PROJECT DESCRIPTION

Trout Unlimited's (TU) East Branch Delaware River Trout Habitat Improvement Project (HIP) expanded upon the water temperature monitoring and riparian planting work that has been underway since 2016 to include a barrier assessment and fish movement study.

Volunteers during 2017 Spring planting event located at Hubbell Farm (Photo G. Markos).

Since 2016, Trout Unlimited Ashokan-Pepacton Watershed Chapter members have deployed temperature loggers at multiple locations upstream and downstream of the Halcottsville dam at Wawaka Lake. Following the initial review of the data in 2016 which showed elevated summer water temperatures, TU began working with landowners in the watershed to plant trees in priority riparian locations. Working in partnership with the Delaware County Soil and Water Conservation District/Catskill Stream Buffer Initiative and the Arbor Day Foundation, the team completed multiple plantings at sites directly downstream of the dam and at the Hubbell Farm (Map 1).

The temperature monitoring was initiated by TU Chapter members in 2016 and continued annually through summer 2020. Working closely with NYS DEC Region 4 fisheries and habitat/fisheries biologists, the team tagged and tracked both hatchery raised and wild trout to understand potential challenges faced by trout in the East Branch. Trout were tagged and tracked in 2018 and 2019 and tracked. The temperature and tracking results will aide in the development of mitigation strategies and management recommendations that will ameliorate potential impacts to this important coldwater fishery.

PROJECT LOCATION

The Project was located in the Upper East Branch Delaware River Watershed (HUC 0204010203) with a focus on the mainstem and the Pleasant Valley (HUC 020401020302), Batavia Kill (HUC 020401020301) and portions of the Huckleberry Brook (HUC 020401020306) subwatersheds. The project area is located mostly within the Town of Roxbury but also includes portions of the Town of Middletown. The entire project is within Delaware County (Map 1).

PROJECT GOAL

The goal of the project was to understand potential challenges faced by trout in the East Branch and develop mitigation strategies and management activities to reduce potential impacts and increase wild and native trout populations.

OBJECTIVES

The HIP Project objectives are designed to support recommendation #14 of the East Branch Delaware River Stream Corridor Management Plan:

Enhancement of East Branch Watershed Fisheries by working with landowners around Wawaka Lake to reduce negative thermal effects on trout and to enhance trout migration in this reach of the East Branch Delaware River.

Objective 1: Assess thermal impacts caused by the Wawaka Lake dam through the deployment and monitoring of temperature loggers at sites upstream and downstream of the dam.

Objective 2: Use data from the temperature monitoring study, Eastern Brook Trout Joint Venture riparian planting priority tool, and TU's Eastern Brook Trout Conservation Portfolio and Range-Wide Analysis to locate opportunities to revegetate stream buffers to improve water quality.

Objective 3: Develop and implement fish tracking study to better understand fish movement in the watershed and potential challenges.

Objective 4: Complete initial review of road stream crossing impacts to fish movement, followed by a formal survey at potential barriers to a develop barrier replacement strategy.

Objective 5: Engage the community in hands-on environmental service projects.

SCOPE OF WORK

Objective 1: Stream Temperature Monitoring

Task: Plan for 2019 temperature monitoring.

Deliverable: 20 water temperature monitoring loggers deployed within project area.

Task: Retrieve loggers; download and analyze data.

Deliverable: 2017-2019 temperature data summarized.

Status: COMPLETE - TU completed temperature monitoring at 12-20 sites along the East Branch from 2016-2020. The results of the temperature study are summarized below and can be found at the public accessible SHEDS Stream Temperature Database. http://db.ecosheds.org/viewer.

Objective 2: Riparian Buffer Planting

Task: Locate priority planting projects and secure landowner support.

Deliverable: Four planting projects completed.

Task: Monitor plant survival

Deliverable: Plant survival data analysis completed and summarized.

Status: COMPLETE - TU in partnership with Delaware County SWCD and the Catskill Stream Buffer Initiative have completed 6 projects on sites within the East Branch Delaware River with the help of TU chapter members, local community and students.

Objective 3: Fish Movement

Task: Install RFID and water level loggers.

Deliverable: 8 RFID devices installed

Task: Surgically install tags in hatchery raised and wild trout.

Deliverable: 1,041 hatchery raised Brown Trout; 8 electrofishing sessions and tagged 674 wild Brown, Rainbow and Brook Trout.

Task: Maintain RFID tracking batteries and equipment.

Deliverable: Weekly visits to all stations to check on equipment and charge batteries.

Task: Review, manage and summarize tracking data.

Deliverable: Final report summarizing data.

Task: Develop fisheries management strategies and recommendations.

Deliverable: Data used to develop strategies and recommendations for improving cold-water fish management in Project area.

Status: COMPLETE - TU tagged and tracked 605 wild and 1041 hatchery trout from 2018-2020. The results of the project (through 2019) are summarized below.

Objective 4: Road Stream Crossing Barrier Assessment

Task: Collect existing data and meet with local municipalities to discuss road stream crossing priorities and collect existing data.

Deliverable: Meetings complete with Town of Roxbury, Town of Middletown and Delaware County Public Works and existing data and priorities collected.

Task: Complete initial road stream crossing survey.

Deliverable: Data entered into NAACC database and analyzed for aquatic passage and hydraulic capacity; results mapped and summarized.

Task: Develop road stream crossing replacement strategies and recommendations.

Deliverable: Present final results to local stakeholders.

Status: COMPLETE - TU completed a modified road stream crossing assessment within the project site. We have discussed priorities with the town of Roxbury and Middletown and have identified three high priority replacement sites within the project reach that could improve aquatic passage and infrastructure condition and flooding. The information on the survey can be viewed at https://trout.maps.arcgis.com/apps/webappviewer/index.html?id=cf6ee6cb21bb4ede8fb0da746db2d0e1&extent=-15215009.2001%2C2449683.4771%2C-6996499.9189%2C6886700.095%2C102100.

Objective 5: Community Engagement

Task: Engage community members and students in project activities.

Deliverable: Volunteers engaged in planting, monitoring and tagging activities.

Status: COMPLETE - TU chapter members and community members have been engaged in all aspects of the project. Over 374 volunteer hours have been spent on the project by volunteers helping with the temperature deployment, fish tagging and tracking and planting.

Objective 1: Temperature Monitoring

Using HOBO Water Temperature Pro v2 Data Loggers, stream temperature was collected from 2016 – 2020 at sites throughout the East Branch Delaware River upstream and downstream of Wawaka Lake in the Hamlet of Halcottsville, NY (Map 1). Each temperature logger was placed in the deepest pools at the identified reach during the monitoring season (July-September). Temperature data was gathered every hour over the monitoring period. Data analysis considered daily mean and maximum temperatures as well as the rolling seven-day average daily maximum water temperature in order to better understand long term impacts of temperature on East Branch Delaware River trout. Temperature data is stored and accessible for viewing and downloading through the SHEDS Stream Temperature Database http://db.ecosheds.org/viewer.

