Biological Assessment of Foundry Brook and Clove Creek

Based on benthic macroinvertebrate sample analysis

Prepared for
Hudson Highland Land Trust

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SUMMARY

In July 2019, the Hudson Highlands Land Trust assessed 2 streams (Foundry Brook and Clove Creek) in the lower Hudson River watershed to determine baseline water quality at previously unassessed sites and to compare water quality trends at a previously studied site. A total of eight sites were assessed (four sites on each stream).

Physical, chemical and biological parameters were used to determine that three of the sites were non-impacted. Another three sites were slightly impacted and two of the sites were moderately impacted, based on the benthic macroinvertebrate community. The most likely source of impact at the sites was either from organic, municipal/industrial inputs, and/or impoundment effects.

The NYS DEC SBU Quality Assurance Work Plan (Duffy, 2018) for biological stream monitoring procedures for data collection and analysis were followed.

BACKGROUND

Foundry Brook is an approximately 6.5 mile long brook arising from the Cold Spring Reservoir and flowing south east into the Hudson River at Foundry Cove. The watershed covers approximately 5.5 square miles. Approximately 91% is forested and 9% is urban with an estimated 1.75% as impervious surface.

Clove Creek is an approximately 14 mile long creek arising from the Clarence Fahnestock State Park initially flowing southeast then turning north and eventually flowing into the Fishkill Creek. The watershed covers approximately 20 square miles. Approximately 92% is forested and 8% is urban with an estimated 2.6% as impervious surface.

A map of the site locations and watershed boundary is available at this link: https://drive.google.com/open?id=1FarcgPFL_SqIS8oqKBLEzhI3GGbQpOwk&usp=sharing

New York State has over 52,000 river miles, but due to limited resources, the NYS Department of Environmental Conservation (DEC) has completed assessments on only 16.5% of these rivers. The last time an assessment was conducted at Foundry Brook and Clove Creek, at a single site, was in 2002 with the water quality determined to be slightly and non-impacted respectively.

All waterbodies in the United States are classified by the US Environmental Protection Agency according to designated usage, as mandated by the Clean Water Act. Each classification must meet certain chemical and biological parameters, and discharge into a waterbody that alters those parameters, thereby impairing its designated usage, is not permitted. The classification of (T) or (TS) indicates the waterbody is suitable for trout survival or trout spawning. Foundry Brook sections are either class C(T) or A(T) designated. Clove Creek sites are all classified as C(TS).

Table 1

Classification	Narrative
C	"The best usage of Class C waters is for fishing. These waters shall be suitable for fish propagation and survival. The water quality shall be suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes".
A	In addition to class C waters usage "The Class A waters are assigned to waters used as a source of drinking water".
T and TS	"T waters shall be suitable for trout fish survival and TS waters shall be suitable for trout fish survival and propagation".

See Google map for site locations:
https://drive.google.com/open?id=1FarcgPFL_SqIS8oqKBLEzhI3GGbQpOwk&usp=sharing

METHODS

Each site was evaluated for percent canopy cover, current speed, percent of rock, rubble, gravel, sand, and silt, and the embeddedness of the substrate. The depth and width of the stream were also measured.

Water temperature (accuracy ± 0.2° C); specific conductance (range of 0 – 100 mS with a resolution of 4 digits); pH, with a range of 2 to 12 units (accuracy ± 0.2 units); and dissolved oxygen, with a range of 0 to 50 mg/L and an accuracy of ±0.2 mg/L, were obtained at each site using a YSI® 556 probe following the manufacturer calibration guidelines.

For physical and chemical data results see appendix.

Macroinvertebrate samples were collected at each site using an 800-900 micron mesh kick net (9 by 18 inch). Samples were collected by disturbing the substrate by foot upstream of the net and continuing over a five-meter transect for five minutes, as described in the Quality Assurance Work Plan for Biological Stream Monitoring in New York State (Duffy, 2018). Samples were separately preserved in 95% ethyl alcohol and were then sub-sampled in the lab by randomly selecting 15 cc of detritus from the sample and examining it under a dissecting microscope. Invertebrates larger than 1.5 mm were removed until 100 organisms were obtained for each sample. Macroinvertebrates were identified to genus/species level to determine the water quality category for each site and to determine the Impact Source Determination (ISD) described by Riva-Murry et al. (2002).

