



Department of
Environmental
Conservation

FISHERY-INDEPENDENT MONITORING FOR THE DELAWARE TAILWATERS, 2018-2020

**Prepared for the Fisheries Investigation Plan
for the Delaware Tailwaters**

February 28, 2018

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The New York City (NYC) reservoir tailwaters in the upper Delaware River Basin are an increasingly popular destination water for wild trout fishing. The need for present date trout population data has been identified by the Fisheries Investigation Plan for the Delaware Tailwaters (West Branch Delaware River, East Branch Delaware River, and Delaware River; Figure 1). The New York State Dept. of Environmental Control (NYSDEC) and Pennsylvania Fish and Boat Commission (PFBC) have agreed to support a fishery-independent electrofishing monitoring surveys in the Delaware tailwaters over next three-year term, 2018 – 2020. The intent is to ensure characterization of the present-day trout population; such that anomalous weather or other unforeseen influences do not unduly slant perceptions that could occur under a “once-and-done” synoptic investigation.

Goals/Objectives

Estimates of the following population characteristics are needed for wild brown and rainbow trout in the Delaware tailwaters.

1. Relative abundance of adult and young-of-year (YOY) Brown and Rainbow trout
 - a. Standardize estimates to improve precision and accuracy, by reducing variability associated with collection and environmental variables
 - b. Evaluation of spatial-temporal variability
2. Size distribution of brown and rainbow trout populations (from individual fish length and weight measurements)
 - a. Evaluation of frequency of occurrence of legal and trophy sized trout within the population
 - b. Evaluation of condition factor of trout population
3. Age structure of brown and rainbow trout populations
4. Growth and natural mortality rates

Monitoring Reaches

The sampling effort is focused in the West Branch, given the higher rates of reservoir releases relative to the East Branch. Further, the large river widths of the Delaware River preclude effective electrofishing, particularly for adults, eliminating consideration of those sites for purposes of annual monitoring of adult trout. When documented seasonal movement patterns are taken into account, West Branch population monitoring offers insight into the overall Delaware tailwaters stock status. However, future evolution of monitoring efforts, may seek to include sites (possibly as fixed or randomly selected) in the East Branch.

Survey Design

Annual monitoring will occur at a series of fixed-sites (Table 1). Access to suitable sampling locations remains a limitation in the Delaware tailwaters. Tributary and tailwater shorelines are generally limited to open-to-public fishing accesses¹. Historic sites identified by NYSDEC and PFBC will be included. Seventeen backpack fixed-sites (Figure 2a), five within West Branch main stem reaches, two within the Delaware River main stem reaches, and ten in tributaries (Figure 2b), were chosen over a random survey design. Similarly, trailered boat access in the West Branch is limited with alternative walk-in sites for non-tailored vessels. Night-time boat operation/navigation of the West Branch is not logistically feasible for sampling alternative sites without public access; thus, night-boat monitoring is also restricted to fixed-site sampling specifically within the West Branch main stem reaches (n = 4).

Sampling will specifically target both YOY sized trout (<125 mm TL) and all trout sizes (i.e., YOY, yearlings, and adults). To address trout spawning and movement behaviors (McBride et al. 2002), sampling will encompass both selected tributaries to the West Branch and West Branch main stem reaches. Both main stem shorelines and tributaries will be sampled using backpack electrofishing methodology; whereas main stem thalweg/side main channels/shorelines, will employ night-boat electrofishing methodology. The intent of backpack electrofishing is to ensure representative sampling of YOY trout, though yearlings and adult sized trout will also be documented. Night-boat electrofishing, while successfully capturing all sizes of trout, tends to under-represent YOY relative abundance, given the need to sample deep waters for larger-sized trout.

An extended sampling period is necessary to ensure representative sampling. Once-a-month sampling, beginning April through October has been defined as the sampling period. Sampling dates are reflective of the time-period when Rainbow Trout are expected to be migrating upriver from the Delaware River into the West Branch tributaries during springtime; and when Delaware River summertime water temperatures potentially encourage trout into the West Branch seeking thermal refugia. By taking advantage of known movement patterns, limiting sampling to only the West Branch will still likely provide adequate representation of adult trout relative abundance for the tailwaters.

Annual characterization of defined fixed-sites is crucial for the long-term success of any monitoring program intending to describe population trends. In addition to the swept area sampled, annual variation of habitat within the fixed-site may impact the occurrences of trout and hence, inferences on their relative abundance. For example, chronic sedimentation may eventually render a fixed-site that was initially prime trout habitat into unsuitable habitat. Thus, a declining trend in relative abundance at that site may be more related to a fixed-site degradation rather than a decline in the overall trout population. During the 2017 season, extensive review and experimental sampling for designation of fixed-sites occurred to document initial habitat conditions. Included within these protocols are metrics for annually documenting changes of habitat to aid in interpretation of relative trout population annual trends.

Fixed-site Descriptions

¹ http://www.dec.ny.gov/docs/fish_marine_pdf/pfrwestbranch.pdf;
http://www.dec.ny.gov/docs/fish_marine_pdf/pfreastbranch.pdf

Backpack Electrofishing Monitoring

Young-of-the-year trout will be specifically targeted using day-time back-pack (i.e., DC) electrofishing gear type. Each fixed-site will be sampled as a single-pass. Within main stem tailwater sites, shallow, flowing waters along/near the shorelines will be targeted. Site lengths are variable. Based on a priori determinations, the historical backpack main stem sites will remain as 300 m total length; but, upriver main stem sites and all tributary sites are 100 m total length (Table 1; Figures 3-19). The intent of retaining the longer length sites at downriver locations, allows for a greater probability for capturing YOY trout, in habitats where they are typically uncommon to rare occurrences. Scarcity of YOY trout at downriver main stem sites, may not be reflective of annual production, but rather a function of habitat suitability in any given year. At upriver main stem sites and tributary sites, YOY trout are commonly captured, thus not requiring the exceptionally lengthy sites for successful capture of YOY trout. Flagged start/end points will be maintained at each backpack fixed-site to ensure consistency of swept area.

Sampling is expected to occur at all sites (n = 17) once-a-month, July – October (Table 2). A total of 68 independent samples are anticipated annually. All sampling will be accomplished within a single week of each month, concomitantly with night-boat electrofishing monitoring. Sampling dates are reflective of the time-period when both YOY Brown Trout and YOY Rainbow Trout are susceptible to back-pack electrofishing gear. Typically, a total of 30 - 45 minutes is required to accomplish each site, allowing six to seven sites being completed in a day. All backpack fixed-sites will begin no earlier than one hour after official sunrise and no later than one hour prior to official sunset.

Night-boat Electrofishing Monitoring

All sizes of trout, inclusive of YOY, yearlings, and adults, will be targeted via night-boat electrofishing for only West Branch main stem fixed-sites (Table 1; Figures 20-23). Electrofishing will occur during the night-time to reduce trout avoidance, allowing higher probability of capture; and safety concerns of using high-voltage electricity around anglers fishing the pools in the daytime. Electrofishing, using pulsed direct current (DC), will concentrate sampling either along the banks and/or the mid-channel/thalweg to maximize trout capture. Two electrofishing runs will be accomplished at each site. The separate runs will be considered as independent samples. Trout are to be held within in-river live cars after the first run to prevent duplicate sampling during the second run.