The distribution and abundance of trout within the East Branch watershed is in part driven by stream temperatures. By monitoring temperature, we can begin to understand potential thermal barriers for trout, since water temperature influences every phase of a trout's life history. Eastern Brook Trout (*Salvelinus fontinalis*) is a native trout species found in the East Branch Delaware River. Brook Trout are known to prefer colder water than Brown or Rainbow Trout.[1] The optimal temperature for Brook Trout growth is considered 10˚C to 16˚C (50˚F to 60˚F); For Brown Trout, considered more tolerant to warmer temperatures, optimal temperature range is 12˚C to 19˚C (53˚F to 66˚F). Although there are many variables such as duration and intensity of water temperature that influence a fish's ability to withstand fluctuations in water temperature, 24-26˚ C (75-80° F) is considered the upper tolerable limit for short durations for trout[2]. Temperature limits and tolerances vary in the literature due to acclimation differences between local and regional populations and seasonal temperature cycles provide trout populations the necessary acclimation period needed to tolerate annual temperature extremes[3]. For the purposes of this study, 20 ˚ C is used as the optimal temperature threshold and 24 ˚ C is used as the upper tolerable limit in order to be consistent with NYS Department of Environmental Conservation.

The results of the temperature monitoring help us better understand the extent of thermal impacts caused by the impoundment at Wawaka Lake as well as give us a better understanding of the temperature regime elsewhere on the mainstem outside of the influence of the dam. Since riparian condition, stream discharge (flow) and in-stream habitat (pools, undercut banks, etc.) are also important factors influencing water temperature condition, understanding temperatures in the system will help guide trout management actions and restoration efforts.

Temperature monitoring results are summarized below for 2017-2019 (Table 1-3) and visually displayed for the same years (Figure 1-3). The data results are compared for four to five sites (Map 1): upstream of the Wawaka Lake

[1] Xu, C.L.; Letcher, B. H.; Nislow, K. H. (June 2010). "Size-dependent survival of brook trout *Salvelinus fontinalis* in summer: effects of water temperature and stream flow". Journal of Fish Biology. 76 (10): 2342–2369.
[2] Fry, F. E. J., Hart, J. S., & Walker, K. F. 1946. Lethal temperature relations for a sample of young speckled trout. Salvelinus fontinalis, 1-47.
[3] Wehrly, K. E., Wang, L., & Mitro, M. 2007. Field-based estimates of thermal tolerance limits for trout: incorporating exposure time and temperature fluctuation. Transactions of the American Fisheries Society, 136(2):365-374.

impoundment at the bridge on Old River Road (Temp Site 4), at the dam release pool (Temp Site 6), downstream at the Hubbell Farm across from the farm spring (Temp Site 9), at the mouth on Batavia Kill (RFID Site 16; 2019 only) and further downstream below the mouth of Batavia Kill at East Hubbell Hill Road (Temp Site 11). Highest temperature spikes were recorded downstream of the dam and cooler temperatures were observed upstream of the Lake and on Batavia Kill tributary. The mean, maximum and minimum daily temperature difference between upstream and downstream of the impoundment are summarized in Table 4. Annual differences in stream temperatures are evident from the data which can be influenced by flow and air temperature. Flow data from the USGS gage station in Roxbury, NY, located upstream of Wawaka Lake at the furthest upstream extent of the project reach was used to better understand flow conditions for the three-year study (Figure 4).

Table 1: 2017 Stream Temperature Data Summary

Data Summary	Upstream of Lake at Old River Road (Site 4)	Dam Release Pool (Site 6)	Hubbell Hill Farm (Site 9)	Below Batavia Kill at East Hubbell Hill Road (Site 11)
Daily Mean ° C/F (all records)	18.3°C/64.9°F	20.3°C/68.5°F	19.9°C/67.8°F	19.2°C/66.6°F
Daily Max ° C/F (all records)	25.7°C/78.3°F	26.2°C/79.2°F	27.4°C/81.3°F	25.7°C/78.3°F
% 7 DADMAX Periods Exceeding 20 °C (Brook Trout Stress)	66%	78%	78%	74%
% 7 DADMAX Periods Exceeding 24 °C (Brook Trout Lethal)	3%	13%	18%	3%

Table 2: 2018 Stream Temperature Data Summary

Data Summary	Upstream of Lake at Old River Road (Site 4)	Dam Release Pool (Site 6)	Hubbell Hill Farm (Site 9)	Below Batavia Kill at East Hubbell Hill Road (Site 11)
Daily Mean ° C/F (all records)	18.6°C/65.5°F	20.3°C/68.5°F	19.8°C/67.6°F	19.7°C/67.5°F
Daily Max ° C/F (all records)	27.4°C/81.3°F	30.2°C/86.4°F	30.3°C/86.5°F	28.5°C/83.3°F
% 7 DADMAX Periods Exceeding 20 °C (Brook Trout Stress)	43%	78%	65%	63%
% 7 DADMAX Periods Exceeding 24 °C (Brook Trout Lethal)	20%	13%	22%	20%

Table 3: 2019 Stream Temperature Data Summary

Data Summary	Upstream of Lake at Old River Road (Site 4)	Dam Release Pool (Site 6)	Hubbell Hill Farm (Site 9)	Batavia Kill (RFID Site 6)	Below Batavia Kill at East Hubbell Hill Road (Site 11)
Daily Mean ° C / F (all records)	19.3°C /66.8° F	21.5°C/70.7°F	20.8°C/69.4°F	17.8°C/64.0°F	ND
Daily Max ° C /F (all records)	27.8°C /82.0°F	27.9°C/82.2°F	29.4°C/84.9°F	25.1°C/77.2°F	ND
% 7 DADMAX Periods Exceeding 20 °C (Brown Trout Stress)	66%	73%	94%	58%	ND
% 7 DADMAX Periods Exceeding 24 °C (Upper Tolerable Limit for	23%	40%	53%	0%	ND

*Temperature logger was removed from the water and placed on the bank for a portion of the monitoring season rendering the data unusable. Batavia Kill site was used in this comparison.

Results of the temperature study confirm that the Wawaka Lake impoundment is increasing stream temperatures downstream at the dam release pool (Site 6). Temperature difference from upstream to directly downstream were as high as 4.46°C (8.03°F). Stream temperature at the Hubbell Farm (Temp Site 9), 1.25 miles downstream, are still warmer than above the dam with a maximum temperature difference of 3.03°C (5.45°F). Temperatures at East Hubbell Hill Road (Temp Site 11) begin to resemble above the dam temperature conditions, likely due to the input of cold water from Batavia Kill. Batavia Kill, a main tributary of the East Branch, is colder than upstream of the dam with a mean temperature of 17.8°C (64.04°F).

Another common metric to monitor lethally warm water temperatures is the rolling seven-day average of daily maximum water temperature (7DADMAX). According to the literature, Brook Trout are likely to be present in waters that do not exceed 19°C(66°F) for long periods.[4] The data shows 43% to 63% of the total 7-day periods above the 19 ° C threshold above the dam (Site 6) and 73% to 78% of 7-day periods above the temperature threshold at the dam release pool (Temp Site 6) and 65% to 94% at Hubbell Farm (Temp Site 9). Flows during the study period were both higher (2018) and lower (2017, 2019) than mean conditions contributing the difference in the data from year to year (Figure 4). Site conditions also contribute to the diversity of the temperature regime, most notably, the Hubbell Farm site is located on a reach of the river that is wide, slow moving with limited riparian cover. The data suggests that these local conditions are contributing to elevated summer temperatures.