The metrics used to determine water quality were those recommended by the NYS DEC Stream Biomonitoring Unit.

The expected variability of single sample macroinvertebrate sampling results is stated in Smith and Bode (2004).

The five community metrics utilized were: Species Richness (Plafkin et al. 1989), EPT richness (Lenat, 1987), Hilsenhoff's Biotic Index (Hilsenhoff, 1987), Percent Model Affinity (PMA) (Novak and Bode, 1992) and Nutrient Biotic Index (NBI-P) (Smith et al. 2007). See table 2.

Table 2

Multi metrics used for kick samples and Biological Assessment Profile	
Species Richness (SR)	is the total number of taxa found in the sub-sample. Higher richness values are mostly associated with clean water conditions.
EPT Richness (EPT)	is the number of different species or taxa in the three most pollution sensitive orders: Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies) that are present. Generally, the more EPT taxa, the better the water quality or the better the habitat. However, some pristine headwater streams may be naturally low in richness, due to a relative lack of food (quantity and different types) and generally lower abundance of organisms.
Biotic Index (BI)	is the Hilsenhoff Biotic Index and is calculated by multiplying the number of individuals of each species or taxa by its assigned tolerance value, summing these products, and dividing the total number of individuals. Tolerance values range from intolerant (0) to tolerant (10). High BI values are suggestive of organic (sewage) pollution, while low values indicate a lack of sewage effects.
Percent Model Affinity (PMA)	is a measure of similarity to a model non-impacted community based on percent abundance of seven major groups. The lower the similarity value the greater the impact.
Nutrient Biotic Index NBI-P	is calculated by multiplying the number of individuals of each species or taxa by its assigned tolerance value, summing these products, and dividing the total number of individuals. Tolerance values range from intolerant (0) to tolerant (10). High NBI values are suggestive of excessive phosphorus and resultant impacts to the habitat, while low values indicate a lack of phosphorus effects.
Biological Assessment Profile (BAP)	is the assessed impact for each site. The BAP score is the mean value of the above 4 metrics after converting each metric score to a common scale of 0 - 10. The higher the BAP score the better the assessed impact category. There are four impact categories in NYS: non-, slightly, moderately, or severely impacted.

The score for each particular metric from each site was used to calculate each site's Biological Assessment Profile (BAP) by converting each metric score to a common scale of 0 – 10. The BAP score categorizes the overall water quality assessment into one of four categories: non-, slightly, moderately, or severely impacted (Bode et al. 2002). See table 3.

Table 3

Abridged NYS DEC BAP water quality category definitions	
Non-impacted (BAP score >7.5 – 10)	Indices reflect very good water quality. The macroinvertebrate community is diverse. Water quality should not be limiting to fish survival or propagation. This level of water quality includes both pristine habitats and those receiving discharges which minimally alter the biota.
Slightly impacted (BAP score >5 - 7.5)	Indices reflect good water quality. The macroinvertebrate community is slightly but significantly altered from the pristine state. Water quality is usually not limiting to fish survival, but may be limiting to fish propagation, especially sensitive coldwater fish taxa.
Moderately impacted (BAP score >2.5 - 5)	Indices reflect poor water quality. The macroinvertebrate community is altered to a large degree from the pristine state. Water quality often is limiting to fish propagation, but usually not to fish survival.
Severely impacted (BAP score 0 - 2.5)	Indices reflect very poor water quality. The macroinvertebrate community is limited to a few tolerant species. The dominant species are almost all tolerant, and are usually midges and worms. Often 1-2 species are very abundant. Water quality is often limiting to both fish propagation and fish survival.

Impact Source Determination (ISD) was calculated for each site. ISD compares test site communities to model communities empirically derived from macroinvertebrate data; the greater the similarity of a test site community to a model community, the more likely a particular impact source is affecting the test community. Data is most conclusive if a test community exhibits at least 50% similarity to a model community (Bode et al. 2002). Riva-Murray et al. (2002) found that ISD correlated well with impairment sources inferred from chemical, physical, and watershed characteristics, and biomonitoring results.