Sampling is expected to occur at all sites (n = 4) once-a-month, April – October (Table 2). A total of 56 independent samples are anticipated annually. All sampling will be accomplished within a single week of each month, concomitantly with backpack electrofishing surveys. Sampling is expected to require 1 – 2.5 hours of electrofishing and another 1 – 3 hours of processing. Depending on processing efficiencies, the doubling up of two night-boat sites into one night may be beneficial to avoid unfavorable weather and/or reduce monetary costs associated with travel; otherwise only one night-boat site per night will be scheduled. Night-time sampling will begin approximately one hour after official sunset.

Site lengths are anticipated to be approximately constant among surveys. Yet, river conditions may dictate total site lengths. For example, low river stage may prevent navigating a dewatered, or shallow reach. Distance traveled for each sampling run will be measured via a GPS track.

Sampling Protocols

Backpack Electrofishing Monitoring

- The starting point is at the downstream end, with electrofishing progressing upstream
 - Within main stem sites, shallow (< 0.3 m), flowing habitat is targeted
 - Within tributary sites, all available trout habitats are to be surveyed
 - ✓ Within wider tributaries, a sinusoidal pattern may be necessary and/or doubling back to adequately survey all available habitat
 - ✓ Care should be given to ensure all trout habitats (i.e., shoreline woody debris, root wads, boulder velocity breaks, etc.) are adequately electrofished.
- All captured YOY and yearling, adult trout are temporarily held (i.e., portable live car) when electrofishing
- All collected trout are processed, as needed, or at the end of the site, depending on density within the portable live car
- Habitat and other meteorological parameters are recorded after electrofishing on the day of sampling
- Water quality parameters (e.g., water temperature, etc.) are measured on the bottom, in water depths where YOY were successfully captured or expected to be captured unless otherwise noted in the Recorded Parameters section
 - Flow rate (cfs) is determined using balls, and time distance traveled.

Night-time Boat Electrofishing Monitoring

- Electrofishing will begin at the upriver most point of the pool into the head riffle, proceeding downriver to the top of the pool tail-out riffle
 - If necessary buoys can be deployed prior to sunset to mark start/end points
- Sampling will proceed in a sinusoidal pattern to encompass bank to mid-channel habitat
- Dependent on vessel type the maximum number of netters that can safely be onboard, will be necessary to reduce potential saturation
 - NYSDEC, cartopper: 1 bow netter, 1 operator
 - PFBC, trailered boat, 2 bow netters, 1 operator
- All trout (YOY and adult sizes) are to be netted and temporarily placed into a live tub amidships
- All trout will be transferred to in-stream live cars prior to initiating subsequent electrofishing runs
- Habitat and other meteorological parameters are recorded after electrofishing on the day of sampling
- Water quality parameters (e.g., water temperature, etc.) are measured within the thalweg, unless otherwise noted in the Recorded Parameters section
 - Flow rate (cfs) is determined estimated using DRBC basin tool and/or nearest USGS gage

Fish Processing/Weight-Scale Sub-sampling

- Processing fish for gathering biological data will occur after all electrofishing has been accomplished or dependent on the fish densities within the live cars
 - If excessive numbers of trout are being captured, to the point of filling the live car(s), electrofishing will be temporarily halted to focus on sample processing
 - All trout processed prior to the completion of electrofishing will be marked (e.g., caudal fin clip) to ensure against duplicate sampling

- All trout, regardless of size/age, will be identified to species and measured for total length (TL) to nearest millimeter (mm)
- All captured legal-sized (> 300 mm TL) trout will be scanned for presence of PIT tag captured from either tributaries or West Branch main stem sites.
 - If a PIT tag is detected, only total length and weight (g) will be recorded along with the PIT tag number
 - Within tributaries sites, if no PIT tag is detected in legal-sized trout (tributaries: > 175 mm; West Branch main stem: > 300 mm TL), the fish will be measured for total length, total weight, scales taken for ageing, a PIT tag will be inserted, and the adipose fin clipped
- Total weight and scale (for ageing) samples will be sub-sampled only for those trout captured during night-time boat electrofishing, that are not legal-sized (< 300 mm TL)
 - Non-legal-sized trout may also be PIT tagged, depending on availability of smaller tags
 - All trout, excepting YOY (< 125 mm TL), will need to be scanned/tagged as per legal-sized trout, using the smaller tags

Sub-sampling for weight/scales

Length-weight relationships and individual trout ages will be estimated from sub-sampling of captured trout, per species, in addition to those scales collected via PIT tagged trout. Weight and age frequencies of the sub-samples will then be applied to each month's catch. Only catches from the night-boat electrofishing surveys will be prosecuted for weight and scale sub-sampling. As needed, age of any adult trout caught from the backpack electrofishing surveys can be estimated from age-length keys derived from the night-boat electrofishing surveys.

- A total of ten (10) individuals, per species, will be processed for total weight (g) and scales, per 25 mm length group (e.g., 100 – 124, 125 – 149, 150 – 174, 175 – 199, etc.)
 - All trout PIT tagged will be measured for total weight and scales taken for age determination regardless of the total sampling frequencies
 - Recaptured PIT tagged trout will not have scales taken
- Sub-sampling is cumulative for all night-boat electrofishing sites, for every two months' time-period. Thus, when a size group is filled (i.e., 10 individuals have been sampled), then no more weights/scales will be recorded/collected for that size class, until the next period of sampling.
 - Trout can be exceptionally fast growing; such that, a small-sized trout captured early in the sampling period, may be nearly the same age as a larger trout captured towards the end of the same growing period (i.e., summer)
 - Bimonthly collection of scales and generation of age-length keys will reduce miss-assignment of the late season capture of larger trout as incorrectly older trout.
 - Bimonthly weight/scale sampling is defined as:
 - ✓ April - May
 - ✓ June – July
 - ✓ August – October

Recorded parameters

Recorded parameters will generally follow NYSDEC data sheet recorded parameters. Those parameters listed in Appendix A are considered essential. These will be populated for each fixed-site. Thus, for night-boat electrofishing fixed-sites, each recorded parameter will be noted per run.

Milestone Table

The timelines for work tasks are outlined in the table below. Interim reports are anticipated as descriptive summaries of work accomplished from the previous year. The final report, inclusive of the 2020 field season, will summarize all three years of data collection. Time-series trend analysis and data standardization are anticipated to occur within the three-year final report.

YEAR/TASK	PERSONNEL (MINIMUM REQUIRED)	J	F	M	A	M	J	J	A	S	O	N	D
2018													
Backpack electrofishing monitoring	NYDEC 2 Biologists, 3-4 days/month, ~ 10 hrs. PFBC 1 Biologist, 3-4 days/month, ~ 10 hrs.							✓	✓	✓	✓		
Night-boat electrofishing monitoring	NYDEC 2 Biologists, 3-4 days/month, ~ 8 hrs. PFBC 1 Biologist, 3-4 days/month, ~ 8 hrs.				✓	✓	✓	✓	✓	✓	✓		
Scale processing (age interpretation)	2 Biologists (1 each agency), TBD time commitment											✓	✓
Data analyzes	2 Biologists (1 ec agency), TBD time commitment											✓	✓
2019													
2018 Interim report	2 Biologists (1 each agency)	✓	✓										
Backpack electrofishing monitoring	NYDEC 2 Biologists, 3-4 days/month, ~ 10 hrs. PFBC 1 Biologist, 3-4 days/month, ~ 10 hrs.							✓	✓	✓	✓		
Night-boat electrofishing monitoring	NYDEC 2 Biologists, 3-4 days/month, ~ 8 hrs. PFBC 1 Biologist, 3-4 days/month, ~ 8 hrs.				✓	✓	✓	✓	✓	✓	✓		
Scale processing (age interpretation)	2 Biologists (1 each agency), TBD time commitment											✓	✓
Data Analysis	2 Biologists (1 ec agency)												
2020													
2019 Interim report	2 Biologists (1 each agency)	✓	✓										
Backpack electrofishing monitoring	NYDEC 2 Biologists, 3-4 days/month, ~ 10 hrs. PFBC 1 Biologist, 3-4 days/month, ~ 10 hrs.							✓	✓	✓	✓		
Night-boat electrofishing monitoring	NYDEC 2 Biologists, 3-4 days/month, ~ 8 hrs. PFBC 1 Biologist, 3-4 days/month, ~ 8 hrs.				✓	✓	✓	✓	✓	✓	✓		
Scale processing (age interpretation)	2 Biologists (1 each agency), TBD time commitment											✓	✓
Data Analysis	2 Biologists (1 ec agency)												
2021													
Final report	2 Biologists (1 each agency)	✓	✓	✓	✓								