Overall the data confirm the potential challenges trout likely experience throughout the East Branch Delaware River and without the thermal impacts of the impoundment the East Branch could be between 1.50°C (2.7°F) and 2.08°C (3.7 °F) degrees colder during the hottest times of the year, making conditions more suitable for trout. Riparian restoration

[4] Wehrly, K. E., Wang, L., & Mitro, M. 2007. Field-based estimates of thermal tolerance limits for trout: incorporating exposure time and temperature fluctuation. Transactions of the American Fisheries Society, 136(2):365-374.

efforts focused on the Hubbell Farm reach could also help improve stream temperature. Batavia Kill appears to provide important coldwater inputs to the system almost mimicking upstream stream temperature conditions and should be the focus of additional riparian planting activities and aquatic passage projects to further improve opportunities for coldwater refugia.

Table 4: Stream Temperature Difference from Upstream to Downstream of Wawaka Lake

Difference from Upstream at Old River Road (Site 6) To Locations Downstream									
Data Collection Year	2017			2018			2019		
Statistic Evaluation	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
Dam Release Pool (Site 8)	2.08 C	3.69 C	-1.61 C	1.50 C	4.46 C	-0.07 C	2.21 C	4.51 C	-0.01 C
Hubbell Hill Farm (Site12)	1.67 C	2.94 C	0.49 C	1.23 C	3.03 C	-0.05 C	1.49 C	2.57 C	0.41 C
Batavia Kill (Site 14)	ND	ND	ND	ND	ND	ND	-1.51 C	-0.80 C	-2.17 C
Below Batavia Kill at East Hubbell Hill Road (Site 15)	0.94 C	2.58 C	-1.36 C	1.15 C	2.53 C	-0.03 C	ND	ND	ND

*To calculate temperature differences in Fahrenheit x Celsius by 1.8.

Objective 2: Riparian Buffer Planting

Plants that grow within the riparian corridor are critical to maintaining stream health. Riparian vegetation provides numerous benefits to water quality. The root structures of the plants provide protection against bank erosion and flood damage. Riparian vegetation also buffers the stream against pollution, such as nutrient, pesticides and sediment runoff; while providing food and shelter for aquatic and upland wildlife. The input of branches and leaves into the stream provides food for insects which are then eaten by fish such as trout. The natural recruitment of trees into the stream and the creation of log jams plays a significant role in influencing the geomorphology of the river and contributes to instream habitat diversity. Riparian trees and shrubs also shade the stream which helps to moderate fluctuations in stream temperature. The loss or modification of the riparian forest can destabilize the stream system, resulting in the potential for radical channel adjustments which cause bank erosion, sedimentation, and the degradation of aquatic habitat.[5]

Planting event led by Catherine Skalda (DC SWCD) Volunteers help plant along Hubbell Farm (2017).

[5] Merritt, D.M, 2013. Reciprocal relations between riparian vegetation, fluvial landforms, and channel processes. In: Shroder, J. (Editor in Chief), Wohl, E. (Ed.), Treatise on Geomorphology. Academic Press, San Diego, CA, vol. 9, Fluvial Geomorphology, pp. 219–243

Riparian buffer plantings were an integral component of the HIP and continued during the spring and fall of 2017, 2018 and 2019. Buffer plantings were organized and implemented in partnership with private landowners and Delaware County Soil and Water Conservation District/NYC DEP Catskill Stream Buffer Initiative. Priority locations focused on parcels directly downstream of the dam on the Kelly and the Castellitto Property (Map 1). Six planting events were held at these and the Hubbell Farm. During those events, 127 volunteers planted 1,416 native trees and shrubs creating a 6.63-acre buffer along the East Branch Delaware River. Additional work was done to identify priority planting locations on Batavia Kill for future planting events.

Table 5: Planting Summary for East Branch sites 2017-2019.

Location	Planting Year	Town/ Village	Stream	Linear Feet	Acres	# plants	# volunteers
Castellitto	2019	Halcottsville	East Branch Delaware River	325	0.45	108	12
Castellitto	2019	Halcottsville	East Branch Delaware River	200	0.50	141	55
Kelly	2018	Halcottsville	East Branch Delaware River	300	2.62	60	14
Castellitto	2018	Halcottsville	East Branch Delaware River	120	0.41	82	26
Hubbell	2018	Halcottsville	East Branch Delaware River	15	0.03	25	2
Kelly	2017	Halcottsville	East Branch Delaware River	300	2.62	1,000	18
				1,260	6.63	1,416	127

Objective 3: Fish Movement

Native eastern Brook Trout, Brown Trout (*Salmo trutta*) and Rainbow Trout (*Oncorhynchus mykiss*) are the coldwater fish of the East Branch Delaware River. Current trout management (and planned future management according to the Draft Fisheries Management Plan) consists of monitoring and stocking Brown Trout along portions of the East Branch, however wild trout of all three species are also present in the watershed. Wild trout are those fish that are born, grow and reproduce in natural stream conditions. NYS DEC's goal is to conserve and enhance New York State's abundant and diverse populations of freshwater fishes, while providing the public with quality recreational angling opportunities. The goal of the project was to provide insight to fish movement and migration patterns. The study was designed to provide an understanding of how hatchery raised, naturalized and wild trout use the river; if thermal refugia are being used during time of thermal stress; and if fish are able pass the Wawaka Lake dam. The information gathered from the study will help NYS DEC understand how best to manage the coldwater fishery of the East Branch.

The fish movement study consisted of installing stream-wide Radio Frequency Identification (RFID) units at eight locations above and below Wawaka Lake (Map 1: 4 major tributaries -Pleasant Valley Brook, Bragg Hollow, Batavia Kill and Hubbell Hill Hollow; 1 below the dam and 3 additional locations on the mainstem). The RFID at the dam was problematic and did not work during the study despite significant and ongoing effort. RFID tracking is a wireless system

of tags and readers. The reader emits radio waves receiving and recording signals from the tag. Tags use radio waves to communicate their identity and other information to nearby readers. Radio frequency identification does not require line of sight, tags can be read if they are within the range of a reader.

During the study, two-year old hatchery raised, Brown Trout were implanted with a tag prior to 2018 stocking effort. The tags are implanted using a minor surgical procedure. Following 2018 trout stocking, six sessions of electro fishing took place during 2018 and 2019 field season; 1,646 fish were tagged and tracked for two years. During electrofishing, additional fish to include wild Brook and Brown Trout were also tagged. Table 5 summarizes fish tagging effort.

Table 5: Trout Tagging Summary

	Brook Trout	Brown Trout
Total Tagged	**163**	**1,483**
Wild	**163**	**442**
Hatchery	**0**	**1,041**
Upstream	**160**	**251**
Downstream	**3**	**248**
Meeker	**26**	**10**
Bragg Hollow	**3**	**39**
Batavia Kill	**0**	**101**

The results of the trout tracking effort showed 131 fish out of 1,646 tagged (8%) were detected at an RFID antenna during the study. Of those, 82 individual fish (5%) moved during the study. The percentage of fish that moved to an upstream RFID was 68.3% and those that moved to a downstream RFID was 29.3%; two fish (2.4%) moved both upstream and downstream during the study. Of the fish detected to have moved, seven (8.5%) were Brook Trout and 75 (91.4%) were Brown Trout. All the Brook Trout were wild fish, 47 fish (57.3%) were wild Brown Trout, and 28 fish (34.1%) were hatchery raised Brown Trout.

Almost half of all moves were fish moving into Batavia Kill - 40 out of 88 (45.5%). Of the 40 fish moving to Batavia Kill, 36 (90%) came from a mainstem site, and four (10%) came from another tributary. Overall, if a trout was tagged in a tributary it did not move, except for one trout that was tagged in Meeker Hollow and moved downstream to the Roxbury Highway Garage RFID Site. The only other movement by a tributary tagged trout was to move from one tributary to another. Two fish moved downstream from Bragg Hollow RFID site to Hubbell Hill Hollow, and one moved from Batavia Kill RFID upstream to Bragg Hollow RFID. The movement data is summarized in Table 6.