See appendix for the macroinvertebrate taxa list, BAP and ISD results for each site.

RESULTS

Foundry Brook: Two sites were slightly-impacted by the Biological Assessment Profile (BAP); two were moderately impacted (see appendix). Impact Source Determination (ISD) suggested natural, organics, impoundment, and municipal/industrial inputs as the likely impact sources. (See Figure 1 and appendix).

Foundry Brook sites dissolved oxygen concentration ranged from 5.1 to 8.8 mg/l, and dissolved oxygen percent saturation ranged from 62.6 to 95%. Water temperature ranged from 18.53 to 25.3 degrees Celsius; specific conductance ranged from 82 to 166 μmhos/cm; and pH ranged from 6.7 to 7. See appendix for a chemical summary chart.

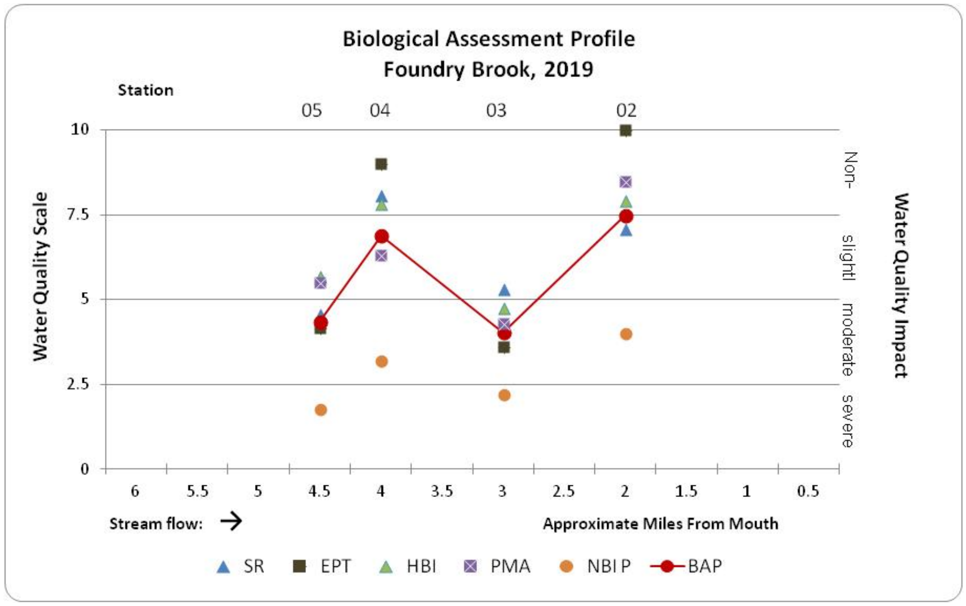

Figure 1 Multi-metric and BAP graph of Foundry Brook sample sites.

Clove Creek: One site was slightly-impacted by the Biological Assessment Profile (BAP); three were non-impacted (see appendix). Impact Source Determination (ISD) suggested natural conditions at the non-impacted site and the slightly-impacted site ISD was less conclusive. (see Figure 2 and appendix).

Clove Creek sites dissolved oxygen concentration ranged from 8 to 8.8 mg/l, and dissolved oxygen percent saturation ranged from 93.1 to 102.7%. Water temperature ranged from 20.44 to 23.47 degrees Celsius; specific conductance ranged from 82 to 464 μmhos/cm; and pH ranged from 7.1 to 7.7. See appendix for the chemical summary chart.

