Monitoring Hughesville Dam Removal Project, Post Hurricane Sandy

Evaluating the impact of the dam removal on fish passage and water quality in the Musconetcong River, New Jersey

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Introduction

In the wake of Hurricane Sandy (October-November 2012), the U.S. Department of the Interior (DOI) provided $304 million to fund 167 projects within the Hurricane Sandy Coastal Resiliency Program that were designed to reduce ecosystem and community vulnerability to the growing risks from threats such as coastal storms, flooding, and erosion. Aquatic connectivity projects play a pivotal role in ecosystem restoration and resilience building, particularly in the Northeastern United States. These initiatives aim to restore stream habitats, enhance passage for resident and migratory fish, and mitigate climate-related risks. Understanding the impact of these projects on both ecosystems and society is paramount for refining implementation strategies and ensuring cost-effectiveness in future endeavors.

One such initiative involved mitigating the risk of dam failure posed by the Hughesville Dam, located in Pohatcong Township, Warren County, NJ, and Holland Township, Hunterdon County, NJ. Additionally, this project aimed to restore approximately 3 miles of fish habitat. The removal of the Hughesville Dam was successfully completed in 2016, resulting in the restoration of five miles of free-flowing river from the confluence of the Delaware River. To evaluate the effectiveness of this restoration effort, the Musconetcong Watershed Association implemented a monitoring protocol aimed at quantifying the impacts of the restoration through habitat assessments, pebble counts, macroinvertebrate taxonomic assessments, flow measurements, water chemistry, continuous sensor monitoring for temperature and specific conductance, fish surveys and analyze immediately parameters (pH, dissolved oxygen, temperature, specific conductance).

The rate of dam removal in the United States is unprecedented. According to American Rivers, out of approximately 90,000 dams nationwide, around 1,300 have been removed, with the majority of these removals occurring in the past 25 years. However, the number of dams that have undergone thorough study is remarkably low (American Rivers (2014) and Bellmore et al. (2015)). As a result, both the scientific and management communities have consistently emphasized the need for increased stream monitoring following dam removals (Babbitt, 2002; Graf, 2003). For dam removal to be embraced as a restoration tool there must be an understanding of the effects of dam removal through rigorous monitoring and effective communication strategies. Hurricane Sandy-associated dam removals provided an extraordinary opportunity to rigorously evaluate the impact of dam removals on ecosystems and society.

Following the removal of the Hughesville Dam, the lower section of the Musconetcong River achieved a significant milestone by becoming eligible for designation under the Wild and Scenic Rivers Act. This notable status was formally adopted, transforming 28 miles of the river as Wild and Scenic. This designation not only recognizes the river's outstanding natural, cultural, and recreational values but also secures enhanced funding and support from the National Park Service.

This development has facilitated the formation of the Musconetcong River Management Council (MRMC), comprising local municipal members, governmental agencies, other NGOs, such as Trout Unlimited, and made it true partnership of river management. The council is tasked with overseeing the preservation and management of the river's unique attributes. The partnership emphasizes collaborative stewardship and sustainable management practices aimed at maintaining the river's integrity and ecological health for future generations. This collaboration represents a proactive approach to river conservation, ensuring that the river remains a valuable natural resource for the surrounding communities.

Objectives

The primary objectives for the removal of the Hughesville Dam from the Musconetcong River in New Jersey are to enhance river flow and water quality, to reestablish the river's connectivity for both resident and migratory fish populations and enhance the river's resilience to natural events and improve flood mitigation. This project was spearheaded by the Musconetcong Watershed Association (MWA) and enjoys the collaboration of the Musconetcong River Restoration Partnership. The initiative is further supported by a broad coalition of stakeholders, including local property owners, engineering teams, construction contractors, and institutional partners such as the U.S. Fish and Wildlife Service, along with the New Jersey Department of Environmental Protection's Office of Natural Resource Restoration and the Division of Fish and Wildlife. This concerted effort aims to restore the river to a more natural state, promoting ecological balance and enhancing biodiversity within the river ecosystem. This approach aligns with sustainable river management practices that emphasize the importance of natural river functions as a means to manage flood risks more effectively. The project supports broader environmental resilience goals by enabling a more adaptive response to climatic variability and extreme weather conditions.