The majority (77%) of fish that moved upstream only, went upstream to the next closest site; only fourteen fish that moved upstream went farther than one site. One fish, a hatchery raised 351 mm Brown Trout, was recorded over 130,000 times over 49 days on the first antenna at the Roxbury Highway Garage RFID site. It was at the site from May-August, swam between the Railroad antennas, then returned to the first antenna from September until the last reading in October.

Table 6: Trout Movement Summary from Batavia Kill

From	# Trout	Movement Direction
Stocking Site (A)	1	Downstream
Stocking Site Horse Farm Road (C)	1	Downstream
Stocking Site Halcottsville Dam (F)	2	Downstream
Stocking Site Hubbell Farm (G)	7	Downstream
Stocking Site Bragg Hollow RFID	1	Downstream
Stocking Site (I)	1	Upstream
Stocking Site RT 39 Crossing (J)	1	Upstream
Stocking Site (L)	1	Upstream
Stocking Site Hubbell Hill Hollow (H)	2	Upstream
Stocking Site Hanah Golf Course (J)	21	Upstream
Total (individual Movers)	**38**	
Upstream Movers	**12**	**32%**
Downstream Movers	**26**	**68%**

Most movement occurred during the summer months (60.2% Figure 5) and 67% of the moves occurred below the dam. During the spawning months of September-December, 31.8% of the movements occurred. During the month of May, only seven movements were detected, or 8%. The highest number of movements by trout from mainstem to the tributaries was during the summer months (37.5% Figure 6). Occasional moves to a tributary from the mainstem happened during the fall spawning months (4.5%). Highest average movement was 1.49 ± 2.6 km for the month of June; and lowest average movement was 0.17 ± 0.1 km in the month of December. Fifty-three total movements occurred from June-August, 33 (62.2%) were to a tributary from the mainstem and all 33 of those movements occurred downstream of dam.

In total, 38 of the 88 detected moves (43%), were a fish moving from the mainstem into a tributary. Looking at it another way, out of the 38 movements that occurred from the mainstem to a tributary, 89.1% occurred during the summer months, and 10.9% occurred during the spawning months. All the detected moves from the mainstem to a tributary that occurred during the summer months happened downstream of the dam; the detections were fish moving into Batavia Kill, usually from the downstream Hanah Golf Course site. Average movement among all fish regardless of species or stocking status downstream of the Lake was 1.5 ± 2.2 km, and average movement upstream of the Lake was 0.7 ± 1.1 km. When accounting for species and stocking status, the highest average movement was 3.6 ± 3.6 km for hatchery raised Brown Trout in June, and the lowest movement was 0.1 km in October for hatchery raised and wild Brook Trout. Lowest average movement was 0.17 ± 0.1 km in December for wild Brown Trout.

Big movers (4-9 sites)

Six fish were in the 'big mover' category. The longest upstream movement was 6 sites by a hatchery raised Brown Trout in August moving to Batavia Kill. The remaining fish were one wild, and four hatchery raised Brown Trout. The longest downstream movement was 9 sites from the Roxbury School Site to the mouth of Batavia Kill. Two of the fish went upstream four sites either from Batavia Kill RFID site to Bragg Hollow RFID site, or from Stocking Site E to Roxbury Highway Garage RFID site. The remaining fish both went downstream four sites either from Bragg Hollow to East Hubbell Hill Road or from Stocking Site C at Horse Farm Road to Batavia Kill.

Medium movers (2-3 sites)

Twenty fish were in the 'medium mover' category. All but one of the fish were Brown Trout; eight, including the only Brook Trout, were wild fish and 12 were hatchery raised fish. Nine moved downstream and 11 moved upstream. Over half, 11 fish, moved into Batavia Kill from the mainstem and nine of those moves occurred in the summer months.

Small movers (1 site)

The remaining 62 fish were in the" small mover' category and only moved up or downstream a single site and 23 of those moved from the mainstem to Batavia Kill during the summer months. Twenty-one fish moved within one of the tributaries. Three moved from Briggs Road to the Roxbury Highway Garage RFID site, two moved from Roxbury School Tagging Site to the first antenna at Kirkside Park RFID, and the remainder moved between the array antennas at the Roxbury Highway Garage and Kirkside Park RFID sites.

Objective 4: Road Stream Crossing Barrier Assessment

Inadequately constructed culverts present as big a threat to stream ecosystem health as dams, degrading water quality and causing a seasonal or year-round barrier to fish or wildlife. Barriers of this nature fragment habitat and disconnect the natural flow of organisms, material, nutrients and energy along the river system. Poorly engineered culverts can reduce opportunities for spawning and survival since fish need to move easily through a stream to feed, find cooler water, avoid predators, and reach spawning habitat. In the East Branch, which supports spawning of native and wild trout, habitat fragmentation can reduce the availability of spawning grounds, which can impact population sustainability for migrating fish such as trout[6]. The loss of opportunities to renew the population can lead to local extinctions which in turn can increase the likelihood of system-wide decline. Long-term effects of fragmentation may also cause reproductive isolation within a stream network, limiting the ability of populations to recover from environmental impacts such as floods.[7] Habitat fragmentation also presents a risk to aquatic populations in the main river systems due to loss of spawning and rearing habitat as well as access to cold-water refugia during seasonal water temperature increases. The loss of stream connectivity is a critical threat to valuable and already vulnerable species such as the native Brook Trout (*Salvelinus fontinalis*) and is a focus of the HIP.

There are 110 mapped road stream crossings (9 State; 11 County; 88 Town; 2 Private) in the Project area. Delaware County Public Works has completed a thorough assessment of road stream crossings that are greater than 5-feet. The TU team discussed the project with local highway supervisors to understand current local goals and priorities. Following these initial discussions, the TU team focused on Town structures and completed a drive-by survey of 76 road stream crossings within the project area. Of those sites visited, 40 were considered potential barriers to trout. Of those, four were flagged as in poor condition. Noted below in Table 5 are the barriers identified on the main tributaries within the project areas upstream and downstream of Wawaka Lake. Since Batavia Kill is considered an important tributary for trout seeking coldwater refuge, additional review of the Batavia Kill data is provided in the report. All of the tributaries have been analyzed and this information will be presented to the Towns to help determine suitable culvert replacement projects that will benefit trout and help improve town infrastructure and flood resiliency.

[6] Gosset, C., Rives, J. and Labonne, J. (2006), Effect of habitat fragmentation on spawning migration of brown trout (*Salmo trutta L.*). Ecology of Freshwater Fish, 15: 247–254. doi: 10.1111/j.1600-0633.2006.00144.x

[7] Letcher B.H., K.H. Nislow, J.A. Coombs, M.J. O'Donnell, T.L. Dubreuil. 2007. Population response to habitat fragmentation in a stream-dwelling brook trout population. PLoS ONE 2(11):e1139. doi:10.1371/journal.pone.0001139.