Data Organization

- All collected data will be recorded on the NYSDEC standard data entry forms.
- The EPA Rapid Bioassessment form (Barbour et.al. 1999) will also be populated, per site to capture embeddedness and sedimentation, as per those protocols.
- All data will be entered and stored in NYSDEC data base, excepting tributary sites within Pennsylvania, which will be entered into PFBC resource data base
 - Sherman Creek Back-pack upper site
 - Balls Creek Back-pack site
 - Shehawken Creek Back-pack upper and lower sites
- Summary MS Excel spreadsheets, inclusive of all site specific physical and biological data, will be generated from the respective data bases for data analysis.
 - Summary spreadsheets will be maintained separately by year of survey, with individual tab within a spreadsheet representing a site.
- Quality control/assurance will follow agency specific internal protocols.

Data Analysis

Relative Abundance

- Trout abundance will be expressed as CPUE (fish/hr.) for each independent sample by gear type
 - Graphical illustrations of CPUE will be used to explore potential spatial-temporal variation
- Species-specific YOY CPUE will be generated from backpack electrofishing monitoring, only
 - Total combined estimate, inclusive of all tributary and main stem sites
 - Partitioned by tributary and main stem estimates.
 - The two fixed-sites located within the Delaware River main stem will be specifically excluded, given the infrequent catches in potentially thermal fringe YOY habitats.
- Species-specific estimates of adult abundances will be generated from both the backpack and night-boat electrofishing monitoring
 - Tributary estimates encompass only backpack electrofishing
 - ✓ Relative trout abundance, by species, will be partitioned based on YOY size (< 125 mm TL), only
 - Main stem estimates will be limited solely to night-time boat electrofishing fixed-sites
 - ✓ Relative trout abundance, by species, will be partitioned based on size
 - ↪ All sizes combined
 - ↪ legal-sized trout (> 12 inches)
 - ↪ ≥16 inches
 - ↪ ≥20 inches trout, by species.
- Species-specific annual relative abundance will be expressed as geometric means separately for YOY and adult size categories
 - Individual CPUEs are natural log transformed, plus one, and averaged among the fixed-sites, by year.
 - Confidence intervals (95%) about annual estimates will aid in determining significant deviations among years.
 - Basic benchmarks, such as the time-series mean, median and quartiles all provide a frame of reference for the status of the trout population.
 - ✓ No management actions are presently, associated with any benchmarks.
 - Use of geometric means reduces the occurrence of a single value unduly influencing resultant estimations of relative abundance.
- The assumption of electrofishing monitoring data as a metric of population change requires critical evaluation. Other influential factors may potentially unduly influence resultant monitoring CPUE estimates, unrelated to any potential changing of a population trend. Standardization of annual relative abundance indices can be accomplished by utilization of a generalized linear model (GLM). This approach accounts for variability associated with collection and/or environmental influences by removal of significant covariates from the residual sums-of-squares.
 - Data standardization via GLM requires multiple years of sampling. Thus, data standardization will be delayed until the proposed 3-year data collection has been completed.
 - Initial GLM models will be inclusive of variables likely to account for catchability and environmental influences on the catch rate at the time-of-capture.
 - Non-contributing variables will be removed from the GLM based on their F-statistic probability significance in a stepwise fashion.

- Separate GLMs will be developed for characterizing annual juvenile production and total trout population.

Size Distribution

- Total length will be expressed as a percent frequency of contribution, by species, and gear type
 - Distributions will be illustrated monthly and annually, separated by gear type and river reach
 - Descriptive statistics including mean, mode, and quartiles will be used to examine spatial-temporal variation of size distributions
- Total weight distributions, by species, will only include the night-boat electrofishing sampling; and characterized in a similar manner as total length.
- Length-weight and condition factor will be evaluated from the individual PIT tagged trout.
 - Spatial-temporal trends will be examined with the intent to evaluate characterizing declines/improvement of condition potentially relating to poor/favorable environmental conditions, respectively. Specific comparisons will be dependent the extent of variation fishes encountered during the three-year survey.

Age Distribution and Growth/Mortality Estimation

- Individual trout age will be interpreted from scale microstructure.
 - Processing scale ages will follow those discussed in AFS Fisheries Techniques (Murphy and Willis 1996)
 - Interpretation of age will be based on a single experienced reader.
 - Given the proposed targeted total number of PIT tagged trout (tributaries: N = 1,000, West Branch main stem: N = 1,000) sub-sampling for scales (i.e., ageing) will need to be further refined/reduced to avoid excessive processing. Ideally total number of scales for processing annually should not exceed 500 samples.
 - ✓ A random selection of scales taken from PIT tagged trout will be sub-sampled based on the bi-monthly schedule.
 - ✓ If necessary further sub-sampling (i.e., five trout/ length group, bi-monthly) may be required to reduce the total number of scales to be processed to keep the work load reasonable.
- Bimonthly age-length keys (i.e., three/year) will be generated as the collective of all aged scales, within each year
 - All trout catch will be assigned an age, based on the bimonthly age-length key of time-of-capture
- Age distribution will be expressed as the collective of all captured trout, as assigned ages via age-length keys or directly by scale interpretation within each year surveyed
 - Annual age distribution will be expressed as percent frequency of contribution per age class
 - Separate age distributions are anticipated to be developed by gear type and tributary sites vs. main stem sites
- Mean-size-at-age will be estimated per year, by trout species
 - Estimates will be based on the combined night-boat electrofishing sites only, for the entire sampling period
- Growth is assumed to be expressed by the Von Bertalanffy model (AFS Fisheries Techniques)
 - Growth rate (i.e., k) and theoretical maximum size (i.e., L infinity) will be estimated as the combined collective of all aged scales from night-boat electrofishing sites only
- Total mortality (Z) estimates will be calculated using a bias-correction Chapman and Robson (1960) mortality estimator described in Smith et al., (2012) from night-boat electrofishing sites only

$$Z = \log_e \left(1 + \bar{T} - T_c - \frac{1}{N} \right) - \frac{(N-1)(N-2)}{N[N(\bar{T} - T_c) + 1][N + N(\bar{T} - T_c) - 1]}$$

where:

\bar{T} is the mean age of fish in the sample greater than or equal to age T_c

T_c is age of full recruitment

N is the sample size of fish greater than or equal to age T_c

PIT Tagging and Redd Counts

As outlined in the Investigation Plan, a PIT tag and redd count study will be completed concurrently with the electrofishing study described here. This electrofishing survey will serve a role in the PIT tag study for collecting fish for tagging and for monitoring movement through recapture identified through handheld PIT tag readers. Plans have been developed that describe the objectives and methods of these studies.