Parameters

Habitat Monitoring and Pebble Counts

Habitat assessments, including Wolman pebble counts, were used to evaluate the ecological status of the habitat annually over a five-year period utilizing the EPA Visual Habitat Assessment. The rapid habitat assessment typically involves the collection of key data points related to habitat characteristics, such as substrate composition, vegetation cover, channel morphology, and instream habitat features. These data points are critical to understanding the suitability of the system to sustain populations of keystone macroinvertebrate species and support fish populations, especially with the anticipated return of the American shad. The Wolman pebble count allowed for an understanding of sediment dynamics, channel stability, evaluation of the habitat restoration and inform adaptive management, for not only this project but similar projects moving forward.

Macroinvertebrate Monitoring

Macroinvertebrate assessments are a key ecological indicator of stream health. Their presence/absence and assemblages provide a holistic understanding of the in-stream conditions. By conducting assessments in early spring each year, this monitoring provides a deeper understanding of the change occurring both in the immediately impacted area (dam impoundment) and further upstream and downstream of the focus area. Taxa richness, %EPT, and other metrics were used to assess 5 sites using the NJ High Gradient Macroinvertebrate Index. It should be noted that through this monitoring effort, it was discovered that the Musconetcong River had been infested with the invasive New Zealand mudsnail. A management plan has been written and submitted to USF&WS. In addition, this management plan and its decontamination protocols have laddered up to a state Aquatic Invasive Species (AIS) management plan that is in its final stages of approval within the Governor's office.

Water Chemistry Monitoring

Water chemistry and in-situ measurements were collected from April through October of each year and across all 5 locations in the focus area. Nutrients, TSS, turbidity, specific conductivity, temperature, pH and dissolved oxygen were analyzed for trends and against surface water quality standards for criteria limit violations. Limited dissolved oxygen is a known impact of dam impoundments. Due to this side effect, anoxic zones can form and be further complicated by the collection of nutrients in the sediments that gather in the impoundment, especially phosphorus, as it is “sticky” and binds to sediment. These anoxic zones can severely hinder aquatic life and prevent passage, even if they can get over the physical barrier, as American eels are known to do.

Flow and Continuous Monitoring

Monitoring the depth and discharge was enabled by using a continuous monitoring network, EnviroDIY sensor stations. The flow or discharge was measured at various depth intervals with an OTT MF Pro and then rating curves were created. The formula, with a high R^2 percentage, could then be used as a surrogate by using just the depth on the EnviroDIY stations. This enabled the water quality (WQ) staff to understand the volume of water moving through the system at any given time. This was a more precise and accurate way to determine the volume of water at 3 points in the focus area, since there is only one USGS station on the Musconetcong River. It is located well above the project area and is confounded by other dams and inputs from tributaries, as well as hyper-localized weather in the gorge. This flow data informed WQ staff on planning for sampling and fish surveys and helped inform residents, since it is an open-source platform that can be viewed on https://monitormywatershed.org .

Fish Monitoring

Fish surveys within the focus area were conducted as a means of quantitatively evaluating the ecological benefits resulting from the removal of the dam and restoration of 6 miles to the resident and anadromous fishery utilizing this section of the Musconetcong River, such as American shad and American eels. Three reaches in the focus area were monitored to evaluate the current state of the fish community within the river reach immediately affected by the dam removal as compared to the fish community upgradient and down gradient of the dam removal. In the beginning of the project electro-shocking was employed, but eDNA was used as an adaptive management strategy in the 2nd half of the project due to high-flow conditions and Covid restrictions. The varying widths and depths of the Musconetcong River make it challenging to effectively use electroshocking combined with a seine net for capturing stunned fish. Similarly, operating a barge for this purpose is only feasible at very specific river depths.

