1.5	1.5	1.5	1.5	7.5
1236	Beaver Brook	4803	11172	2.4	8.3	**12.0**	1.5	1.5	1.5	4.5	1.5	1.5
1239	Burhams Brook	4800	11171	2.2	1.2	**33.0**	7.5	1.5	7.5	1.5	7.5	7.5
1435	Cedar Pond Brook	4803	11173	2.7	8.0	**15.0**	4.5	1.5	1.5	1.5	4.5	1.5
1748	PENDLETON HILL BROOK	1001-02	10630	2.5	4.0	**33.0**	7.5	1.5	7.5	7.5	1.5	7.5
1941	Bebbington Brook	3206-10	11227	3.2	2.2	**12.0**	4.5	1.5	1.5	1.5	1.5	1.5
1981	Carse Brook	6009	10505	2.4	5.4	**12.0**	4.5	1.5	1.5	1.5	1.5	1.5
2291	Branch Brook	3203-10	11225	2.0	4.9	**18.0**	4.5	1.5	1.5	1.5	7.5	1.5
2293	Knowlton Brook	3205-01	11228	2.9	6.8	**21.0**	7.5	1.5	1.5	1.5	1.5	7.5
2294	Gardner Brook	3206-09	11242	3.4	1.4	**39.0**	7.5	4.5	4.5	7.5	7.5	7.5
2295	Mott Hill Brook	4008-03	11067	2.2	2.8	**45.0**	7.5	7.5	7.5	7.5	7.5	7.5
2296	Beaver Meadow Brook	4015-02	10997	3.0	1.7	**33.0**	7.5	1.5	4.5	7.5	4.5	7.5
2297	Hemlock Valley Brook	4016-11	10998	3.0	2.8	**21.0**	7.5	1.5	4.5	4.5	1.5	1.5
2298	Hungerford Brook	4016-10	10999	3.4	2.7	**18.0**	4.5	1.5	7.5	1.5	1.5	1.5
2299	Rugg Brook	4302-04	10432	1.9	2.1	**30.0**	4.5	1.5	1.5	7.5	7.5	7.5
2301	Kettle Brook	4308-13	10429	1.8	1.5	**39.0**	4.5	7.5	7.5	7.5	4.5	7.5

Station ID	Stream Name	basin id	sample id	% IC	Mi2	**VT CW IBI score**	Intolerant Species	% CW stenotherms	% GF	% TC	WBK/100m2	WBK age classes
2302	Roaring Brook	4308-11	10430	1.5	1.6	**42.0**	4.5	7.5	7.5	7.5	7.5	7.5
2303	Powder Brook	4313	11223	2.2	1.0	**30.0**	4.5	4.5	1.5	7.5	4.5	7.5
2304	Day Pond Brook	4700-02	11287	3.2	1.3	**21.0**	7.5	1.5	7.5	1.5	1.5	1.5
2305	Elbow Brook	4700-09	10989	2.7	0.9	**27.0**	4.5	1.5	7.5	1.5	4.5	7.5
2306	Flat Brook	4700-	11257	3.1	2.4	**27.0**	7.5	1.5	7.5	1.5	1.5	7.5
2307	Early Brook	4800-01	11169	3.2	2.2	**30.0**	4.5	1.5	7.5	1.5	7.5	7.5
2308	Muddy Brook	4800-06	11170	2.9	1.3	**36.0**	4.5	1.5	7.5	7.5	7.5	7.5
2309	Flat Brook	6200-05	10506	2.5	2.8	**39.0**	7.5	4.5	4.5	7.5	7.5	7.5
2310	Whiting Brook	6200-06	10507	1.2	0.9	**42.0**	4.5	7.5	7.5	7.5	7.5	7.5
2311	Hall Meadow Brook	6901	10802	2.1	10.6	**27.0**	7.5	1.5	4.5	4.5	1.5	7.5
2312	Jakes Brook	6902-02	10803	2.1	1.6	**42.0**	4.5	7.5	7.5	7.5	7.5	7.5
2331	Stonehouse Brook	3204	11229	2.7	5.4	**12.0**	4.5	1.5	1.5	1.5	1.5	1.5
2334	Chatfield Hollow Brook	5105	10863	3.2	11.3	**15.0**	1.5	1.5	1.5	7.5	1.5	1.5
2342	Brown Brook	6201	10508	1.2	5.6	**21.0**	4.5	1.5	4.5	1.5	1.5	7.5

Table 13. Fish species indicative of each stream classes of least disturbed sites as identified by indicator species analysis. Stream classes were determined using cluster analysis and NMS ordination.

Fish Stream Class	Species	Habitat Use	Indicator Value (percent)	p value
1	Brook trout *(Salvelinus fontinalis)*	FS	53.7	0.0026
1	Golden shiner (*Notemigonus crysoleucas)*	MG	41.7	0.0145
2	Chain pickerel *(Esox niger)*	MG	71.4	0.0005
2	Tessellated darter *(Etheostoma olmstedi)*	FS	71.4	0.0002
2	Fallfish *(Semotilus corporalis)*	FS	65.5	0.0005
2	Bluegill *(Lepomis macrochirus)*	MG	49.3	0.0105
2	Largemouth bass *(Micropterus salmoides)*	MG	45.9	0.0100
2	Common shiner *(Luxilus cornutus)*	FD	39.6	0.0316
2	White sucker *(Catostomus commersoni)*	FD	39.5	0.0693
3	Creek chub *(Semotilus atromaculatus)*	MG	36.4	0.0372

Table 14. Number of samples collected at each of the 30 stations selected for the least disturbed watershed project. Macroinvertebrate samples were not collected at Stickney Hill Brook, Branch Brook, Bebbington Brook, Powder Brook, Whiting Brook, and Roaring Brook due to inadequate flow.