Personnel

It is intended for this proposed monitoring to be easily facilitated; yet, sampling effort is dictated by availability of personnel resources. Monitoring is being proposed as a collaborative effort between NYSDEC and PFBC. Back-pack electrofishing, targeting YOY trout, minimally requires two personnel. Boat electrofishing is typically an effective sampling gear for adult trout, which requires three personnel (boat operator and two netters). It is anticipated all sampling be accomplished in a single week per month. Concomitant YOY and adult sampling dates were derived when possible to limit personal requirements. Thus, on the three weekday dates dedicated to both YOY and adult sampling, three people will be needed; versus, the remaining two weekday dates dedicated solely to YOY sampling, which requires only a minimum of two people to accomplish. The anticipated large number of PIT tagged trout may dictate more personnel being committed to processing catches. Coordination of sampling will occur with National Park Service, Upper Delaware Scenic and Recreational River (NPS-UPDE) to assist with electrofishing and sample processing.

Data analyzes and report writing will be a joint exercise between NYSDEC and PFBC.

Literature Cited

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish, second edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Fisheries Investigation Plan for the Delaware Tailwaters 2018-2020, New York State Department of Environmental Conservation and Pennsylvania Fish and Boat Commission, 2017

Murphy, B.R., and D.W. Willis, editors. 1996. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Appendix A - Recorded parameters for electrofishing surveys

Recorded parameters will generally follow NYSDEC data sheet recorded parameters. Those parameters list below are considered essential. These will be populated for each fixed-site. Thus, for night-boat electrofishing fixed-sites, each recorded parameter will be noted per run.

- Date (mm/dd/yy) – sampling date
- Start time (hh:mm AM/PM) – starting time electrofishing was initiated
- Site name – Descriptor/ID number of each site as assigned by NYSDEC statewide database
- Crew – listing of personnel accomplishing work
- Electrofisher
 - Make/Type
 - DC volt output
 - Amp output
 - Pulse width (if available)
 - Pulse-per-second (if available)
- Number of netters
- Site length (m) as measured by GPS tracks; anticipated as a proxy of swept area
- Time electrofished (sec)
- Electrofishing efficiency Rated (1 -3)
 - 1: No problems encountered to reduce overall crew efficiency
 - 2: Some minor problems that reduce efficiency overall (e.g., sun glare causing visibility problems, crew not as experienced with electrofishing or physically tiring causing the missing of trout capture, water clarity is not the best, but still somewhat see bottom, etc.);
 - 3: Major limitations precluding effective electrofishing (e.g., bottom not visible, crew movement or capture of trout is highly impaired due to thick SAV/sediment; high flows, etc.). A scoring of this value may be cause for excluding the sample from subsequent data analyzes.
- Water clarity/visibility classification
 - Clear: clearly see bottom
 - Weakly turbid (tea): Can see the bottom, but rocks appear as shapes, not clearly seen. Still have fair chance to spot YOY trout; not/nominal impairment to crew electrofishing efficiency
 - Strongly turbid (coffee): Bottom is mostly not visible, moderate impairment of crew electrofishing efficiency; but still able to identify YOY Trout, mostly in the upper water column
 - Highly turbid (chocolate): Cannot see below the surface; bottom is not visible; crew electrofishing efficiency highly impaired
- Secchi depth (m) in water being electrofished (expected to correlate with water clarity)
- Water depth (m) in the surveyed area; expected to equal secchi depth, if bottom is clearly visible
- Water temperature (oC): measured within the survey area on the bottom

- pH, if available
- D. O. (mg/l and/or percent saturation); if available
- Cloud cover (percentage of visible sky)
- General description of prevailing weather conditions (e.g. scattered showers, strong northerly wind, etc.)
- Shoreline vegetation (type, sparse/dense/ percent cover)
- Shade cover on the water (percentage)
- Instream habitat cover (type, sparse/dense/percent cover), e.g., SAV, Didymo. Should add to 100%
- Bottom substrate (type, percent cover by type, embeddedness): bedrock, boulder, cobble, woody debris. Should add to 100%
- Embeddedness – as per EPA RBP score (Barbour et. Al. 1999)
- Sedimentation – as per EPA RBP score (Barbour et. Al. 1999)
- Flow rate (cfs) as measured by one of the three below mechanisms
 - Measured via ping-pong balls as the time traveled/floated for a set distance (30 ft). Typically used only at tributary backpack sites.
 - Calculated by DRBC web-based application estimator
 - Nearest USGS gage station for main stem fixed-sites
- River stage (m) – measured by
- River width (m), as an average stream width within the site, for only tributary backpack sites

TABLE 1. Listing of electrofishing monitoring fixed-sites. GPS points are considered to approximate start/end points, in that river conditions may dictate actual start/end points.

Site	RM	Target	Stream Bank	Site Length (m)	Start		End		Start Point Description
					lat	long	lat	long	
Back-pack electrofishing sites									
West Branch									
Laurel Bank	15.4	YOY/SY	RL	100	42.072378	75.408764	42.073178	75.408203	200m downstream of access
Men's Club	13.2	YOY/SY	RR	100	42.044604	75.420839	42.045482	75.420914	Across from access
Balls Eddy	4.6	YOY/SY	RR	300	41.969167	75.332222	41.969899	75.334399	250 m downstream access
Hancock	1.7	YOY/SY	RR	300	41.952016	75.291698	41.954095	75.293605	Point bar just below bridge
Shehawken	0.5	YOY/SY	RR	300	41.941962	75.285175	41.942542	75.289032	200 m downstream access, skip mudflat 50 m
Delaware River									
River Rd	329.8	YOY/SY	RR	300	41.906730	75.267873	41.908496	75.268831	250 m downstream access
Buckingham	325.0	YOY/SY	RR	300	41.867689	75.263796	41.867877	75.264252	200 m downstream access
Tributaries to West Branch									
Cold Spring Creek	2.8	YOY/SY	RR/RL	100	42.117960	75.396334	42.118788	75.396042	Upstream side of Dug Road
Cold Spring Creek	5.1	YOY/SY	RR/RL	100	42.147338	75.400060	42.147934	75.399147	Where 20 turns into Beech Hill Road
Sherman Creek	0.3	YOY/SY	RR/RL	100	42.002471	75.394506	42.001662	75.395058	90 m downstream of bridge
Sherman Creek	1.8	YOY/SY	RR/RL	100	41.994655	75.417757	41.994978	75.418771	100 m downstream of bridge
Roods Creek	0.1	YOY/SY	RR/RL	100	42.004749	75.359357	42.005367	75.358451	Upstream side of Silver Lake Road
Sands Creek	7.1	YOY/SY	RR/RL	100	42.043002	75.297453	42.043899	75.297700	Next to DOT building just upstream of bridge
Sands Creek	0.07	YOY/SY	RR/RL	100	41.958015	75.296118	41.958901	75.286327	90 m downstream of bridge
Balls Creek	0.02	YOY/SY	RR/RL	100	41.970399	75.336346	41.969538	75.336021	41 m upstream of mouth near large tree
Shehawken Creek	0.1	YOY/SY	RR/RL	100	41.940877	75.288513	41.940239	75.289339	Downstream side of small braid
Shehawken Creek	3.9	YOY/SY	RR/RL	100	41.901321	75.330272	41.900490	75.330532	100 m downstream of Old State Road bridge crossing
Night-boat electrofishing sites									
West Branch									
Laurel Bank		Adult/SY	RR	450					Upstream end of pool just below Cold Spring riffle
Airport Road		Adult/SY	RR/M	275					Just below boulders upstream of access
Shehawken		Adult/SY	RL	500					Just upstream of access
Ball's Eddy	4.6	Adult/SY	RR/RL	500					Upstream end of pool

TABLE 2. Site-specific scheduling. Sampling July through October is reflective of double shift work days; using daylight hours for back-pack sampling, then accomplishing the night-boat electrofishing after sunset of the same day.