Table 6: Barriers Identified during Road Stream Crossing Survey on all main tributaries to East Branch

Tributary	Type of Barrier	# Barriers on Mainstem Tributary	# Barriers in Watershed*	Location from Dam
Montgomery Hollow	Culvert	1	1	Upstream
Pleasant Valley Brook	Culvert	1	1	Upstream
Unnamed Stratton Falls	Natural Falls	1	1	Upstream
Meeker Hollow	Natural Falls	4	4	Upstream
Bragg Hollow	Natural Falls	2	5	Downstream
Batavia Kill	Natural Falls	4	5	Downstream
Hubbell Hill Hollow	Natural Falls	4	4	Downstream

*This is the total number of barriers in each subwatershed to include both mainstem tributary barriers and barriers on tributaries to the mainstem tributary.

Table 7: Road Stream Crossing Barrier Assessment Summary for Batavia Kill

Barrier Number/Structure Type	GPS Location	Road	Miles from Mouth
1 (Falls)	42.183254, -74. 586411	Hogg Mountain Road	0.97
2 (Dam)	42.244423, -74.541264	Stewart Road	6.44
3 (Culvert)	42.259333, -74.517836	George Lawrence Road	8.22
4 (Culvert)	42.259485, -74.512883	Sherwood Road	8.47
5 (Culvert); tributary	42.260321, -74.508982	Bed Hollow Road	8.69

Batavia Kill Barrier Photos

Batavia Kill Potential Barrier#1 Natural Falls (RFID was installed in 2020 to determine if trout are moving up the falls.

Batavia Kill - Barrier #2 at Stewart Road

Batavia Kill - Barrier #3 at George Lawrence Road

Batavia Kill - Barrier #4 at Sherwood Road

Batavia Kill Tributary - Barrier #5 at Bed Hollow Road

TU RIVERS app webmap.[8] There are four main tributaries above the dam and three downstream (Map 1). A summary of barriers and connection information for each tributary can be found in Table 6.

Objective 4: Community Engagement

TU is a national nonprofit organization with over 200 staff and more than 150,000 grassroot members dedicated to conserving, protecting, and restoring North America's cold-water fisheries and their watersheds. The mission of the organization is to ensure that robust populations of native and wild cold-water fish once again thrive within their North American range, so that our children can enjoy healthy fisheries in their home waters. TU applies many strategies in pursuit of our mission; all of which are driven by science and evolve as new ecological understanding develops. Our strategies include working closely with private landowners, local municipalities and state and federal agencies as well as partnering with local contractors and other conservation organizations to complete protection, restoration and reconnection projects across the country.

Using our restoration as the backdrop, the East Branch Trout HIP will provide hands-on opportunities to foster this stewardship with the goal of connecting students and the community to nature and their local environment. TU believes that "place-based" education increases a student's sense of stewardship and environmental consciousness and adds to their sense of attachment to place".[9] Place-based learning is central to TU's Mission. There were several opportunities for volunteers to participate in the HIP. Riparian planting is a great way to engage community members and students of all ages in meaningful service-learning activities. Volunteers from the local TU Chapter have spearheaded the temperature monitoring and will continue to lead these activities. Other activities included fish tagging.

[8] https://trout.maps.arcgis.com/apps/webappviewer/index.html?id=cf6ee6cb21bb4ede8fb0da746db2d0e1&extent=-15215009.2001%2C2449683.4771%2C-6996499.9189%2C6886700.095%2C102100.

[9] Louv, R. 2005. Last Child in the Woods: Saving Our Children From Nature-Deficit Disorder, Algonquin Books of Chapel Hill.

Management Implications

- Trout located downstream of the dam moved more frequently and further in October compared to upstream which may indicate that trout needed to travel further to find suitable habitat to spawn. An expansion of the project could include redd and habitat surveys to identify spawning and quantify suitable spawning habitat and opportunities for restoration below the dam.
- Trout moved more outside of the spawning season downstream of the dam which may indicate that trout need to move in order to find suitable coldwater refugia. Consider opportunities for riparian restoration throughout the mainstem with focus on instream habitat and riparian restoration projects along the Hubbell Farm reach.
- Trout move from the mainstem to the tributaries during the summer months. Batavia Kill is an important thermal refuge for trout. Additional work should concentrate on quantifying and improving habitat in the tributaries below the dam in order to provide suitable thermal refuge for trout to mitigate thermal impacts caused by the dam. With the threat of warmer years ahead as a result of climate change, reducing stream temperatures will be the best strategy for maintaining a coldwater fishery in the East Branch.
- Wawaka Lake dam is impacting trout movement and increasing stream temperature downstream. The best way to mitigate the negative impacts for the dam on the East Branch is to remove the dam and restore the river. Since the dam is privately owned and operated as a kayak/birding destination resort, the landowner is interested in maintaining an impoundment above the dam; they are also interested in protecting the river and trout. TU and NYS DEC have had discussions with the landowners about alternative strategies for the dam from a fish bypass channel to partial and full breaching of the dam. This discussion was expanded to engineers that have extensive experience with creative dam removal solutions. Recently, TU applied for funding to support a feasibility study to allow us to gather the data we need to come up with a solution that could work for both the landowner and the river. To date we have not received funding to take this project to the next step, but our goal is to continue to apply for funding to support this work.
- Use the culvert assessment data to discuss priorities with the Town of Middletown and Roxbury highway departments and find funding to help the Towns replace aquatic barriers on the main tributaries. Prioritize replacement work on Batavia Kill, Bragg Hollow and Hubbell Hill Hollow downstream of the dam.

Special thanks to Steve Swenson Region 4 Senior Ecologist at NYS Department of Environmental Conservation for his dedication and commitment to the project. Steve and his team at NYS DEC were critical to the success of our work. Additional thanks go to Catherine Skalda at Delaware County Soil and Water Conservation District for her tireless work herding the TU volunteer planting team. Her patience and good humor were the only reason they kept showing up. Further accolades and appreciation go out to the Ashokan-Pepacton Chapter of Trout Unlimited for their support with the temperature monitoring and planting activities. A special call out and standing ovation for members Lenny Millen, Peter Marx and George Markos for their four years of dedication to our work on the East Branch. Caroline Shafer, TU Field Technician, contributed significant time working with Steve and the temperature monitoring team on every aspect of the project. Additional support came from the TU PA team, Shawn Rummel, Allison Lutz and Kathleen Lavelle, who contributed significant time to tagging trout and analyzing the tracking data