Station ID	Stream	proximity	landmark	%IC	Basin id	Grab Chemistry	Macro-invertebrates	Habitat	Fish
1236	Beaver Brook	Downstream	bridge at 55-123 Beaver Brook Road	**2.4**	4803	9	1	X	1
2296	Beaver Meadow Brook	US	commuter lot e1it 8 off Rt 9	**3.0**	4015-02	7	1	X	1
1941	Bebbington Brook	adjacent to Bicknell Road	at Hastings Memorial Forest (Joshuas Trust) sign	**3.2**	3206-10	5	0	X	1
2291	Branch Brook	Upstream Westford Road	at mouth	**2.0**	3203-10	5	0	X	1
2342	Brown Brook	at	Route 63	**1.2**	6201	7	1	X	1
1239	Burhams Brook	at	Mouth	**2.2**	4800	6	1	X	1
1981	Carse Brook	between	route 7 and mouth	**2.4**	6009	7	1	X	1
1435	Cedar Pond Brook		US of route 156 near 134 Beaver Brook road	**2.7**	4803	6	1	X	1
2334	Chatfield Hollow Brook	at	Mouth on River Road	**3.2**	5105	5	1	X	1
2304	Day Pond Brook	at	mouth	**3.2**	4700-02	6	1	X	1
2307	Early Brook	at	Haywardville Road	**3.2**	4800-01	6	1	X	1
2305	Elbow Brook	at	Route 196 and Wopowaug Road	**2.7**	4700-09	6	1	X	1
2309	Flat Brook	at	Lower Barrack Road	**2.5**	6200-05	7	1	X	1
2306	Flat Brook	at	Route 16	**3.1**	4700-	6	1	X	1
2294	Gardner Brook	Upstream	Route 89 and adjacent Slade Rd	**3.4**	3206-09	5	1	X	1
2311	Hall Meadow Brook	at	park access road bridge	**2.1**	6901	7	1	X	1
2297	Hemlock Valley Brook	at	Bone Mill Road	**3.0**	4016-11	5	1	X	1
2298	Hungerford Brook	parallel to Old Town Street	at mouth	**3.4**	4016-10	7	1	X	1
2312	Jakes Brook	at	Route 272	**2.1**	6902-02	5	1	X	1
2301	Kettle Brook	MDC east access road	at mouth	**1.8**	4308-13	7	1	X	1
2293	Knowlton Brook	Between	Cushman Rd and confluence with Squaw Hollow Brook	**2.9**	3205-01	6	1	X	1
2295	Mott Hill Brook	off Hunt Ridge Drive	at Private Drive for houses # 107-109	**2.2**	4008-03	6	1	X	1

2308	Muddy Brook	at	Hopyard Road	**2.9**	4800-06	6	1	X	1
1748	Pendleton Hill Brook	Upstream Grindstone Hill Road	Near Clarks Falls	**2.5**	1001-02	15	1	X	1
2303	Powder Brook	at old road crossing	access across from Locust Road off Route 72	**2.2**	4313	8	0	X	1
2302	Roaring Brook	MDC east access road	at mouth	**1.5**	4308-11	6	1	X	1
2299	Rugg Brook	US first road crossing from reservoir	at #224 Old Waterbury Turnpike	**1.9**	4302-04	6	1	X	1
766	Stickney Hill Brook	upstream	Brown road	**2.1**	3104	5	0	X	1
2331	Stonehouse Brook	off old trail	downstream Palmer Road	**2.7**	3204	5	1	X	1
2310	Whiting Brook	at	Under Mountain Road	**1.2**	6200-06	6	0	X	1

Table 15. Summary statistics for general chemical parameters from 30 least disturbed watersheds in Connecticut.

Parameter	unit	N	Mean	StDev	Minimum	Q1	Median	Q3	Maximum	Range
Chloride	PPM	118	8.2	7.8	0.6	3.84	6.58	11.77	73.3	72.7
Alkalinity	PPM	193	23.46	29.95	3.44	7.00	11.00	21.19	147.00	143.56
Hardness	PPM	192	27.36	29.52	5.00	11.00	16.00	27.00	151.00	146.00
Solids, Total	PPM	191	73.59	34.06	23.00	48.00	66.00	90.00	188.00	165.00
Solids, Total Susp.	PPM	191	5.56	6.84	2.00	2.00	2.00	7.00	45.00	43.00
Turbidity	NTU	193	1.68	2.42	0.19	0.50	0.97	1.91	21.70	21.51

Table 16. Summary statistics for nitrogen and phosphorous parameters 30 least disturbed watersheds in Connecticut.