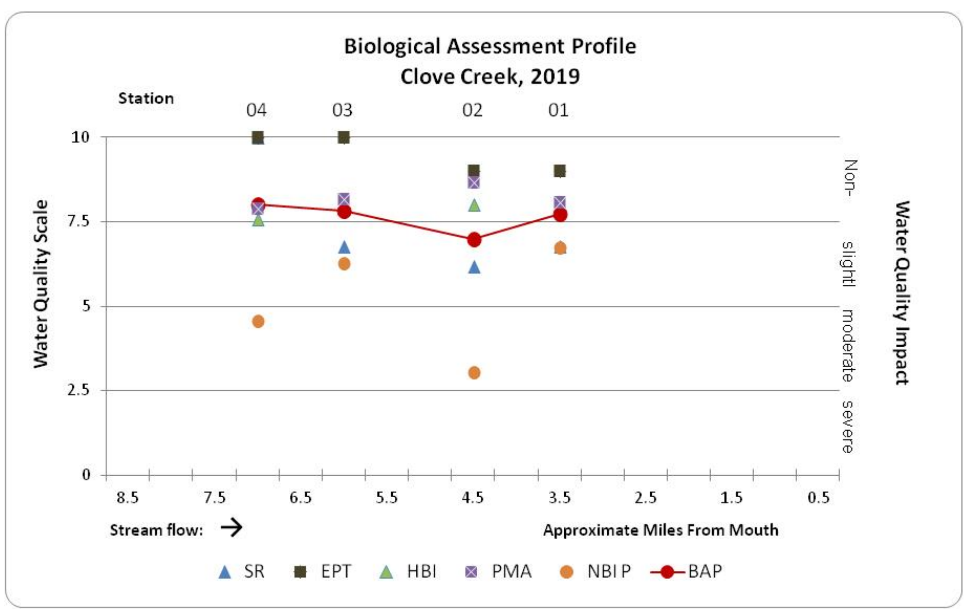

Figure 2 Multi-metric and BAP graph of Clove Creek sample sites.

DISCUSSION

The effects of lake outlets, impoundments, and land use on benthic macroinvertebrate community structure and water quality have been well-documented (Hynes, 1975; Allan, 1995; Roy et. al., 2003; Ometo et al., 2000; Tate and Heiny, 1995; Imert and Stanford, 1996) (see Rational for Data Collected). These anthropomorphic influences appear to be influencing the water quality of both Foundry Brook and Clove Creek, based on resident benthic macroinvertebrate community structures, at several testing sites.

Foundry Brook site 05 is located below Cold Spring Reservoir and Barett Pond. The influence of these impoundments is manifested on the downstream resident benthic macroinvertebrate community structure at site 05 (increased suspended food resources and increased water temperature). The overabundance (48%) of the filter feeding benthic macroinvertebrate family Hydropsychidae; Hydropsyche *betteni* and Cheumatopsyche *sp.* is indicative of the suspended food resources, phytoplankton, made available by the impoundments. The paucity of the intolerant stenothermic benthic macroinvertebrate orders Ephemeroptera and Plecoptera is notable. Water temperature was 25.35 degrees Celsius, the highest temperature recorded among all the Foundry Brook sites, and exceeding optimal water temperature for this class trout stream by ~7 degrees Celsius. The overall water quality score (BAP), is 4.33 which indicates moderately impacted water quality. ISD indicated impoundment, organics, and municipal/industrial inputs as the most likely impact sources.

The water quality rebounds at FDRY 04, located downstream of FDRY 05, and has a diverse benthic macroinvertebrate community structure (species richness of 28 unique taxa) compared to FDRY 05 (17 unique taxa). The family Hydropsychidae percent abundance dropped to 24% (1/2 the number compared to FDRY 05). FDRY 04 also supports four genera of the stenothermic and intolerant stonefly Plecoptera: Sweltsa *sp*. Leuctra *sp*. Perlesta *sp*. and Isoperla *sp*. The water temperature dropped by over 5.5 degrees Celsius (19.79 degrees Celsius) compared to the FDRY 05 site. The overall water quality score (BAP) is 6.87 which indicates slightly impacted water quality. ISD was less conclusive.

FDRY 03 is located downstream of FDRY 04 and appears, by satellite to be located just below a wetland or impoundment (see Google map https://drive.google.com/open?id=1FarcgPFL_SqIS8oqKBLEzhI3GGbQpOwk&usp=sharing). The BAP score drops to 4.02 indicating moderately impacted water quality. Species richness declines to 19 unique taxa and the sample is dominated (52% of the sample) by the crustaceans Caecidotea *sp*. and Hyalella *sp.* both tolerant groups to excessive organic enrichment inputs. There is a complete loss of the stenothermic and intolerant order of Plecoptera compared to upstream site FDRY 04. ISD indicated organic enrichment as the most likely impact source.