Map 1: East Branch Delaware River Project Map

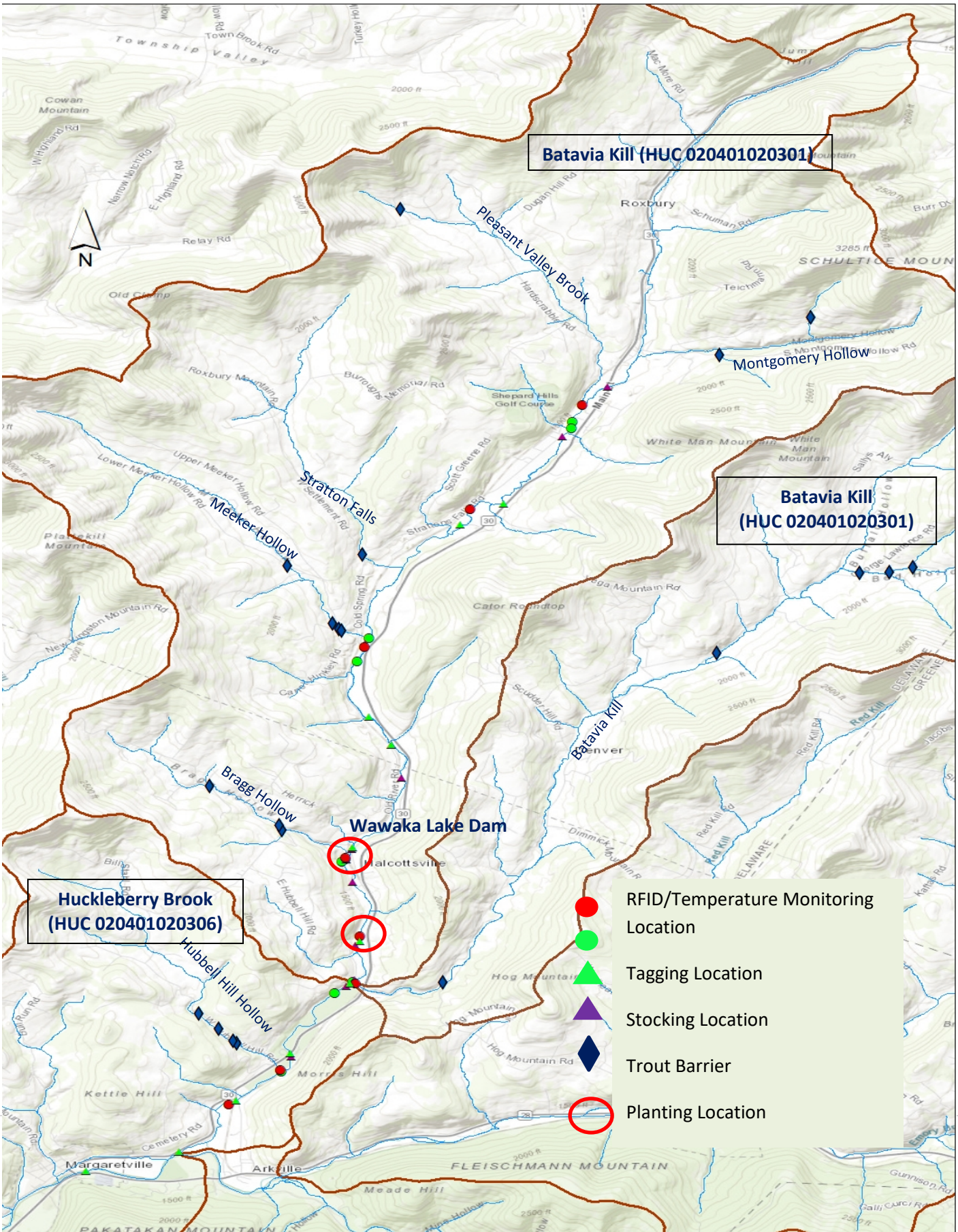

Figure 1: East Branch Delaware River Study Results (2017)
Mean Daily Temperature

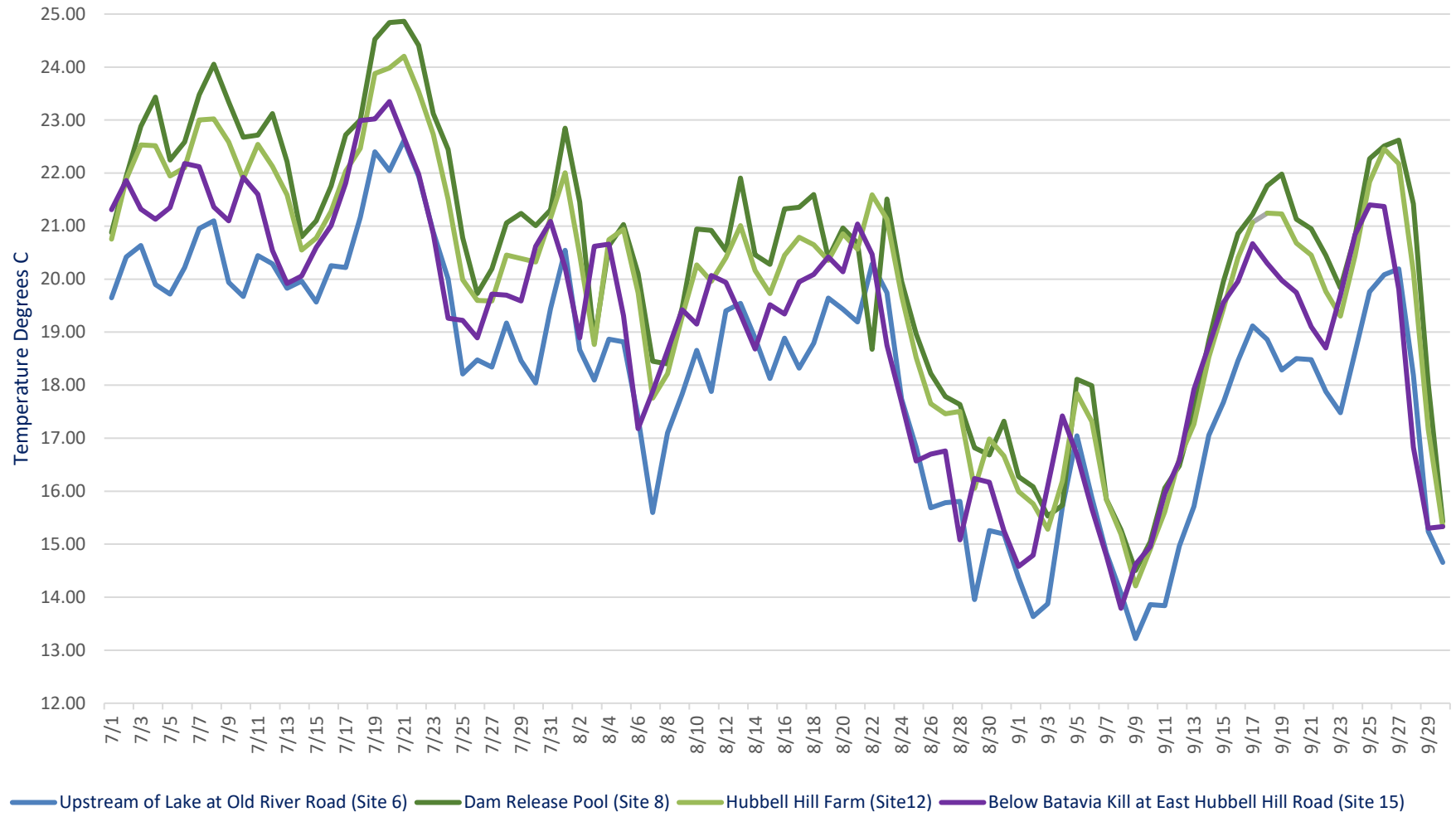