Hughesville Post-dam Removal Monitoring Schedule	2018	2019	2020*	2021	2022
Habitat Assessments	Annually in spring	Annually in spring	Annually in spring	Annually in spring	Annually in spring

	Pebble Counts	Annually in summer or baseflow conditions	Annually in summer or baseflow conditions	Annually in summer or baseflow conditions	Annually in summer or baseflow conditions	Annually in summer or baseflow conditions
	Macroinvertebrate Assessments	Annually in spring	Annually in spring	Annually in spring	Annually in spring	Annually in spring
	Water Chemistry	Monthly (April-Oct)	Monthly (April-Oct)	Monthly (April-Oct)	Monthly (April-Oct)	Monthly (April-Oct)
	Flow/Continuous Monitoring	Flow measured at various depth intervals / 3 continuous sensors collecting data at 5 min intervals	Flow measured when needed to fill data gaps	Flow measured when needed to fill data gaps	Flow measured when needed to fill data gaps	Rating curves complete
	Fish Surveys*	Annually	Not performed due to high water	Not performed due to Covid restrictions	Annually	

*Covid restrictions delayed or canceled some monitoring

Outreach and Education

Community and Stakeholder Engagement

The MWA is committed to engaging with the community and disseminating information about the ongoing restoration efforts along the Musconetcong River through a multifaceted communication strategy. Key to this strategy is the publication of project updates and results in our quarterly "Musconetcong River News," which is mailed to members, member organizations, and watershed municipalities. Additionally, copies are distributed in public spaces within the watershed such as libraries and post offices to ensure broad community access.

Further extending our outreach, MWA maintains an active presence online with updates on our Facebook page and a dedicated section on our website under 'What We Do'. This section highlights a variety of MWA's restoration projects and water quality data, providing insights and updates to a wider audience. Additionally, MWA hosts the monthly River Talk series, which are public forums that often feature discussions on current projects and are open to community participation and engagement.

MWA also adheres to a rigorous reporting schedule, meeting quarterly with the Musconetcong River Management Council and the Musconetcong River Restoration Partnership to discuss progress and future plans. Quarterly reports are also provided to the National Park Service in alignment with the Musconetcong's status as a National Wild and Scenic River.

Documentation such as Quality Assurance Project Plans and Standard Operating Procedures developed during these projects are made available to other groups who wish to undertake similar initiatives, facilitating knowledge sharing and collaboration across projects and boundaries.

Our proactive media engagement includes issuing frequent press releases to local newspapers, contributing to listservs, and participating in interviews on local radio stations. These efforts are aimed at raising awareness about the importance of river restoration and protection efforts and garnering support from residents, local, state, and federal governments, as well as other organizations and funders. Through these comprehensive outreach initiatives, MWA aims to foster a community that is well-informed about and actively involved in the sustainable management and conservation of the Musconetcong River.

Conference Presentations

The Water Quality Program Manager successfully presented monitoring results at the 2023 National Water Monitoring Conference in Virginia Beach, receiving positive feedback, particularly for the innovative use of eDNA in fish surveys. This presentation drew a global audience of monitoring professionals and sparked engaging discussions. Additionally, her work will be further showcased at the upcoming Society of Freshwater Scientists Conference in Philadelphia, where she is slated to deliver an oral presentation on the five-year project outcomes. Complementing this, Craig Fleming, the Water Quality Field Specialist, is preparing a poster presentation to emphasize the fish survey work and direct attention to the oral session.