FDRY 02 is the furthest downstream site. Species richness rebounds, compared to FDRY 03, to 25 unique taxa with 15 unique species within the sensitive order of Ephemeroptera, Plecoptera, and Trichoptera (EPT). The reappearance of the stenothermic sensitive Plecoptera Leuctra *sp*. and the greater diversity of EPT taxa are notable compared to the upstream sites. The BAP score is 7.49 indicating slightly impacted water quality although this score is near the non-impacted category (non-impacted >7.5 - 10). ISD indicates a naturally influenced community structure.

Clove Creek site CLVC 04 is located just east of Hubbard Lodge and is the furthest upstream site sampled on Clove Creek. The species richness was diverse with 35 unique taxa identified in the subsample with an additional five unique species identified in the post subsample scan. Of the 35 species nineteen species were within the sensitive orders of Ephemeroptera, Plecoptera, and Trichoptera (EPT multimetric group). The sensitive Plecoptera (stonefly) Pteronarcys *sp*. was also noted in the post subsample scan (not identified within the subsample). Specific conductance was recorded at 82 μS/cm indicating low ions dissolved in the water (see Rational for Data Collected). Based on the benthic macroinvertebrate community structure the BAP multimetric score is 8 (the highest score achieved in this study) indicating non-impacted water quality. ISD indicates a naturally influenced community structure. Site CLVC 04 represents a model reference community and a water quality level that other Clove Creek sites can achieve.

Site CLVC 03 is located approximately 1.25 miles downstream from CLVC 04 just below East Mountain Road South bridge. The BAP, compared to the upstream site CLVC 04, indicated non-impacted water quality (7.82) however there was a notable decline in the Species Richness metric of 11 taxa compared to CLVC 04. Within the Ephemeroptera Order there is the appearance and a notable percent abundance (15%) of the filter feeding Isonychia *bicolor* compared to CLVC 04 site. ISD indicates a naturally influenced community structure. The specific conductance increases to 230 μS/cm, compared to CLVC 04, indicating an increase in dissolved ions within the water column. Residential and commercial land use is noted to increase on both sides of the creek in this section between CLVC 04 and 03 sites. The increased urban areas and its associated runoff appear to be exerting changes in the benthic macroinvertebrate community structure and water quality at this site.

CLVC 02 is located approximately 1.1 miles downstream of CLVC 03. This section of Clove Creek continues through a residential and commercial landscape which continues to exert an influence on Clove Creeks water quality. The specific conductance increases to 439 μS/cm, compared to CLVC 03. Total species richness declines to 22 unique taxa and the EPT richness declines to 13. The BAP falls to 6.92 indicating slightly impacted water quality. The community structure is similar to CLVC 04 however ISD is less conclusive as to the most likely impact source/s.

Clove Creek site CLVC 01 is just over 0.75 miles downstream from CLVC 02 and located just above Mill Road bridge. This section between CLVC 02 and 01 has less urban area along its course, particularly along its eastern bank, compared to the section between CLVC 03 and 02 (see Google Map: https://drive.google.com/open?id=1FarcgPFL_SqIS8oqKBLEzhI3GGbQpOwk&usp=sharing). Specific conductance increases to 464 µS/cm an increase not as pronounced as occurs between sites CLVC 04, 03, and 02. Species richness increases to 24 and the EPT richness remains the same compared to the upstream site CLVC 02. The percent filter feeding mayfly, Isonychia *bicolor*, increases in sample dominance to 25%. Despite all this the BAP score does improve with a score of 7.72 rebounding back into the non-impacted water quality category. The ISD indicates a naturally influenced community structure. NYS DEC Stream Biomonitoring Unit previously assessed this site, in 2002, as non-impacted.

In summary: impoundments and organic inputs are the most likely source of impact at two sites on Foundry Brook while urban and residential non-point source runoff appear to exert an influence at two sites on Clove Creek. It is beyond the scope and intent of this study to address all potential anthropogenic influences that may be adversely impacting the water quality at sites sampled. See the Appendix: General Watershed Solutions for some basic suggestions that, when implemented, may improve Foundry Brook's and Clove Creek's water quality.