Parameter	unit	N	Mean	StDev	Minimum	Q1	Median	Q3	Maximum	Range
Ammonia Nitrogen	PPM	193	0.013	0.009	0.002	0.005	0.011	0.017	0.047	0.045
Nitrate as Nitrogen	PPM	193	0.163	0.115	0.004	0.079	0.147	0.206	0.590	0.586
Nitrite as Nitrogen	PPM	192	0.002	0.001	0.002	0.002	0.002	0.002	0.007	0.005
Nitrogen + Nitrate	PPM	193	0.165	0.114	0.004	0.080	0.149	0.207	0.590	0.586
Nitrogen, Total	PPM	193	0.343	0.147	0.039	0.236	0.336	0.446	0.747	0.708
Organic Nitrogen	PPM	191	0.167	0.107	0.006	0.086	0.138	0.251	0.488	0.482
TKN	PPM	191	0.179	0.109	0.006	0.099	0.151	0.264	0.500	0.494
Orthophosphate	PPM	185	0.006	0.009	0.002	0.003	0.004	0.007	0.083	0.081
Phosphate, Total	PPM	193	0.016	0.018	0.003	0.007	0.011	0.020	0.170	0.167

Table 17. Water temperature data for stations sampled as part of the least disturbed watershed project. All values are degrees C and were collected during 2007.

station ID	5/21	5/23	5/30	6/5	6/6	6/11	6/12	6/19	6/26	7/9	7/10	7/11	7/17	7/25	7/31	8/7	8/9	8/14	8/28	9/18	9/19	9/21	9/24	9/25	9/28
766	12			17							**22**														
1236		15				18				**21**							**22**								
1239		12				17				19							20							15	
1435		15				18				**21**							20							14	
1748			14.4	16			18	16	17		19		18	18	20	20		18	19					15	
1941	13			17							19														
1981			16		16							24				**22**									
2291	13			17							22														
2293	14.5			17							21														18
2294	12			16							19														18
2295		13				17				17							15				9				
2296		10.5				18				18							19				12				
2297		13				17				19							**21**			12					
2298		13				17				20							20			12					
2299			16		15.5							20				19						14			
2301			13		13							18				18						12			
2302			12		13							19				18						12			
2303			13		14							20				19							13		
2304		14				17				18							18				9				
2305		13				17				18							20				12				
2306		13				16				17							19				10				
2307		13				17				19							20							17	
2308		13				18				18							19							15	
2309			14		14							20				19						14			
2310			12		12							17				17						14			
2311			16		13.5							23				21							13		
2312			14		14							19				18							13		
2331	16			18							24														
2334		16				20											19								
2342			14		16							20				20									

Appendix A. Selected land use attributes of catchments upstream of each sampling point selected for the least disturbed watershed project. The values were determined from data supplied by UConn CLEAR.

Station_ID	Site_Name	sqmi	IC_Pct	% Con. For.	% Dec. For.	% Devel.	% water	% strat. Drft.	Road Crossings/sq mile	Dams/sq mile	AVG river slope_%
766	Stickney Hill Brook	2.281	2.06	58.95	27.65	4.2	1.25	0.81	2.63	0	9.34
1236	Beaver Brook	8.253	2.43	1.466	78.853	4.4	1.13	20.36	3.03	0.73	12.33
1239	Burhams Brook	1.181	2.19	7.9	81.09	3.37	0	2.01	0.85	0	11.62
1435	Cedar Pond Brook	7.99	2.66	1.5	78.17	4.44	1.23	19.61	3	0.75	15.36
1748	Pendleton Hill Brook	4.016	2.51	2.7	76.72	4.94	0.29	9.64	1.25	0.75	13.99
1941	Bebbington Brook	2.177	3.24	2.17	55.46	6.46	0.86	7.31	5.97	0.46	10.96
1981	Carse Brook	5.402	2.43	0.66	84.99	4.72	0.96	4.36	3.15	0.37	11.88
2291	Branch Brook	4.888	1.97	65.78	18.88	3.74	1.86	3.18	3.68	0.2	10.15
2293	Knowlton Brook	6.842	2.89	1.24	73.13	6.26	2.51	0.84	5.55	1.46	14.65
2294	Gardner Brook	1.411	3.37	1.42	67.21	8.82	0.58	14.14	3.54	0	8.83
2295	Mott Hill Brook	2.82	2.17	1.97	83.75	3.08	1.2	7.59	2.48	0.71	9.05
2296	Beaver Meadow Brook	1.725	2.97	27.42	60.03	7.527	0.119	19.69	4.637	0	12
2297	Hemlock Valley Brook	2.794	3	5.53	65.14	6.9	1.89	7.03	2.86	0.72	15.7
2298	Hungerford Brook	2.67	3.41	1.35	69.16	8.52	0.24	2.55	4.87	0.37	12.53
2299	Rugg Brook	2.093	1.93	59.95	23.08	3.77	0.34	0.55	3.34	0.48	10.09
2301	Kettle Brook	1.485	1.77	63.53	31.37	3.03	0.24	0	3.38	0	15.15
2302	Roaring Brook	1.639	1.53	77.61	15.2	2.1	0.18	0	1.83	0	21.86
2303	Powder Brook	0.966	2.23	1	62.97	3.31	2.97	0	3.11	1.04	11.76
2304	Day Pond Brook	1.322	3.17	6.57	72.88	8.28	0.71	2.12	3.03	0.76	19.58
2305	Elbow Brook	0.901	2.67	0	87.66	5.98	0	1.52	3.33	0	11.6
2306	Flat Brook Central	2.439	3.09	1.1	81.88	7.44	0.18	3.19	4.51	0.41	20.73
2307	Early Brook	2.242	3.17	0.69	81.49	7.76	0.11	5.79	2.68	0	10.27
2308	Muddy Brook	1.338	2.91	7.26	79.04	6.71	0.64	0	5.23	0.75	15.9