Project Setting and Monitoring Sites

The Hughesville Dam was located just downstream of State Road 519 and the former paper mill located in Hughesville. The dam, a 12-foot-high timber crib and rock fill dam, spanned the Musconetcong River from Holland Township, Hunterdon County to Pohatcong

Township, Warren County. The dam was located a little over a mile from the next impediment to fish passage, the Warren Glen dam, located in the Musconetcong Gorge. With the removal of the Hughesville dam, the river is free flowing for 6 miles from the confluence with the Delaware River. It is the largest tributary to the Delaware River in New Jersey.

Five monitoring locations were chosen to characterize the dam removal site and upstream and downstream reaches. The identifiers are known in series as such, STA-1, STA-2 and so on. After the first monitoring season STA-2 was dropped and another site took it's place as STA-6 (see Table below).

Site ID	Site Name	Latitude	Longitude	Sensor Station?
STA-1	Mt. Joy	40.6065	-75.172739	Yes-downstream
STA-2*	Below dam	40.6298	-75.140208	No
STA-3	Above dam	40.6301	-75.138191	Yes
STA-4	Gorge	40.6325	-75.130085	No
STA-5	Bloomsbury Water Co.	40.6519	-75.091907	Yes
STA-6**	Warren Glen dam	40.6361	-75.1209	No

Table: Monitoring sites on the Musconetcong River.
*Dropped after 1st monitoring season
**Added after 1st monitoring season

STA-1 and STA-5 serve as reference sites, positioned downstream and upstream respectively, to assess the impacts of environmental changes in the vicinity of the former dam (see Figure below).