	Back-pack electrofishing sites				Night-boat electrofishing sites	
	West Branch	No. Sites	Tributaries	No. Sites	West Branch	No. Runs
Apr-Jun						
Mon	--	--	--	--	Laurel Bank	2
Tue	--	--	--	--	Airport Rd	2
Wed	--	--	--	--	Shehawken/Balls Eddy	2/2
Thu	Reserved for weather delay					
Jul-Oct						
Mon	Laurel Bank Men's Club Bass Eddy Hancock Shehawken River Rd Buckingham	1 1 1 1 1 1	--		Laurel Bank	2
Tue	--	--	Sherman Creek Sands Creek Shehawken Creek	2 2 2	Airport Rd	2
Wed			Balls Creek Rood Creek Cold Spring Creek	1 1 2	Shehawken/Balls Eddy	2/2
Thu	Reserved for weather delay					

Figure 1. Upper Delaware River Basin. Fisheries thermal objectives are displayed, as per the 2017 Flexible Flow Management Plan for perspective.

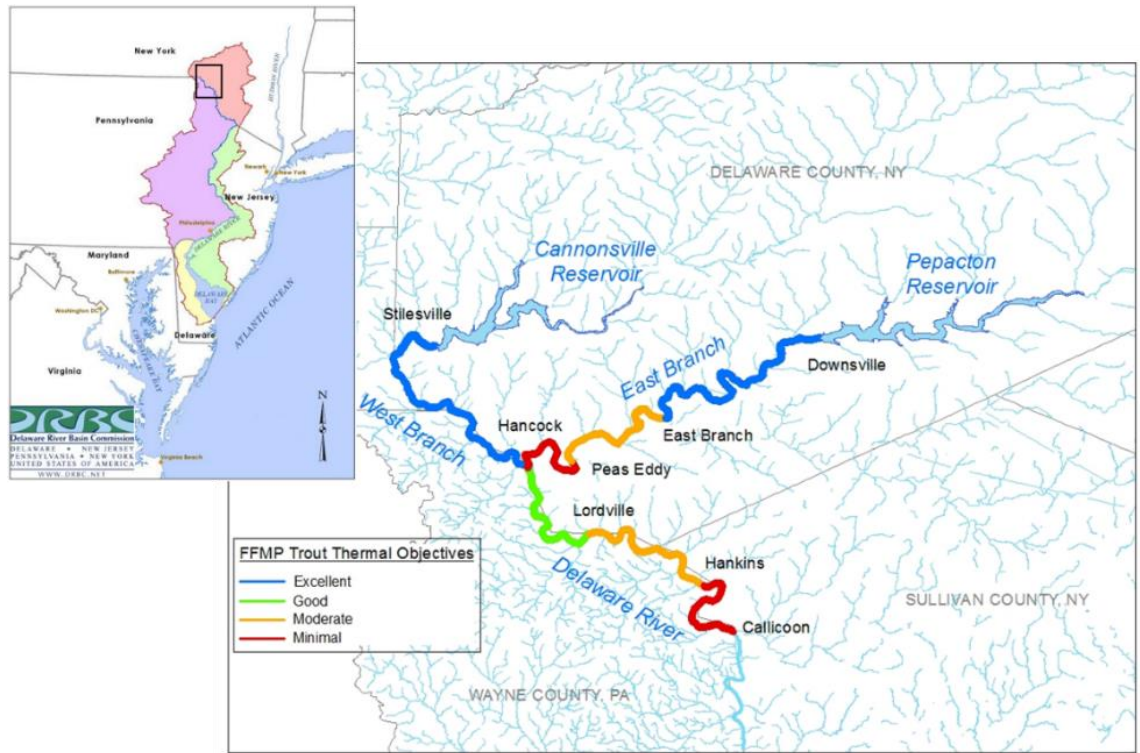


Figure 2a. Back-pack electrofishing sites, targeting YOY trout in both tributaries (green circles), West Branch main stem (purple circles) and Delaware River (black circles).

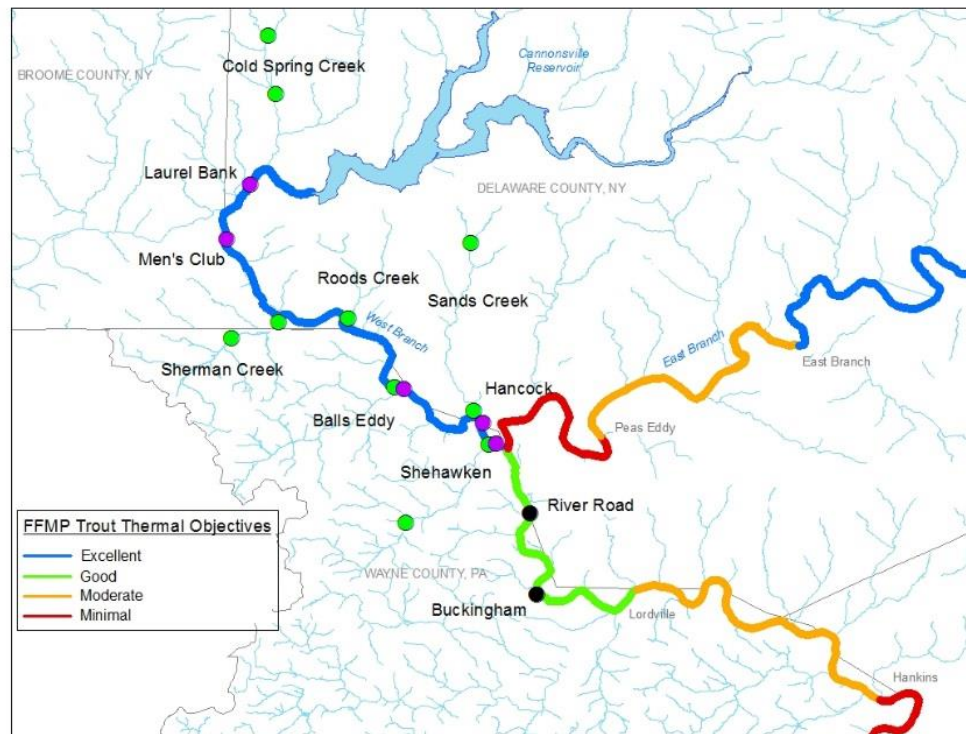


Figure 2b. Night-boat electrofishing sites (yellow circles), targeting all sized trout