Station_ID	Site_Name	sqmi	IC_Pct	% Con. For.	% Dec. For.	% Devel.	% water	% strat. Drft.	Road Crossings/sq mile	Dams/sq mile	AVG river slope_%
2309	Flat Brook North	2.787	2.45	15.24	68.84	4.97	0.11	0.4	2.87	0.36	13.94
2310	Whiting Brook	0.926	1.21	48.89	47.37	0.176	0.04	0	3.24	0	16.28
2311	Hall Meadow Brook	10.6	2.13	35.67	50.13	3.89	0.58	4.58	3.02	0.28	17.68
2312	Jakes Brook	1.62	2.08	23.09	63.94	3.6	0.09	0.25	2.47	0	12.25
2331	Stonehouse Brook	5.444	2.66	0.29	7.98	5.55	1.51	11.9	3.49	1.1	14.95
2334	Chatfield Hollow Brook	11.289	3.2	0.52	75.86	8.27	1.93	5.83	4.78	0.8	16.39
2342	Brown Brook	5.567	1.22	50.63	39.66	0.47	0.94	3.72	1.44	0.54	8.76

Appendix B. Ecological attributes for macroinvertebrate taxa identified from samples collected to support the least disturbed watershed project. Attributes are from the CT DEP 2008 master macroinvertebrate taxa list. Tol= modified Hilsenhoff Scale where the range is 0-10. 0 is not tolerant and 10 is most tolerant. FFG= Functional Feeding Group. PRD= predator, SCR= scraper, C-G= collector-gatherer, SHR= shredder, and C-F= collector-filterer. BCG= an attribute assigned via BPJ by consensus of regional biologists. The scale is 2 through 6. Taxa with attribute 2 are considered to be sensitive and 6 tolerant.

Class	Order	Family	Genus	finalID	Tol	FFG	BCG_Attribute
Arachnida	Trombidiformes	Limnocharidae	Rhyncholimnochares	Rhyncholimnochares	4	PRD	
Arachnida	Trombidiformes	Sperchonidae	Sperchon	Sperchon	4	PRD	4
Bivalvia	Veneroida	Pisidiidae		Sphaeriidae	8	C-F	4
Bivalvia	Veneroida	Pisidiidae	Pisidium	Pisidium	8	C-F	4
Clitellata	Lumbriculida	Lumbriculidae		Lumbriculidae	8	C-G	4
Enopla	Hoplonemertea	Tetrastemmatidae	Prostoma	Prostoma	8	PRD	4
Gastropoda	Basommatophora	Ancylidae		Ancylidae	6	SCR	4
Gastropoda	Basommatophora	Ancylidae	Ferrissia	Ferrissia	6	SCR	4
Gastropoda	Basommatophora	Ancylidae	Laevapex	Laevapex fuscus	5	SCR	4
Gastropoda	Basommatophora	Lymnaeidae	Pseudosuccinea	Pseudosuccinea columella	6	C-G	4
Gastropoda	Basommatophora	Physidae	Physa	Physa	8	C-G	4
Gastropoda	Mesogastropoda	Hydrobiidae	Amnicola	Amnicola limosa	8	SCR	5
Insecta	Coleoptera	Dryopididae	Helichus	Helichus	5	SCR	4
Insecta	Coleoptera	Elmidae		Elmidae	4	C-G	4
Insecta	Coleoptera	Elmidae	Macronychus	Macronychus glabratus	4	SHR	4
Insecta	Coleoptera	Elmidae	Optioservus	Optioservus	4	SCR	4
Insecta	Coleoptera	Elmidae	Optioservus	Optioservus ovalis	3	SCR	4
Insecta	Coleoptera	Elmidae	Oulimnius	Oulimnius	2	SCR	3
Insecta	Coleoptera	Elmidae	Oulimnius	Oulimnius latiusculus	4	C-G	3
Insecta	Coleoptera	Elmidae	Promoresia	Promoresia	3	SCR	3
Insecta	Coleoptera	Elmidae	Promoresia	Promoresia elegans	3	SCR	3
Insecta	Coleoptera	Elmidae	Promoresia	Promoresia tardella	3	SCR	3
Insecta	Coleoptera	Elmidae	Stenelmis	Stenelmis	5	SCR	4
Insecta	Coleoptera	Hydrophilidae	Cymbiodyta	Cymbiodyta	5	?	
Insecta	Coleoptera	Psephenidae	Ectopria	Ectopria	5	SCR	3
Insecta	Coleoptera	Psephenidae	Psephenus	Psephenus herricki	4	SCR	3
Insecta	Coleoptera	Ptilodactylidae	Anchytarsus	Anchytarsus bicolor	2	SHR	3
Insecta	Diptera	Athericidae	Atherix	Atherix	2	PRD	3