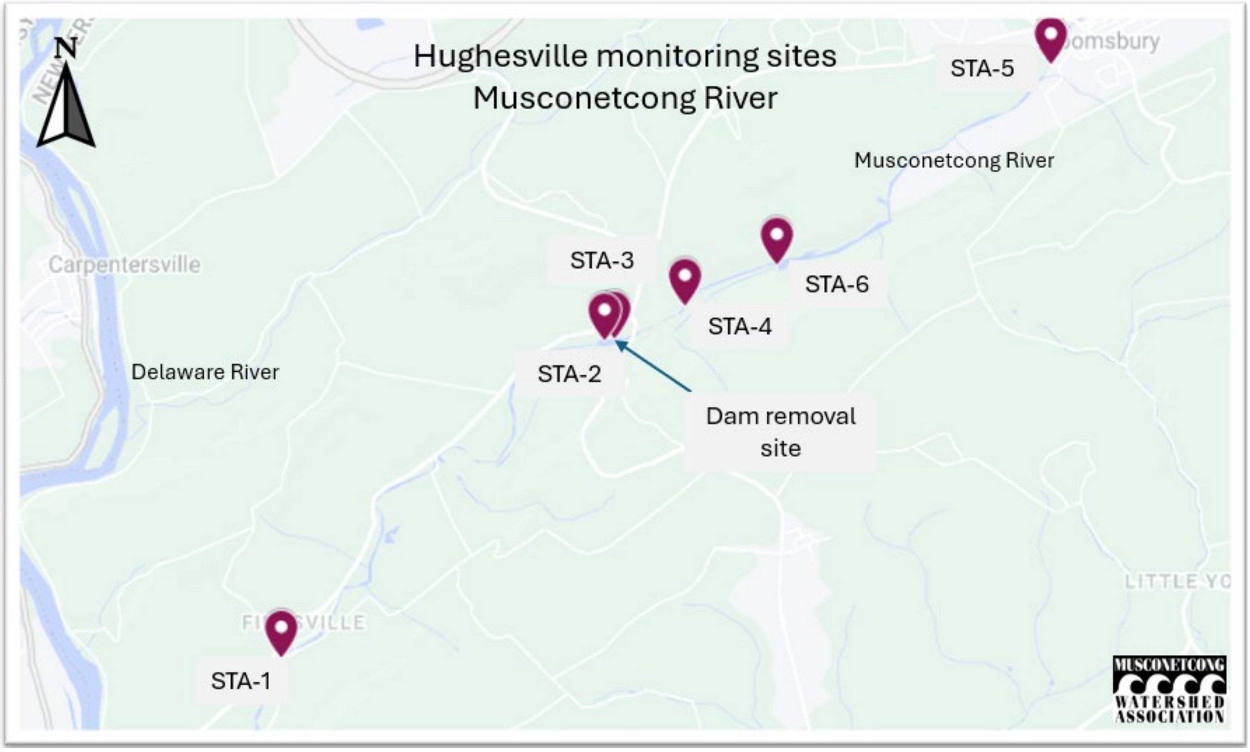

Figure: Map showing monitoring sites and their special relationship to the former Hughesville dam.

Image of the Hughesville dam being notched in 2016.

Image of the site after restoration. This is an upstream view towards State Road 519 from taken from the dam former location.

Image of the site after restoration. This is a downstream view towards where the dam structure was located, from the location of the former impoundment.

Results

Habitat Assessment Results

The EPA rapid habitat assessment uses 10 categories to determine the state of both terrestrial and in-stream conditions. The categories are substrate and available cover for aquatic organisms, embeddedness, velocity/depth regimes, sediment deposition, channel flow status, channel alteration, frequency of riffles/pools, bank stability, bank vegetative cover and bank vegetative zone. Each category is scored 1-20, with a total score of 200 possible. Optimal is from 200-160, sub-optimal is from 159-110, marginal is from 109-60 and poor is 60 and below.

All five sites were assessed while macroinvertebrates were collected. The overall trend of the focus area is a positive trend from sub-optimal to optimal. Individual scores can be seen in the table below.

Site ID	2018	2019	2020	2021	2022
STA-1	Sub-optimal	Sub-optimal	Optimal	Sub-optimal	Sub-optimal
STA-2	Sub-optimal	NA	NA	NA	NA
STA-3	Sub-optimal	Sub-optimal	Sub-optimal	Sub-optimal	Optimal
STA-4	Sub-optimal	Optimal	Optimal	Optimal	Optimal
STA-5	Sub-optimal	Optimal	Sub-optimal	Sub-optimal	Sub-optimal
STA-6	NA	Optimal	Optimal	Optimal	Optimal

Table showing rank of habitat assessment at 5 monitoring locations in focus area of the Hughesville dam removal.