Figure 2: East Branch Delaware River Study Results (2018)
Mean Daily Temperature

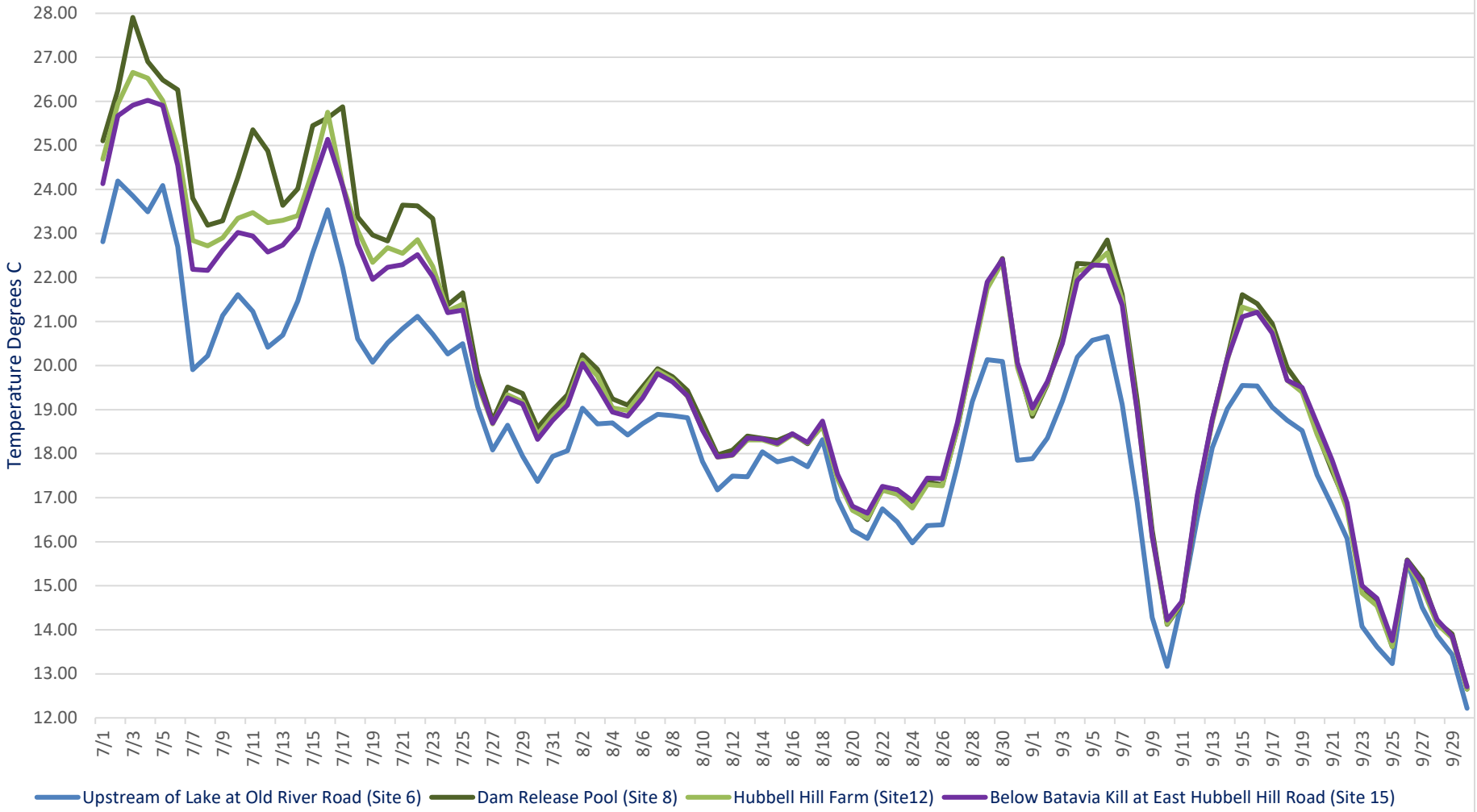

Figure 3: East Branch Delaware River Study Results (2019)
Mean Daily Temperature

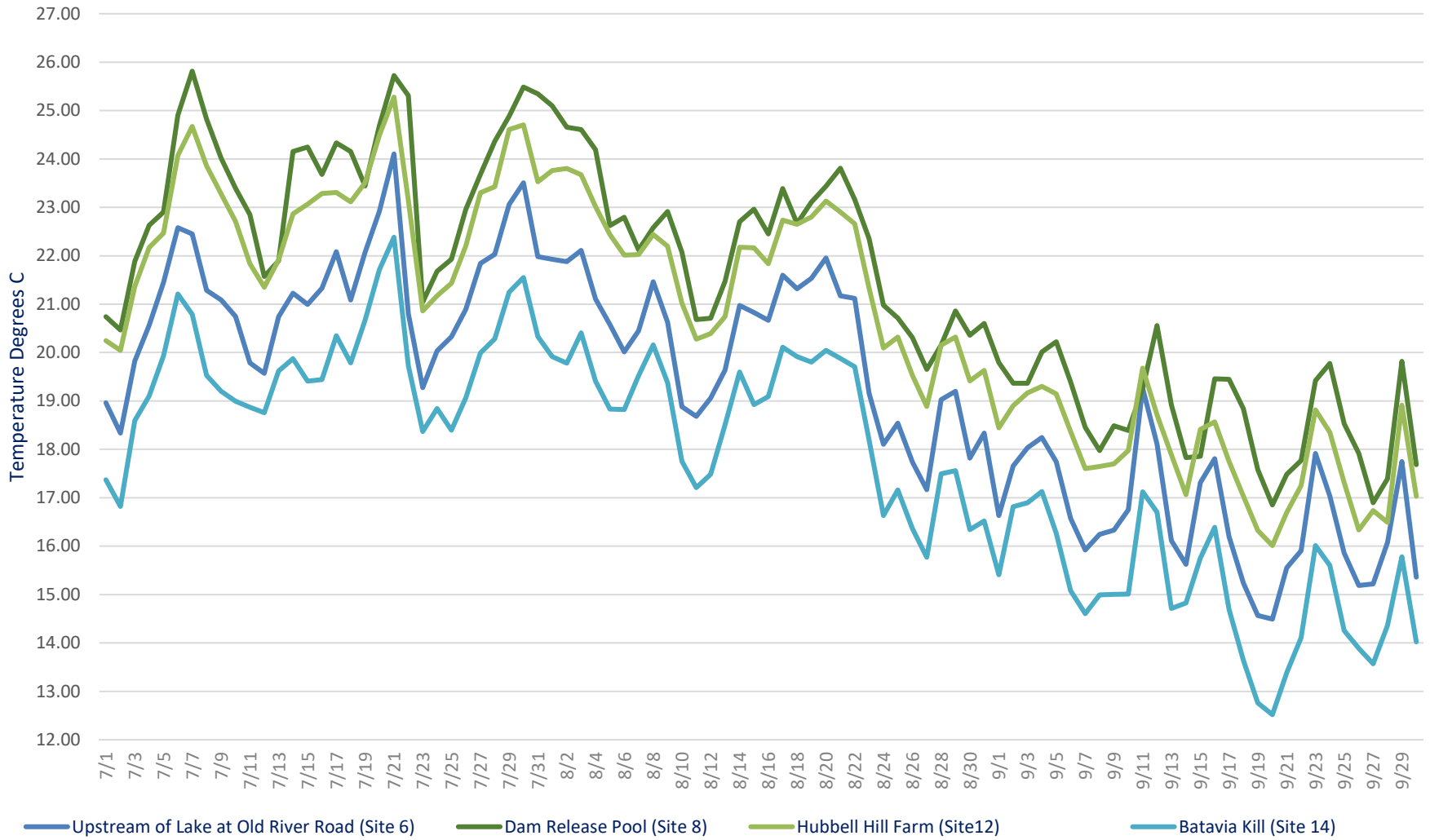