Class	Order	Family	Genus	finalID	Tol	FFG	BCG_Attribute
Insecta	Diptera	Ceratopogonidae	Bezzia	Bezzia group	6	PRD	3
Insecta	Diptera	Chironomidae	Apsectrotanypus	Apsectrotanypus	7	PRD	
Insecta	Diptera	Chironomidae	Brillia	Brillia	5	SHR	4
Insecta	Diptera	Chironomidae	Corynoneura	Corynoneura	7	C-G	3
Insecta	Diptera	Chironomidae	Cricotopus	Cricotopus	7	SHR	6
Insecta	Diptera	Chironomidae	Diamesa	Diamesa	5	C-G	4
Insecta	Diptera	Chironomidae	Eukiefferiella	Eukiefferiella	8	C-G	3
Insecta	Diptera	Chironomidae	Eukiefferiella	Eukiefferiella claripennis group	8	C-G	3
Insecta	Diptera	Chironomidae	Eukiefferiella	Eukiefferiella devonica group	8	C-G	3
Insecta	Diptera	Chironomidae	Eukiefferiella	Eukiefferiella tirolensis	8	C-G	3
Insecta	Diptera	Chironomidae	Limnophyes	Limnophyes	8	C-G	5
Insecta	Diptera	Chironomidae	Lopescladius	Lopescladius	6	C-G	
Insecta	Diptera	Chironomidae	Micropsectra	Micropsectra	7	C-G	3
Insecta	Diptera	Chironomidae	Micropsectra	Micropsectra/Tanytarsus	7	C-G	3
Insecta	Diptera	Chironomidae	Microtendipes	Microtendipes pedellus group	6	C-F	4
Insecta	Diptera	Chironomidae	Microtendipes	Microtendipes rydalensis group	6	C-F	4
Insecta	Diptera	Chironomidae	Nanocladius	Nanocladius	3	C-G	3
Insecta	Diptera	Chironomidae	Natarsia	Natarsia	8	PRD	
Insecta	Diptera	Chironomidae	Orthocladius	Orthocladius (Symposiocladius) lignicola	5	C-G	4
Insecta	Diptera	Chironomidae	Parachaetocladius	Parachaetocladius	2	C-G	
Insecta	Diptera	Chironomidae	Parachaetocladius	Parachaetocladius	2	C-G	3
Insecta	Diptera	Chironomidae	Parametriocnemus	Parametriocnemus	5	C-G	4
Insecta	Diptera	Chironomidae	Paratanytarsus	Paratanytarsus	6	C-F	4
Insecta	Diptera	Chironomidae	Polypedilum	Polypedilum	6	SHR	4
Insecta	Diptera	Chironomidae	Polypedilum	Polypedilum aviceps	6	SHR	4
Insecta	Diptera	Chironomidae	Polypedilum	Polypedilum fallax group	6	SHR	4
Insecta	Diptera	Chironomidae	Polypedilum	Polypedilum tritum	6	SHR	4
Insecta	Diptera	Chironomidae	Rheocricotopus	Rheocricotopus	6	C-G	3
Insecta	Diptera	Chironomidae	Rheotanytarsus	Rheotanytarsus exiguus group	6	C-F	4
Insecta	Diptera	Chironomidae	Rheotanytarsus	Rheotanytarsus pellucidus group	6	C-F	4

Class	Order	Family	Genus	finalID	Tol	FFG	BCG_Attribute
Insecta	Diptera	Chironomidae	Stempellinella	Stempellinella	4	C-G	3
Insecta	Diptera	Chironomidae	Stenochironomus	Stenochironomus	5	C-G	3
Insecta	Diptera	Chironomidae	Stilocladius	Stilocladius	6	C-G	3
Insecta	Diptera	Chironomidae	Tanytarsus	Tanytarsus	6	C-F	4
Insecta	Diptera	Chironomidae	Thienemanniella	Thienemanniella	6	C-G	4
Insecta	Diptera	Chironomidae	Thienemannimyia	Thienemannimyia group	7	PRD	4
Insecta	Diptera	Chironomidae	Tvetenia	Tvetenia bavarica group	5	C-G	4
Insecta	Diptera	Chironomidae	Tvetenia	Tvetenia vitracies group	5	C-G	4
Insecta	Diptera	Empididae		Empididae	6	PRD	4
Insecta	Diptera	Empididae	Hemerodromia	Hemerodromia	6	PRD	5
Insecta	Diptera	Simuliidae	Simulium	Simulium	5	C-F	5
Insecta	Diptera	Tabanidae		Tabanidae	6	PRD	4
Insecta	Diptera	Tabanidae	Hybomitra	Hybomitra	5	PRD	
Insecta	Diptera	Tipulidae	Antocha	Antocha	3	C-G	5
Insecta	Diptera	Tipulidae	Dicranota	Dicranota	3	PRD	3
Insecta	Diptera	Tipulidae	Hexatoma	Hexatoma	2	PRD	2
Insecta	Diptera	Tipulidae	Limnophila	Limnophila	3	PRD	2
Insecta	Diptera	Tipulidae	Limonia	Limonia	6	SHR	
Insecta	Diptera	Tipulidae	Tipula	Tipula	4	SHR	4
Insecta	Ephemeroptera	Baetidae	Baetis	Baetis	5	C-G	4
Insecta	Ephemeroptera	Baetidae	Baetis	Baetis flavistriga	4	C-G	4
Insecta	Ephemeroptera	Baetidae	Baetis	Baetis pluto	4	C-G	4
Insecta	Ephemeroptera	Baetidae	Baetis	Baetis tricaudatus	2	C-G	4
Insecta	Ephemeroptera	Baetidae	Diphetor	Diphetor hageni	5	C-G	
Insecta	Ephemeroptera	Baetidae	Heterocloeon	Heterocloeon	2	SCR	
Insecta	Ephemeroptera	Baetidae	Procloeon	Procloeon	4	C-G	
Insecta	Ephemeroptera	Ephemerellidae	Ephemerella	Ephemerella	1	C-G	3
Insecta	Ephemeroptera	Ephemerellidae	Eurylophella	Eurylophella funeralis	0	C-G	4
Insecta	Ephemeroptera	Ephemerellidae	Serratella	Serratella deficiens	2	C-G	3
Insecta	Ephemeroptera	Heptageniidae	Epeorus	Epeorus	0	SCR	2
Insecta	Ephemeroptera	Heptageniidae	Maccaffertium	Maccaffertium	3	SCR	4
Insecta	Ephemeroptera	Heptageniidae	Maccaffertium	Maccaffertium modestum group	4	SCR	4
Insecta	Ephemeroptera	Heptageniidae	Maccaffertium	Maccaffertium terminatum	4	SCR	4
Insecta	Ephemeroptera	Heptageniidae	Maccaffertium	Maccaffertium vicarium	2	SCR	2
Insecta	Ephemeroptera	Isonychiidae	Isonychia	Isonychia	2	C-G	3