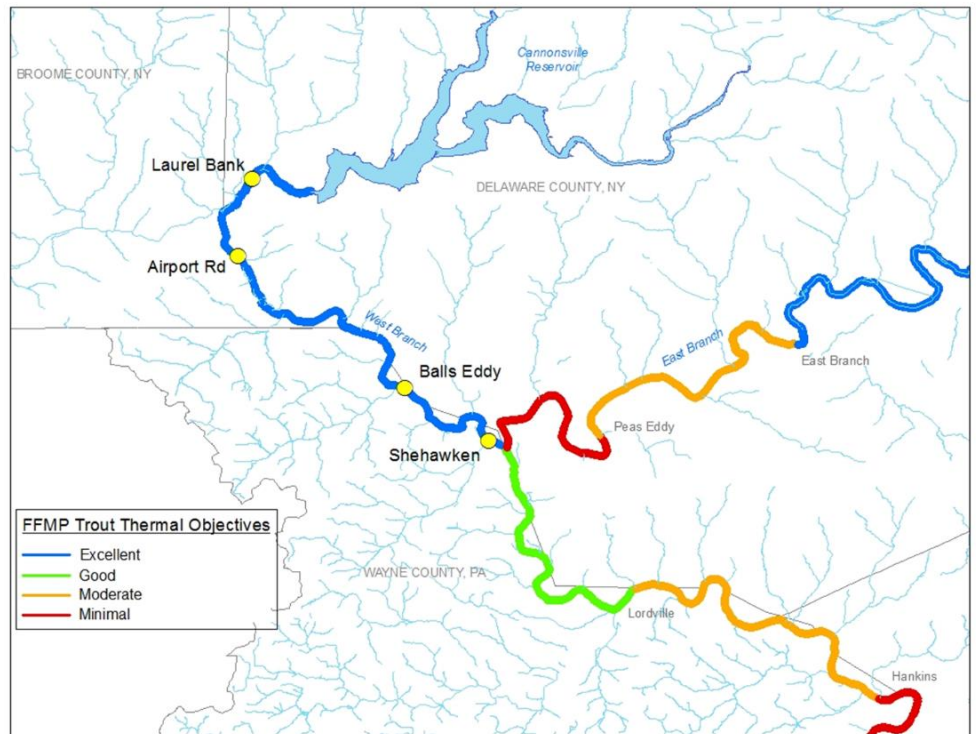


Figure 3. West Branch, Laurel Bank back-pack electrofishing site (RM ##). Located just north of Deposit, NY from the NYSDEC walk-in access off Laurel Bank Avenue, CR 48. Single-pass electrofishing (white line) is accomplished using a portable back-pack electrofisher (one scapper/one operator-scapper) along the shoreline shallow water habitat, located on river left. Total site length is approximately 100 m (328 ft), dependent on river conditions, from start to end points.

Laurel Bank West Branch BP site

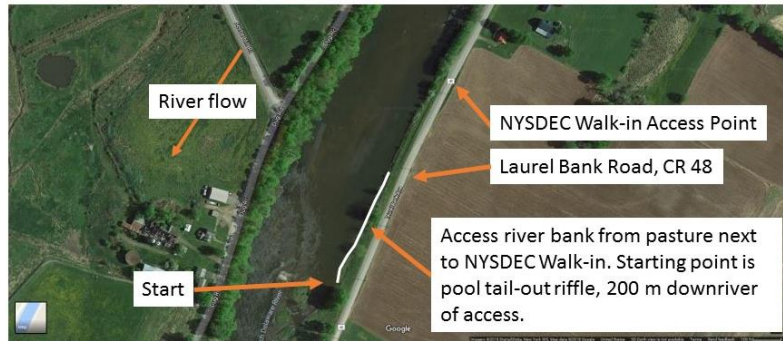


Figure 4. West Branch, Men's Club back-pack electrofishing site (RM ##). Located south of Deposit, NY from the NYSDEC walk-in access off Airport Road. Single-pass electrofishing (white line) is accomplished using a portable back-pack electrofisher (one scapper/one operator-scapper) along the shoreline shallow water habitat, located on river right. Total site length is approximately 100 m (328 ft), dependent on river conditions, from start to end points

Men's Club West Branch BP site



Figure 5. West Branch, Balls Eddy back-pack electrofishing site (RM ##). Located north of Hancock, NY from the PFBC trailered boat access, off Penn-York Road. Single-pass electrofishing (white line) is accomplished using a portable back-pack electrofisher (one scapper/one operator-scapper) along the shoreline shallow water habitat, located on river right. Total site length is approximately 300 m (984 ft), dependent on river conditions, from start to end points

Balls Eddy WB BP site



Figure 6. West Branch, Hancock back-pack electrofishing site (RM ##). Located near Hancock, NY; access is below the PA SR 191 Bridge. Single-pass electrofishing (white line) is accomplished using a portable back-pack electrofisher (one scapper/one operator-scapper) along the shoreline shallow water habitat, located on river right. Total site length is approximately 300 m (984 ft), dependent on river conditions, from start to end points.

Hancock West Branch BP site

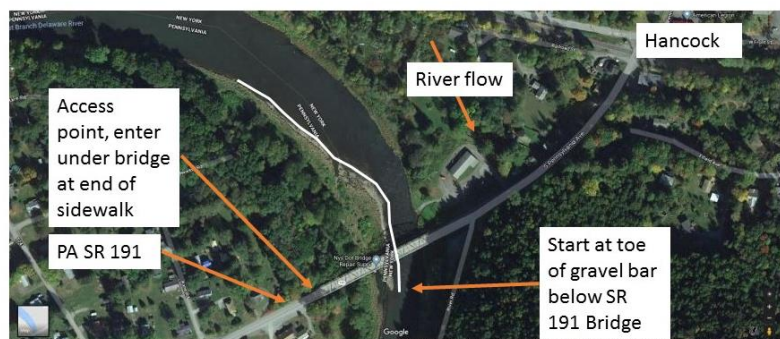


Figure 7. West Branch, Shehawken back-pack electrofishing site (RM ##). Located south of Hancock, NY; access by the PFBC trailered boat launch off PA SR 191. Single-pass electrofishing (white line) is accomplished using a portable back-pack electrofisher (one scapper/one operator-scapper) along the shoreline shallow water habitat, located on river right. Total site length is approximately 300 m (984 ft), dependent on river conditions, from start to end points.

Shehawken WB BP site

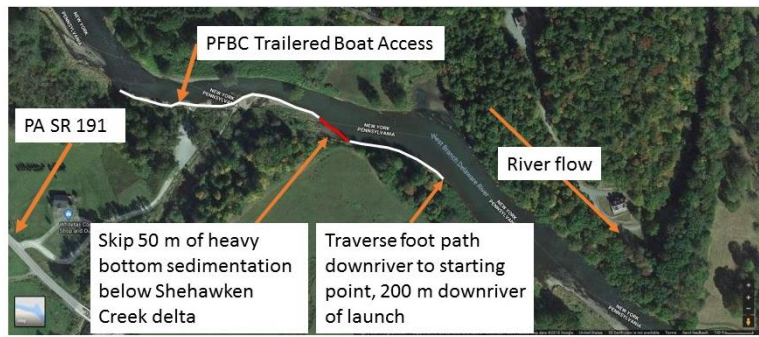


Figure 8. Delaware River, River Road back-pack electrofishing site (RM ##). Located south of Hancock, NY; access by the unimproved boat launch off River Rd; walk downriver 250m to starting point from PA SR 191. Single-pass electrofishing (white line) is accomplished using a portable back-pack electrofisher (one scapper/one operator-scapper) along the shoreline shallow water habitat, located on river right. Total site length is approximately 300 m (984 ft), dependent on river conditions, from start to end points.