Figure 4: USGS 01413088 East Branch Delaware River at Roxbury, NY

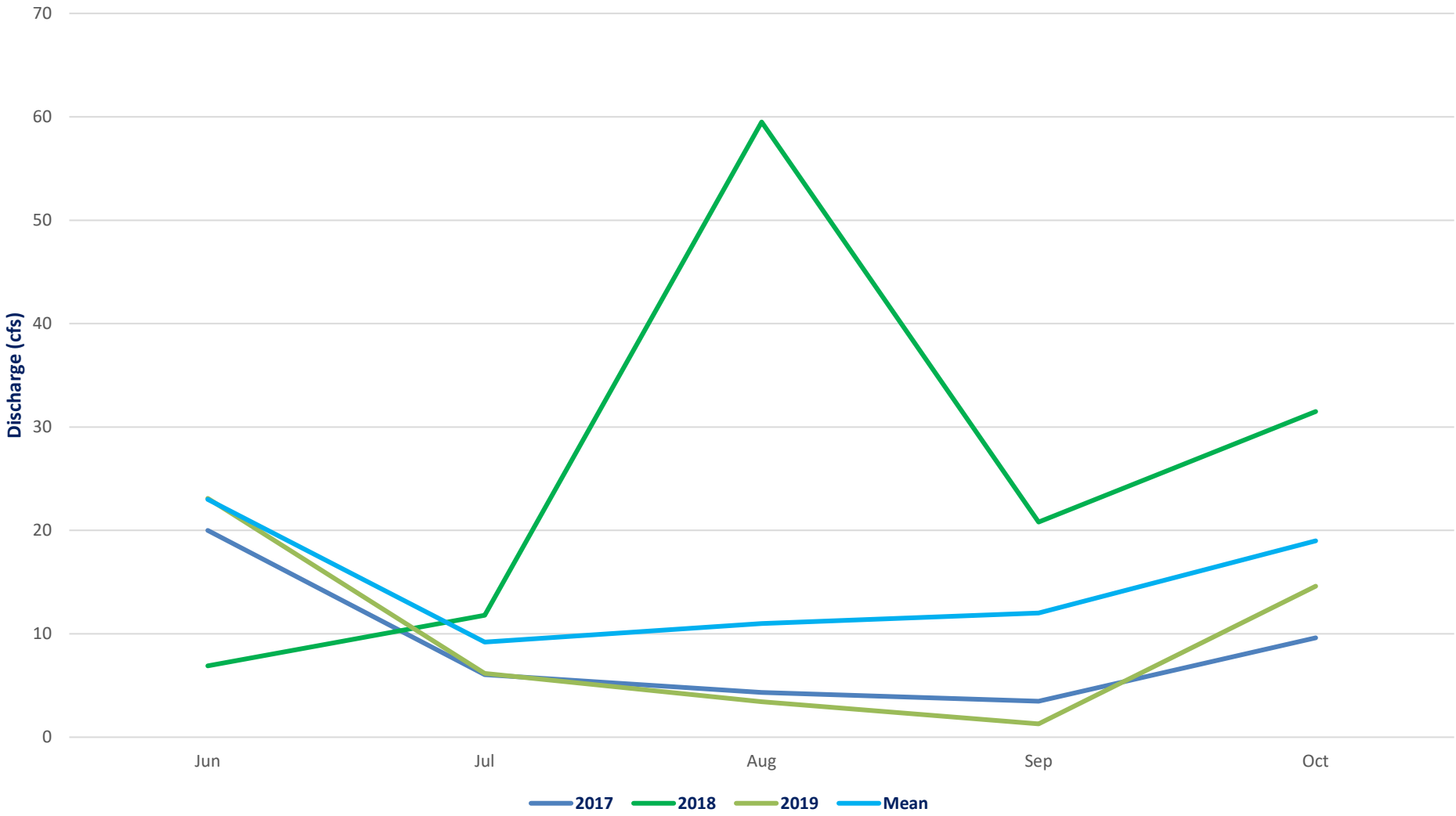

Figure 5: Trout Movement by Month

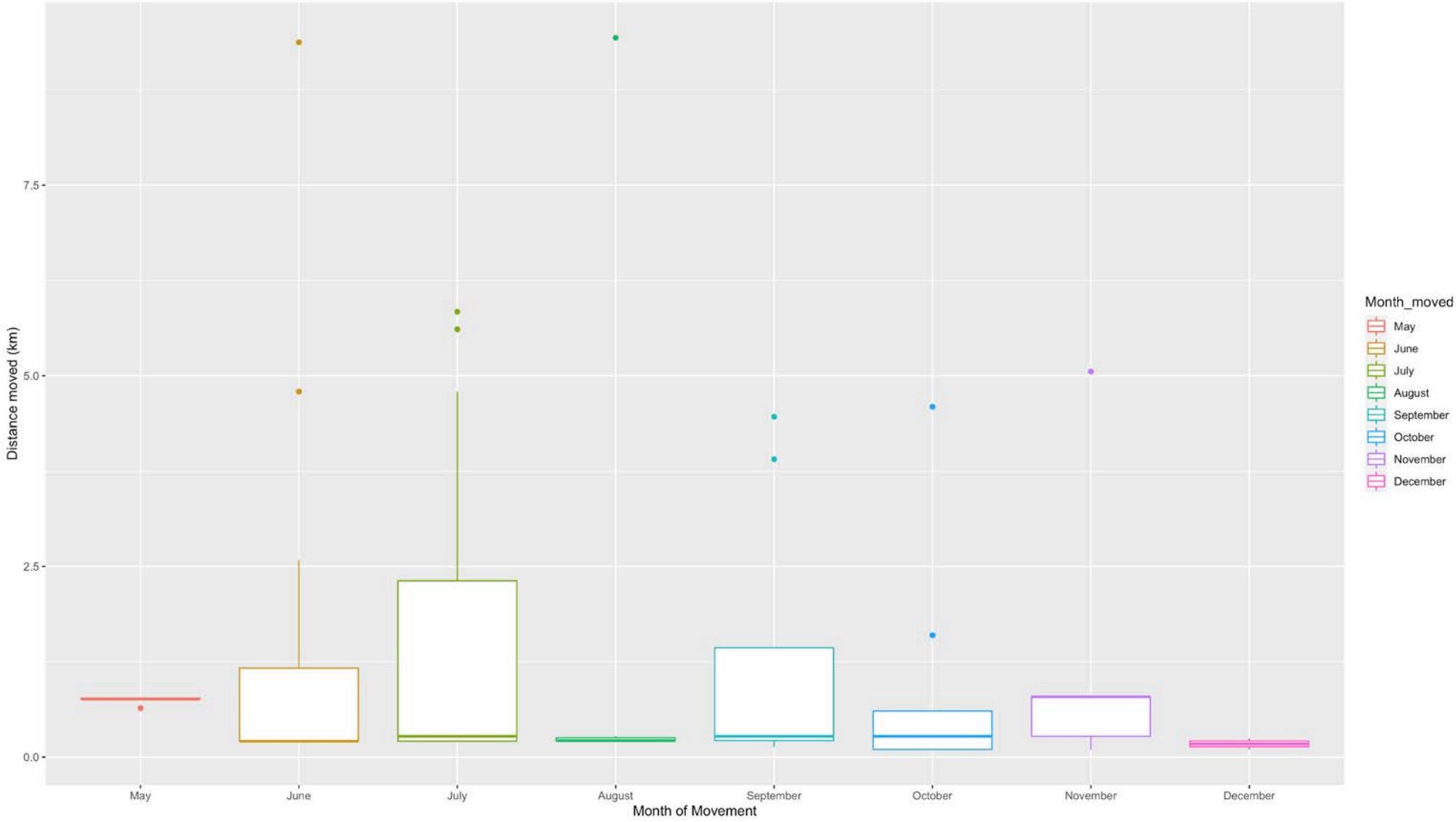

Figure 6: Trout Summer Movement Between Hanah Golf Course and Batavia Kill