Class	Order	Family	Genus	finalID	Tol	FFG	BCG_Attribute
Insecta	Ephemeroptera	Leptophlebiidae		Leptophlebiidae	2	C-G	2
Insecta	Megaloptera	Corydalidae	Corydalus	Corydalus cornutus	6	PRD	4
Insecta	Megaloptera	Corydalidae	Nigronia	Nigronia serricornis	4	PRD	3
Insecta	Megaloptera	Sialidae	Sialis	Sialis	4	PRD	3
Insecta	Odonata	Aeshnidae	Boyeria	Boyeria vinosa	2	PRD	4
Insecta	Odonata	Calopterygidae		Calopterygidae	5	PRD	4
Insecta	Odonata	Cordulegastridae	Cordulegaster	Cordulegaster	3	PRD	3
Insecta	Odonata	Cordulegastridae	Cordulegaster	Cordulegaster maculata	3	PRD	3
Insecta	Odonata	Gomphidae		Gomphidae	1	PRD	3
Insecta	Odonata	Gomphidae	Lanthus	Lanthus	5	PRD	3
Insecta	Odonata	Gomphidae	Lanthus	Lanthus parvulus	5	PRD	3
Insecta	Odonata	Gomphidae	Lanthus	Lanthus vernalis	5	PRD	3
Insecta	Odonata	Gomphidae	Ophiogomphus	Ophiogomphus	1	PRD	2
Insecta	Odonata	Gomphidae	Stylogomphus	Stylogomphus albistylus	0	PRD	3
Insecta	Odonata	Libellulidae		Libellulidae	9	PRD	
Insecta	Plecoptera	Capniidae	Paracapnia	Paracapnia	1	SHR	3
Insecta	Plecoptera	Chloroperlidae		Chloroperlidae	1	PRD	3
Insecta	Plecoptera	Chloroperlidae	Sweltsa	Sweltsa	0	PRD	3
Insecta	Plecoptera	Leuctridae	Leuctra	Leuctra	0	SHR	2
Insecta	Plecoptera	Peltoperlidae	Tallaperla	Tallaperla	0	SHR	2
Insecta	Plecoptera	Perlidae		Perlidae	1	PRD	3
Insecta	Plecoptera	Perlidae	Acroneuria	Acroneuria	0	PRD	3
Insecta	Plecoptera	Perlidae	Acroneuria	Acroneuria abnormis	0	PRD	3
Insecta	Plecoptera	Perlidae	Agnetina	Agnetina capitata	2	PRD	3
Insecta	Plecoptera	Perlidae	Eccoptura	Eccoptura xanthenes	0	PRD	3
Insecta	Plecoptera	Perlidae	Paragnetina	Paragnetina	1	PRD	3
Insecta	Plecoptera	Perlidae	Paragnetina	Paragnetina immarginata	1	PRD	3
Insecta	Plecoptera	Perlidae	Paragnetina	Paragnetina media	1	PRD	3
Insecta	Plecoptera	Perlodidae		Perlodidae	2	PRD	2
Insecta	Plecoptera	Pteronarcyidae	Pteronarcys	Pteronarcys	0	SHR	2
Insecta	Plecoptera	Taeniopterygidae	Taeniopteryx	Taeniopteryx	2	SHR	3
Insecta	Trichoptera			Trichoptera			
Insecta	Trichoptera	Apataniidae	Apatania	Apatania	3	SCR	3
Insecta	Trichoptera	Brachycentridae	Adricrophelps	Adicrophleps hitchcocki	2	SHR	2
Insecta	Trichoptera	Brachycentridae	Brachycentrus	Brachycentrus appalachia	0	C-F	3