River Road WB BP site

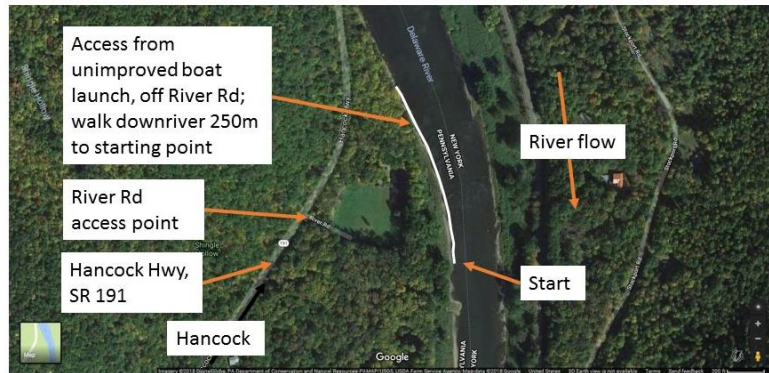


Figure 9. Delaware River, Buckingham back-pack electrofishing site (RM ##). Located south of Hancock, NY; access by the PFBC trailered boat launch off PA SR 191. Single-pass electrofishing (white line) is accomplished using a portable back-pack electrofisher (one scapper/one operator-scapper) along the shoreline shallow water habitat, located on river right. Total site length is approximately 300 m (984 ft), dependent on river conditions, from start to end points.

Buckingham WB BP site



Figure 10. Cold Spring Creek, tributary to West Branch Delaware River, upper back-pack electrofishing site (RM ##). Single-pass electrofishing (white line) is accomplished using a portable back-pack electrofisher (one scapper/one operator-scapper). The creek width typically does not require a sinusoidal track or doubling back to cover all YOY trout habitats. Total site length is approximately 100 m (328 ft), dependent on river conditions, from start to end points.

Cold Spring Ck BP upper site



Figure 11. Cold Spring Creek, tributary to West Brach Delaware River, lower back-pack electrofishing site (RM Single-pass electrofishing (white line) is accomplished using a portable back-pack electrofisher (one scapper/one operator-scapper). The creek width typically does not require a sinusoidal track or doubling back to cover all YOY trout habitats. Total site length is approximately 100 m (328 ft), dependent on river conditions, from start to end points.

Cold Spring Ck BP lower site



Figure 12. Sherman Creek, tributary to West Brach Delaware River, upper back-pack electrofishing site (RM ##). Single-pass electrofishing (white line) is accomplished using a portable back-pack electrofisher (one scapper/one operator-scapper). The creek width is wide enough that may require a sinusoidal track or doubling back to cover all YOY trout habitats. Total site length is approximately 100 m (328 ft), dependent on river conditions, from start to end points.

Sherman BP upper site



Figure 13. Sherman Creek, tributary to West Brach Delaware River, lower back-pack electrofishing site (RM ##). Single-pass electrofishing (white line) is accomplished using a portable back-pack electrofisher (one scapper/one operator-scapper). The creek width is wide enough that may require a sinusoidal track or doubling back to cover all YOY trout habitats. Total site length is approximately 100 m (328 ft), dependent on river conditions, from start to end point.

Sherman BP lower site



Figure 14. Roods Creek, tributary to West Brach Delaware River, back-pack electrofishing site (RM ##). Only one site has been located on Roods Creek. Located off the Roods Creek turn-off from NY SR 17. Single-pass electrofishing (white line) is accomplished using a portable back-pack electrofisher (one scapper/one operator-scapper). The creek width is typically not wide enough that to require a sinusoidal track or doubling back to cover all YOY trout habitats. Total site length is approximately 100 m (328 ft), dependent on river conditions, from start to end points.

Roods Ck BP site

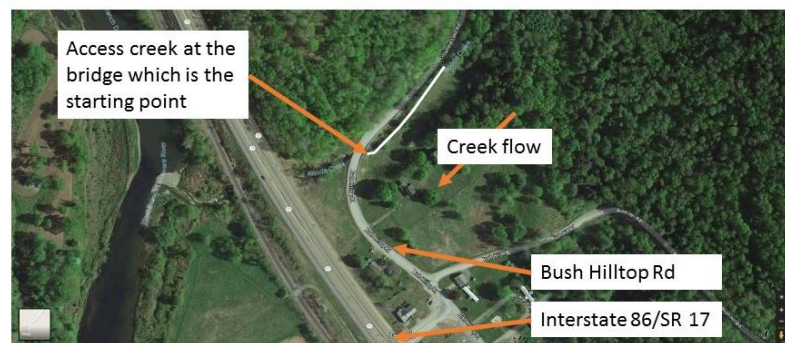


Figure 15. Sands Creek, tributary to West Brach Delaware River, upper back-pack electrofishing site (RM ##). Single-pass electrofishing (white line) is accomplished using a portable back-pack electrofisher (one scapper/one operator-scapper). The creek width is wide enough that may require a sinusoidal track or doubling back to cover all YOY trout habitats. Total site length is approximately 100 m (328 ft), dependent on river conditions, from start to end points.

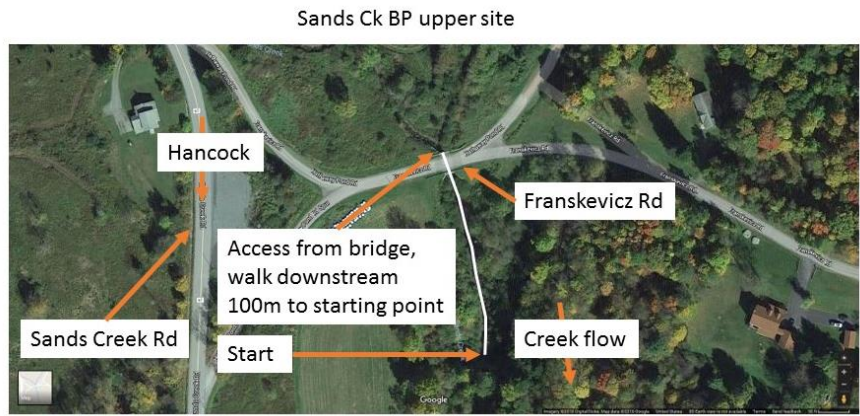


Figure 16. Sands Creek, tributary to West Brach Delaware River, lower back-pack electrofishing site (RM ##). Single-pass electrofishing (white line) is accomplished using a portable back-pack electrofisher (one scapper/one operator-scapper). The creek width is wide enough that may require a sinusoidal track or doubling back to cover all YOY trout habitats. Total site length is approximately 100 m (328 ft), dependent on river conditions, from start to end points.