Glossary

Anthropogenic: caused by man

Assessment: a diagnosis or evaluation of water quality

Benthic: located on the bottom of a body of water or in the bottom sediments or pertaining to bottom-dwelling organisms

Benthos: organisms occurring on or in the bottom substrate of a waterbody

Biomonitoring: the use of biological indicators to measure water quality

Diel cycle: referring to the 24 hr day

Eutrophic: very enriched with dissolved nutrients, resulting in increased growth of algae and other microscopic plants.

Impact: a change in the physical, chemical, or biological condition of a waterbody

Impairment: a detrimental effect caused by an impact

Index: a number, metric, or parameter derived from sample data used as a measure of water quality

Intolerant: unable to survive poor water quality

Macroinvertebrate: a larger-than-microscopic invertebrate animal that lives at least part of its life in aquatic habitats

Mesotrophic: moderately enriched with dissolved nutrients, resulting in increased growth of algae and other microscopic plants.

Non point source: diffuse pollution sources (i.e., without a single point of origin or not introduced into a receiving stream from a specific outlet)

Oligotrophic: few nutrients and relatively few plants and algae.

Periphyton: are algae that grow on a variety of submerged substrates, such as rocks, plants or debris, in lakes or streams

Point source: a stationary location or fixed facility from which pollutants are discharged or emitted. Also, any single identifiable source of pollution, e.g., a pipe, ditch, ship, ore pit, factory smokestack

Rapid bioassessment: a biological diagnosis of water quality using field and laboratory analysis designed to allow assessment of water quality in a short turn-around-time; usually involves kick sampling and laboratory subsampling of the sample

Site: a sampling site on a waterbody

Stenotherms: organisms having a very narrow thermal tolerance and preferring cooler temperatures

Survey: a set of sampling conducted in succession along a stretch of stream

Tolerant: able to survive poor water quality

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Appendix

Rationale for Data Collected

Physical

The *physical survey* is essential to a stream study because aquatic fauna often have specific habitat requirements independent of water composition, and alterations in these conditions affect the overall quality of a water body (Giller and Malmqvist, 1998). Additionally, the physical characteristics of a stream affect stream flow, volume of water within the channel, water temperature, and absorbed radiant energy from the sun.

Testing sites are evaluated for: stream depth, width, and current speed; aquatic vegetation; percent substrate and embeddedness; and percent stream canopy cover. Site photos were taken of the upstream and downstream area and are included with the physical and chemical data.

W*ater temperature* directly affects both the nature of aquatic fauna and species diversity; temperature tolerance is organism specific, and the reproductive cycle (including timing of insect emergence and annual productivity) will vary within different temperature ranges. Temperature can also affect organisms indirectly as a consequence of oxygen saturation levels. As water temperature rises, the metabolism of aquatic organisms increases, with an attendant increase in their oxygen requirements. At higher water temperatures, however, the oxygen carrying capacity of water decreases because of a diminished affinity of the water for oxygen. Optimal water temperature ranges and lethal limits of water temperature vary among different organisms. The ratio of Plecoptera to Ephemeroptera (individuals and numbers of species) has been found to drop as the annual range of temperature increases (Hynes, 1970). The optimal temperature range for Brook trout is 11-16° Celsius with an upper lethal limit of 24° Celsius (Hynes, 1970). NYS DEC does not have a water quality standard for water temperature.

Temperature was recorded using a YSI 556 probe.

Velocity was calculated at the time of macroinvertebrate collection because an optimal macroinvertebrate collection site has a velocity between 0.45 and 0.75 meter/second. Velocity was determined using a Global Water® Flow Probe.

Percent cobble embeddedness, the degree to which gravel-sized and larger particles are surrounded by sand-sized and smaller particles, is an indicator of a stream's ability to support trout survival and propagation. If deposition of sediment occurs in spawning areas, it can be detrimental to trout reproduction. Trout eggs require a well-oxygenated environment; the eggs are laid in permeable gravel beds with many open spaces to allow continuous bathing of the eggs with cool, oxygenated water. Sediment deposition destroys this environment by clogging these open spaces, leading to oxygen deprivation and buildup of metabolic waste. When cobble embeddedness reaches 50-60%, a stream loses its salmonid fry. Furthermore, although habitat quality is still considered fair for trout survival (though not propagation) at 50-75% embeddedness, changes in the bethnic macroinvertebrate fauna population, on which trout feed; begin to occur (Harvey, 1989).