Class	Order	Family	Genus	finalID	Tol	FFG	BCG_Attribute
Insecta	Trichoptera	Brachycentridae	Micrasema	Micrasema	2	SHR	3
Insecta	Trichoptera	Glossosomatidae		Glossosomatidae	0	SCR	4
Insecta	Trichoptera	Glossosomatidae	Agapetus	Agapetus	0	SCR	3
Insecta	Trichoptera	Glossosomatidae	Glossosoma	Glossosoma	0	SCR	4
Insecta	Trichoptera	Goeridae	Goera	Goera	0	SCR	2
Insecta	Trichoptera	Helicopsychidae	Helicopsyche	Helicopsyche borealis	3	SCR	2
Insecta	Trichoptera	Hydropsychidae		Hydropsychidae	4	C-F	
Insecta	Trichoptera	Hydropsychidae	Ceratopsyche	Ceratopsyche sparna	1	C-F	5
Insecta	Trichoptera	Hydropsychidae	Ceratopsyche	Ceratopsyche ventura	4	C-F	5
Insecta	Trichoptera	Hydropsychidae	Cheumatopsyche	Cheumatopsyche	5	C-F	5
Insecta	Trichoptera	Hydropsychidae	Diplectrona	Diplectrona	0	C-F	3
Insecta	Trichoptera	Hydropsychidae	Hydropsyche	Hydropsyche	4	C-F	5
Insecta	Trichoptera	Hydropsychidae	Hydropsyche	Hydropsyche betteni	6	C-F	5
Insecta	Trichoptera	Lepidostomatidae	Lepidostoma	Lepidostoma	1	SHR	2
Insecta	Trichoptera	Leptoceridae	Mystacides	Mystacides sepulchralis	4	C-G	
Insecta	Trichoptera	Leptoceridae	Oecetis	Oecetis persimilis	8	PRD	4
Insecta	Trichoptera	Limnephilidae		Limnephilidae	4	SHR	
Insecta	Trichoptera	Odontoceridae	Psilotreta	Psilotreta	0	SCR	2
Insecta	Trichoptera	Philopotamidae		Philopotamidae	3	C-F	
Insecta	Trichoptera	Philopotamidae	Chimarra	Chimarra aterrima	4	C-F	4
Insecta	Trichoptera	Philopotamidae	Dolophilodes	Dolophilodes	0	C-F	3
Insecta	Trichoptera	Polycentropodidae	Polycentropus	Polycentropus	6	PRD	3
Insecta	Trichoptera	Psychomyiidae	Lype	Lype diversa	2	SCR	4
Insecta	Trichoptera	Rhyacophilidae	Rhyacophila	Rhyacophila	0	PRD	3
Insecta	Trichoptera	Rhyacophilidae	Rhyacophila	Rhyacophila carolina	0	PRD	3
Insecta	Trichoptera	Rhyacophilidae	Rhyacophila	Rhyacophila fuscula	0	PRD	3
Insecta	Trichoptera	Rhyacophilidae	Rhyacophila	Rhyacophila manistee	0	PRD	3
Insecta	Trichoptera	Rhyacophilidae	Rhyacophila	Rhyacophila minora	0	PRD	3
Insecta	Trichoptera	Uenoidae	Neophylax	Neophylax	3	SCR	3
Malacostraca	Decapoda	Cambaridae		Cambaridae	6	C-G	
Malacostraca	Decapoda	Cambaridae	Cambarus	Cambarus	6	C-G	4
Malacostraca	Decapoda	Cambaridae	Orconectes	Orconectes limosus	6	C-G	
Oligochaeta	Lumbricina	Lumbricina	Lumbricina	Lumbricina	8	C-G	4
Oligochaeta	Tubificida	Tubificidae		Tubificidae w/ cap setae	10	C-G	
Turbellaria				Turbellaria	4	PRD	4

Appendix C. Description of statistical assumptions for cluster analysis, nonmetric multidimensional scaling, and indicator species analysis.

EPT Macroinvertebrate and Fish Cluster Analysis

The proportional abundance of EPT taxa was used in a EPT taxa by siteID data matrix (68 species x 24 sites). For fish, the proportional abundance of species by site ID was used in a species by Site ID data matrix (30 species by 30 sites). For both EPT taxa and fish species, proportional abundance data were arcsine square-root transformed to improve normality. Rare species, those that occurred less than 5% of the samples, were removed from the analysis as suggested by McCune and and Grace (2002). This step eliminated 24 species from the EPT analysis and 9 taxa from the fish species matrix. For fish, diadromous species Atlantic salmon (*Salmo salar*) and American eel (*Anguilla rostrata*) were eliminated from the matrix as well as small (<3 cm) undetermined minnow species (Cyprinidae), and stocked salmonids. The resultant 44 EPT taxa by 24 site matrix for EPT and 17 fish species by 30 sites matrix were used in subsequent analysis. The Sorensen distance measure with the flexible beta linkage method (beta = -0.25) was used in all cluster analyses.

Indicator species analysis was used as an objective criterion to choose the level of pruning for the dendrogram. *p*-values, were determined using the Monte Carlo tests (10,000 permutations) and were averaged for all species after pruning the cluster dendrogram into 2, 3, 4, 5, 6, 7 clusters (McCune and Grace 2002). For EPT taxa, three clusters returned the lowest average *p* value=0.29098 of the 44 indicator species and was therefore used to develop 3 macroinvertbrate stream classes. For fish, dendrograms were pruned to 3 clusters (average *p* value=0.18059 for 17 species) to develop 3 fish stream classes.

We used Wishart's objective function and percent information remaining statistic to choose the three sites classes using EPT and fish species. Wishart's objective function indicates how similar or dissimilar sites are to each other based on Bray-Curtis dissimilarity. The percent information remaining statistic indicates the relative distance between sites as defined by the location of the dendrogram branches. Sites that span a short distance of percent information remaining have more homogeneous taxa than sites than span a greater distance.

EPT Macroinvertebrate and Fish Nonmetric Multidimensional Scaling
We used the autopilot (slow and thorough) function in PC Ord to ensure and optimal NMS solution.

Initial run assumptions are as follows:

NMS Fish
Autopilot Slow and Thorough
Ordination of Stations in Species space. 30 Stations 17 Species

The following options were selected:
1. SORENSEN = Distance measure

2. 6 = Number of axes (max. = 6)
3. 500 = Maximum number of iterations
4. RANDOM = Starting coordinates (random or from file)
5. 1 = Reduction in dimensionality at each cycle
6. 0.20 = Step length (rate of movement toward minimum stress)
7. USE TIME = Random number seeds (use time vs. user-supplied)
8. 250 = Number of runs with real data
9. 250 = Number of runs with randomized data
10. YES = Autopilot
11. 0.000000 = Stability criterion, standard deviations in stress
over last 10 iterations.
12. THOROUGH = Speed vs. thoroughness

OUTPUT OPTIONS

13. NO = Write distance matrix?
14. NO = Write starting coordinates?
15. NO = List stress, etc. for each iteration?
18. NO = Plot stress vs. iteration?
17. NO = Plot distance vs. dissimilarity?
16. NO = Write final configuration?
19. UNROTATED = Write varimax-rotated or unrotated scores for graph?
20. YES = Write run log?
21. NO = Write weighted-average scores for Species ?