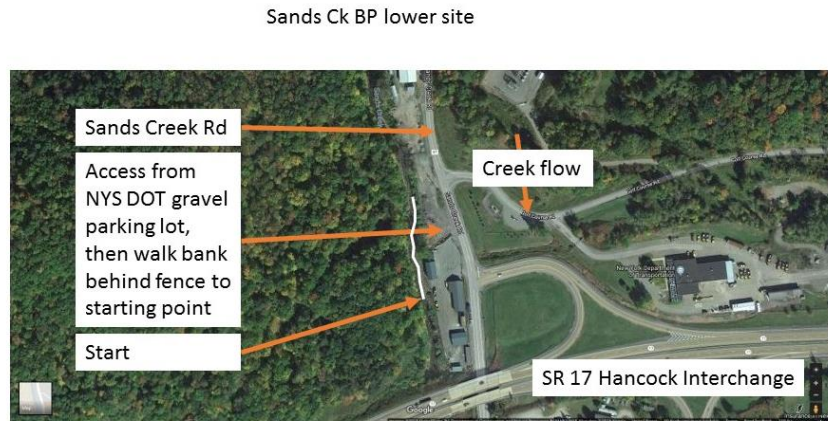


Figure 17. Balls Creek, tributary to West Brach Delaware River, back-pack electrofishing site (RM ##). Only one site has been located on Roods Creek. Single-pass electrofishing (white line) is accomplished using a portable back-pack electrofisher (one scapper/one operator-scapper). The creek width is typically not wide enough that to require a sinusoidal track or doubling back to cover all YOY trout habitats. Total site length is approximately 100 m (328 ft), dependent on river conditions, from start to end points.

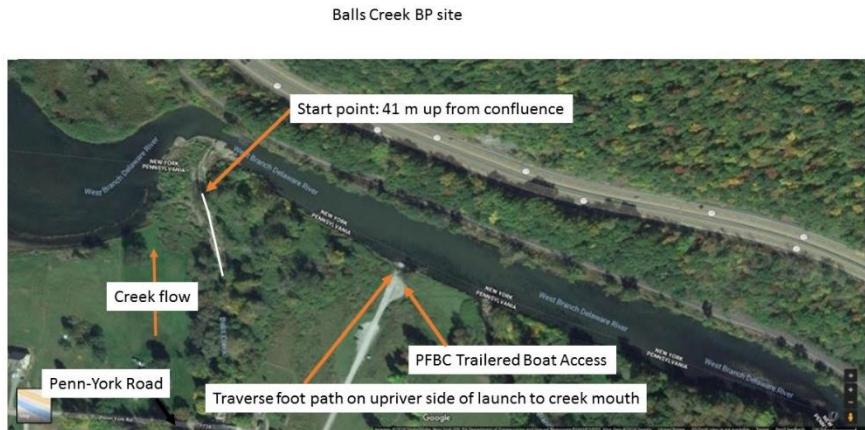
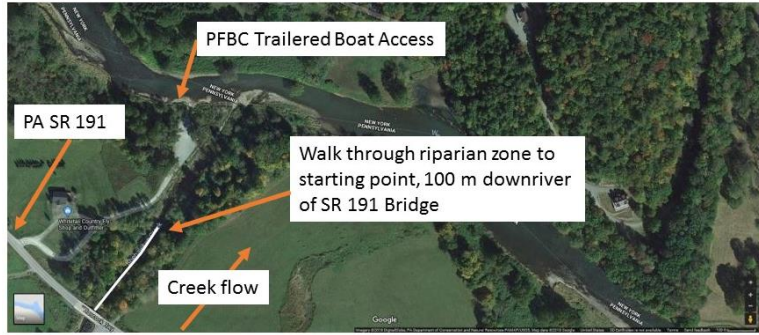


Figure 18. Shehawken Creek, tributary to West Brach Delaware River, upper back-pack electrofishing site (RM ##). Single-pass electrofishing (white line) is accomplished using a portable back-pack electrofisher (one scapper/one operator-scapper). The creek width is typically not wide enough to require a sinusoidal track or doubling back to cover all YOY trout habitats. Total site length is approximately 100 m (328 ft), dependent on river conditions, from start to end points.



Shehawken BP lower site

Figure 19. Shehawken Creek, tributary to West Brach Delaware River, back-pack electrofishing site (RM ##). Single-pass electrofishing (white line) is accomplished using a portable back-pack electrofisher (one scapper/one operator-scapper). The creek width is wide enough that may require a sinusoidal track or doubling back to cover all YOY trout habitats. Total site length is approximately 100 m (328 ft), dependent on river conditions, from start to end points.



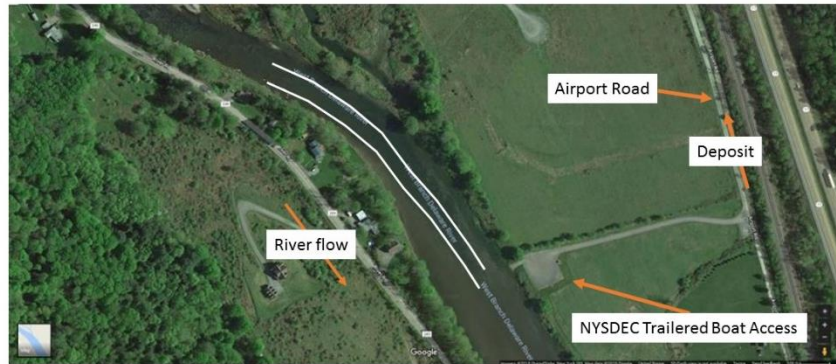
Laurel Bk NBE site

Figure 20. West Branch, Laurel Bank night-boat electrofishing site (RM ##). Located just north of Deposit, NY from the NYSDEC walk-in access off Laurel Bank Avenue, CR 48. Electrofishing is accomplished using the NYSDEC "car topper" boat electrofisher (one netter/one boat operator) launched from the walk-in site. Electrofishing runs are illustrated as tracks (white lines), starting at the pool head riffle, extending downriver to the NYSDEC walk-in launch. Both runs occur over the same swept area. Total site length is approximately 450 m (1,476 ft), dependent on river conditions.



Airport Rd NBE site

Figure 21. West Branch, Airport Road night-boat electrofishing site (RM ##). Located south of Deposit, NY from the NYSDEC trailered boat access off Airport Road. Electrofishing is accomplished using the PFBC trailered electrofisher (two netters/one boat operator) launched from the boat ramp. Electrofishing runs are illustrated as separate tracks (white lines). Starting point is within the boulders across from the braid channel mouth, continuing downriver to across from the NYSDEC launch. Depending on river conditions, both runs may occur over the same swept area. Total site length is approximately 275 m (902 ft), dependent on river conditions.



Balls Eddy NBE site

Figure 22. West Branch, Balls Eddy night-boat electrofishing site (RM ##). Located north of Hancock, NY from the PFBC trailered boat access off the Penn-York Road. Electrofishing is accomplished using the PFBC trailered electrofisher (two netters/one boat operator) launched from the boat ramp. Electrofishing runs are illustrated as tracks (white lines). Depending on river conditions, both runs may occur over the same swept area; however, swept path may also be sinusoidal to encompass both shoreline and main channel waters. Total site length is approximately 610 m (2,001 ft), dependent on river conditions. Starting point is the riffle at the top of the pool, continuing downriver past the braid channel (on PA side), until water depth prevents safe boat operation, before the pool tail-out riffle.



Shehawken NBE site

Figure 23. West Branch, Shehawken night-boat electrofishing site (RM ##). Located south of Hancock, NY from the PFBC trailered boat access off Hancock Highway, SR 191. Electrofishing is accomplished using the NYSDEC "car topper" electrofisher (one netter/one boat operator) launched from the boat ramp. Electrofishing runs are illustrated as tracks (white lines). Both runs occur over the same swept area. Total site length is approximately 500 m (1,640 ft), dependent on river conditions. Starting point is the riffle at the top of the pool, just upriver of the boat launch, continuing downriver to the head of the pool tail-out riffle.