Chemical

Dissolved Oxygen (DO) level is a function of water turbulence, diffusion, and plant respiration. The EPA recommends that dissolved oxygen levels remain above 11 mg/l during embryonic and larval stages of salmonid production and above 8 mg/l during other life stages (EPA, 1987). The NYS DEC standard for dissolved oxygen for class C(T) and C(TS) stream is 6 mg/L and 7 mg/L respectively.

A significant drop in DO concentration can occur over a 24-hour period, particularly if a waterbody contains a large amount of plant growth. Oxygen is released into the water as a result of plant photosynthesis during daylight; dense plant growth within a stream can therefore elevate the DO level significantly. At night photosynthesis ceases and DO may drop to levels maintained by diffusion and turbulence. A pre-dawn DO level will, in this case, reflect the lowest DO concentration in a 24 hour period and thus provide important data on the overall health of the system.
DO was measured using an YSI® 556 probe.

It is also important to consider *percent oxygen saturation*, since dissolved oxygen levels vary inversely with water temperature. Percent saturation is the maximum level of dissolved oxygen that would be present in the water at a specific temperature in the absence of other influences, and is determined by calculating the ratio of measured dissolved oxygen to maximum dissolved oxygen for a given temperature. (The calculation is also standardized to altitude or barometric pressure.) Percent oxygen saturation falls when something other than temperature, such as dissolved solids or bacterial decomposition, affects oxygen levels.

A healthy stream contains near 100 percent oxygen saturation at any given temperature (Hynes, 1970).Trout are particularly sensitive to even a slight drop in oxygen saturation and will migrate away from streams when oxygen saturation falls. Similarly, certain macroinvertebrates are sensitive to varying saturation levels and because the ability of these organisms to migrate away from the changing conditions is limited a drop in saturation can be lethal. NYS DEC has not adopted percent oxygen saturation as a water quality standard.

Specific Conductance or Conductivity is a measure of the ability of an electrical current to pass through a stream; it is dependent on both the concentration of dissolved electrolytes within the water and water temperature. When inorganic ions are dissolved in water, conductivity increases. Organic ions, such as phenols, oil, alcohol and sugar, can decrease conductivity (EPA, 1997). Warmer water is also more conductive and, therefore, conductivity is reported for a standardized water temperature of 25 degrees Celsius. Measurements are reported in microsiemens per centimeter (μS/cm).

In the United States, freshwater stream conductivity readings vary greatly from 50-1,500μS/cm. The conductivity of most streams remains relatively constant, however, unless an extraneous source of contamination is present. A failing septic system would raise conductivity because of its chloride, phosphate, and nitrate content, while an oil spill would lower conductivity.

A YSI™ 556 probe was used to measure conductivity.

The *pH* is a measure of a stream's acidity. A desirable pH for salmonid is 6.5-8.5. A YSI® 556probe used to obtain pH. The NYS DEC standard for pH is 6.5-8.5.

Biological

Macroinvertebrates are collected by kick net and the specimens are preserved. Pollution-sensitive *macroinvertebrates*, a food source for trout, require similar chemical parameters as trout. The relative numbers of different macroinvertebrate groups indicate the overall health of an ecosystem. Perhaps more importantly, macroinvertebrate data demonstrate the effects of problems that may not be detected by chemical testing.

The NYS DEC Stream Biomonitoring Unit has utilized stream biological monitoring and water quality analysis since 1972 but the biological profiles and water quality assessments are not a part of the state's standards. They serve as a "decision threshold" to determine the need for further studies.

The Environmental Protection Agency recommends that states and tribes with biomonitoring experience adopt biological criteria into water quality standards to provide a quantitative assessment of a waterway's designated and supportive use. Currently only five states have done so; NY is not one of these states.

General Watershed Solutions

General Development

Permeable pavements that simulate natural ground conditions reduce runoff, trap pollutants and return water to aquifers. Permeable pavements are more expensive, rougher and weaker than conventional pavement, but allow flow rates of up to 18 gallons per minute. These surfaces are most appropriate for low volume drives, sidewalks and parking lots, particularly near streambeds. Residents can also be encouraged to consider them for home driveways, walkways and patios.