EPT NMS Slow and Thorough
Ordination of Stations in Species space. 24 Stations 44 Species

The following options were selected:

ANALYSIS OPTIONS

1. SORENSEN = Distance measure
2. 6 = Number of axes (max. = 6)
3. 500 = Maximum number of iterations
4. RANDOM = Starting coordinates (random or from file)
5. 1 = Reduction in dimensionality at each cycle
6. 0.20 = Step length (rate of movement toward minimum stress)
7. USE TIME = Random number seeds (use time vs. user-supplied)
8. 250 = Number of runs with real data
9. 250 = Number of runs with randomized data
10. YES = Autopilot
11. 0.000000 = Stability criterion, standard deviations in stress
over last 10 iterations.
12. THOROUGH = Speed vs. thoroughness

OUTPUT OPTIONS

13. NO = Write distance matrix?
14. NO = Write starting coordinates?
15. NO = List stress, etc. for each iteration?
18. NO = Plot stress vs. iteration?

17. NO = Plot distance vs. dissimilarity?
16. NO = Write final configuration?
19. UNROTATED = Write varimax-rotated or unrotated scores for graph?
20. YES = Write run log?
21. NO = Write weighted-average scores for Species ?

Final Solution Fish taxa

NMS Plot for fish.
SORENSEN = Distance measure
Number of runs with real data = 1
Dimensionality assessed with Scree Plot of final stress and number of dimensions
13.55602 = final stress for 3-dimensional solution
0.00000 = final instability
99 = number of iterations
R Squared

Axis	Increment	Cumulative
1	.159	.159
2	.270	.429
3	.366	.795

Final Solution EPT taxa

NMS Plot for EPT Taxa
SORENSEN = Distance measure
Number of runs with real data = 1
Dimensionality assessed with Scree Plot of final stress and number of dimensions
11.29188 = final stress for 3-dimensional solution
0.00000 = final instability
141 = number of iterations

R Squared

Axis	Increment	Cumulative
1	.364	.364
2	.367	.731
3	.150	.881

Appendix D. Ecological attributes for fish species identified in samples collected to support the least disturbed watershed project. Species are sorted alphabetically by Family then Genus species. Trophic guild are TC= top carnivore, GF= generalist feeder, BI= benthic invertivore, WC= Water column invertivore, PF= parasitic feeder. Flow guild are FD= fluvial dependant, MG= macrohabitat generalist, and FS= fluvial specialist. Pollution tolerance are T= tolerant, M= moderately tolerant, I= Intolerant.

Family	Scientific Name	Common Name	Species Code	Origin	Trophic Guild	Habitat Use	Pollution Tolerance
Anguillidae	Anguilla rostrata	American eel	AE	Native	TC	FD	M
Catostomidae	Catostomus commersoni	White sucker	WS	native	GF	FD	T
Centrarchidae	Lepomis auritus	Redbreast sunfish	RS	native	GF	MG	I
Centrarchidae	Lepomis cyanellus	Green sunfish	GR	exotic	GF	FD	T
Centrarchidae	Lepomis gibbosus	Pumpkinseed	PS	Native	GF	MG	M
Centrarchidae	Lepomis macrochirus	Bluegill sunfish	BG	exotic	GF	MG	M
Centrarchidae	Micropterus dolomieu	Smallmouth bass	SM	exotic	TC	MG	M
Centrarchidae	Micropterus salmoides	Largemouth Bass	LM	exotic	TC	MG	M
Cottidae	Cottus cognathus	Slimy sculpin	SC	native	BI	FS	I
Cyprinidae	Cyprinidae	Unknown minnow	UCY		GF		
Cyprinidae	Luxilus cornutus	Common shiner	CS	native	GF	FD	M
Cyprinidae	Notemigonus crysoleucas	Golden shiner	GS	native	GF	MG	T
Cyprinidae	Rhinichthys atratulus	Blacknose dace	BL	native	GF	FS	T
Cyprinidae	Rhinichthys cataractae	Longnose dace	LD	native	BI	FS	I
Cyprinidae	Semotilus atromaculatus	Creek chub	CR	native	GF	MG	T
Cyprinidae	Semotilus corporalis	Fallfish	FF	native	GF	FS	T
Esocidae	Esox americanus	Redfin pickerel	RP	Native	TC	MG	M
Esocidae	Esox niger	Chain pickerel	CP	native	TC	MG	M
Gadidae	Lota lota	Burbot	LL	Native	TC	FS	I
Ictaluridae	Ameiurus natalis	Yellow bullhead	YB	exotic	GF	MG	T
Ictaluridae	Ameiurus nebulosus	Brown bullhead	BB	Native	GF	MG	T
Percidae	Etheostoma fusiforme	Swamp darter	SD	native	BI	MG	I
Percidae	Etheostoma olmstedi	Tesselated darter	TD	Native	BI	FS	M
Percidae	Perca flavescens	Yellow perch	YP	native	TC	MG	M
Salmonidae	Oncorynchus mykiss hatcheryis	Rainbow trout, Stocked	RW	exotic	TC	FD	I
Salmonidae	Salmo salar hatcheryis	Atlantic salmon, fry stocked	SA	native	TC	FS	I
Salmonidae	Salmo trutta	Brown trout, naturalized	WBN	native	TC	FD	I
Salmonidae	Salmo trutta hatcheryis	Brown trout, stocked	BN	exotic	TC	FD	I
Salmonidae	Salvelinus fontinalis	Brook trout, wild	WBK	native	TC	FS	I
Salmonidae	Salvelinus fontinalis hatcheryis	Brook trout, stocked	BK	native	TC	FS	I