Buffer zones of native plants (after eradicating invasive species, where necessary) and grass swales diminish runoff in areas where pavement doesn't encroach the water, and provide a protective barrier between developed areas and freshwater systems. Mowing up to a stream bank should be discouraged. New construction should leave for a protective riparian zone between the structure and freshwater systems.

Individual landowners and businesses should be encouraged to consider installation of rain gardens and landscaping that encourages seepage and discourages runoff, and green roofs that reduce runoff, reduce urban temperatures and improve water quality.

Dams

Dams (impoundments) that have been built simply for esthetic purpose serve no vital function (e.g. power generation or water supply for a population), are detrimental to stream health and should be removed. In areas where a dam is to remain intact, fish ladders should be considered to facilitate natural fish migration.

Litter

Often a pervasive problem is areas. Campaigns to educate the public and change community practices must be part of the solution, and might include "stick and carrot" incentives for detrimental or cooperative action by community members. Simplifying beneficial practices by providing easy access to waste and recycling receptacles/centers, sponsoring school education and initiative programs, instituting public service announcements and social media campaigns and organizing community cleanup days might help to bolster community support for best management practices.

Chemical parameters, Multi-metric, BAP, & ISD tables

Site	FDRY 05	FDRY2 04	FDRY3 03	FDRY4 02	CLVC 04	CLVC5 03	CLVC6 02	CLVC7 01
Date Collect	09-Jul-19	09-Jul-19	09-Jul-19	09-Jul-19	09-Jul-19	09-Jul-19	09-Jul-19	09-Jul-19
Temp C	25.35	19.79	18.53	20.28	23.01	23.47	22.01	20.44
SC µmhos/cm	82	121	166	164	82	230	439	464
DO mg/l	5.14	8.69	5.94	8.77	7.98	8.72	8.45	8.79
DO % Sat	62.6	95.1	63.4	95	93.1	102.7	96.4	97.7
Baropressure mm	748	753.6	754.7	756.6	753.8	755.7	755.6	757
pH	7	6.67	6.75	6.77	7.07	7.17	7.41	7.67

Site	DATE	Species Richness	EPT Richness	HBI	PMA	NBI P	BAP Score	WQ Category
FDRY 05	7/9/2019	17	4	5.96	52	7.29	4.33	moderately
FDRY 04	7/9/2019	28	13	4.19	57	6.72	6.87	slightly
FDRY 03	7/9/2019	19	3	6.7	45	7.12	4.02	moderately
FDRY 02	7/9/2019	25	15	4.09	74	6.4	7.49	slightly
CLVC 04	7/9/2019	35	19	4.44	68	6.18	8	non
CLVC 03	7/9/2019	24	17	4.11	71	5.49	7.82	non
CLVC 02	7/9/2019	22	13	4.01	76	6.78	6.97	slightly
CLVC 01	7/9/2019	24	13	3.96	70	5.31	7.72	non

ISD score results are %

Site	Date	Impoundment	Municipal/Industrial	Natural	Non-point source	Organics	Siltation	Toxins
FDRY_05	09-Jul-19	69	65	28	59	66	48	50
FDRY_04	09-Jul-19	44	35	44	43	41	48	30
FDRY_03	09-Jul-19	26	35	22	30	53	24	35
FDRY_02	09-Jul-19	28	27	54	32	32	43	29
CLVC_04	09-Jul-19	47	46	53	43	38	44	47
CLVC_03	09-Jul-19	24	22	54	31	31	34	24
CLVC_02	09-Jul-19	18	13	48	23	20	30	10
CLVC_01	09-Jul-19	41	40	64	47	34	38	41

Impact Source Determination (ISD) was calculated for each station. ISD compares test station communities to model communities empirically derived from macroinvertebrate data; the greater the similarity of a test station community to a model community, the more likely a particular impact source is affecting the test community. Data is most conclusive if a test community exhibits at least 50% similarity to a model community (Bode et al. 2002).

Field and Lab Data Summary Sheets