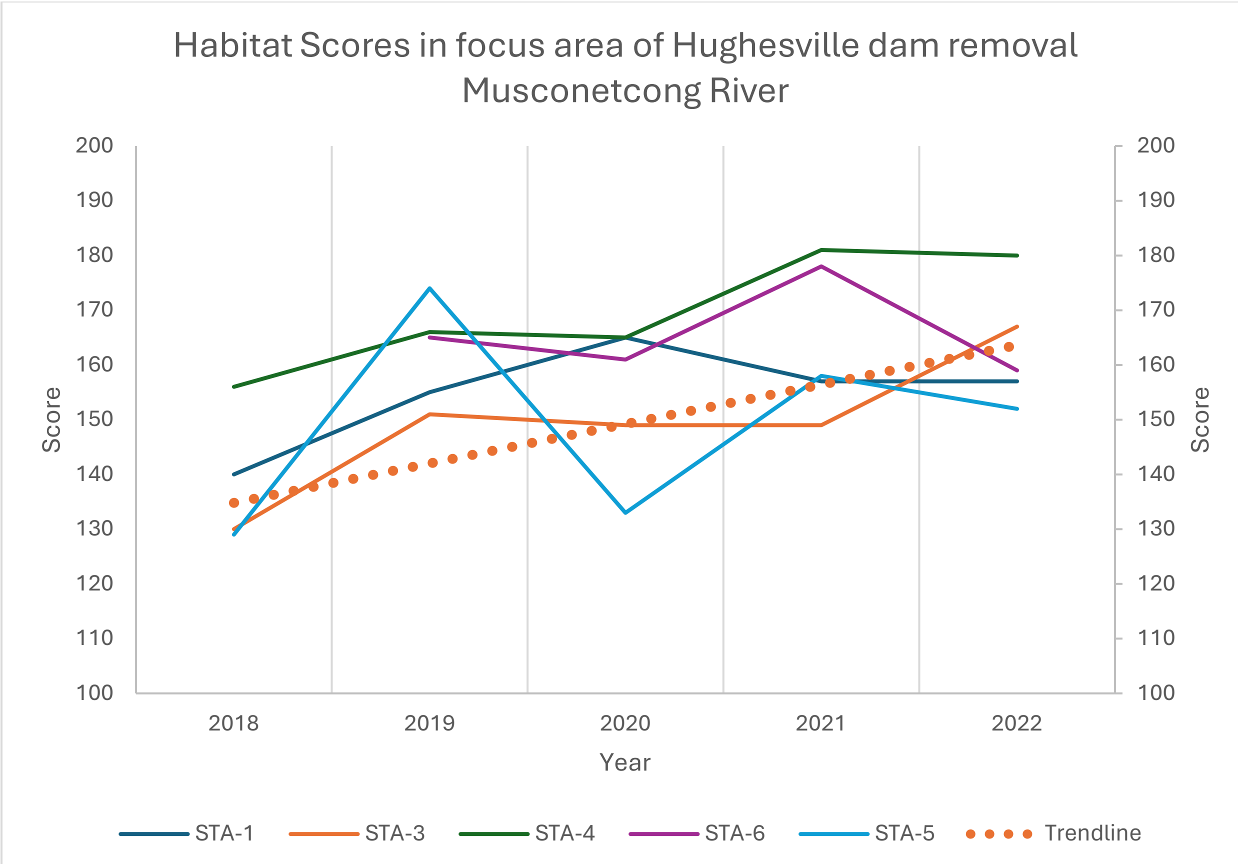

Figure: Habitat scores from all 5 sites from 2018-2022 plotted with overall trendline (dotted orange line). Note that STA-2 was omitted to the site being changed after the first season.

The habitat within the focus area has shown a consistent improvement over time, particularly at STA-3, the former dam impoundment site. Here, not only was the substrate restored with varying size of cobble, but the streamside was also replanted with native trees and herbaceous plant species. The streamside habitat has been a challenge, due to the presence of invasive species, most notably phragmites and purple loosestrife. Targeted herbicide is being employed to tame the spread of phragmites. As the trees reach maturity, the crowns will shade the area and succession will shift from wet meadow species to scrub stage and then a riparian forest climax community.

Pebble Count Results

The Wolman Pebble count method is a technique used in stream surveys to quantify the size distribution of streambed materials, from silt and sand to cobbles and boulders. When paired with habitat assessments, this method provides valuable insights into the physical characteristics of stream habitats, which can influence the distribution and diversity of aquatic life. A gravelometer is used for 3 runs of each reach to calculate a mean average score for grain size. Dam's impoundments are known to trap fine silt and sand. Hydraulic dredging removed approximately 21,000 cubic yards of sediment that was relocated to nearby lagoons within the confines of the now-defunct paper mill. Even with the removal of this astounding amount of sediment, the substrate still contained a thick layer of smaller grains. The impoundment was notched, and water levels were slowly drawn down, so as to not smother the downstream habitat and aquatic life. The pebble count elucidates the movement of sediment through the system. The table and graph below demonstrate how the average grain size increased over time. Looking at STA-3, the average grain size more than doubled within the 5-year period.

Site ID	STA-1	STA-3	STA-4	STA-5	STA-6
2018	NA	40.35	NA	63.45	NA
2019	75.13	48.72	81.26	58.78	46.43
2020	78	62.08	121.95	79.46	81.19
2021	79.39	81.5	101.36	85.28	91.92
2022	98.35	89.53	109.9	80.88	113.5

Table: Mean average grain size across all five sites from 2018-2022.

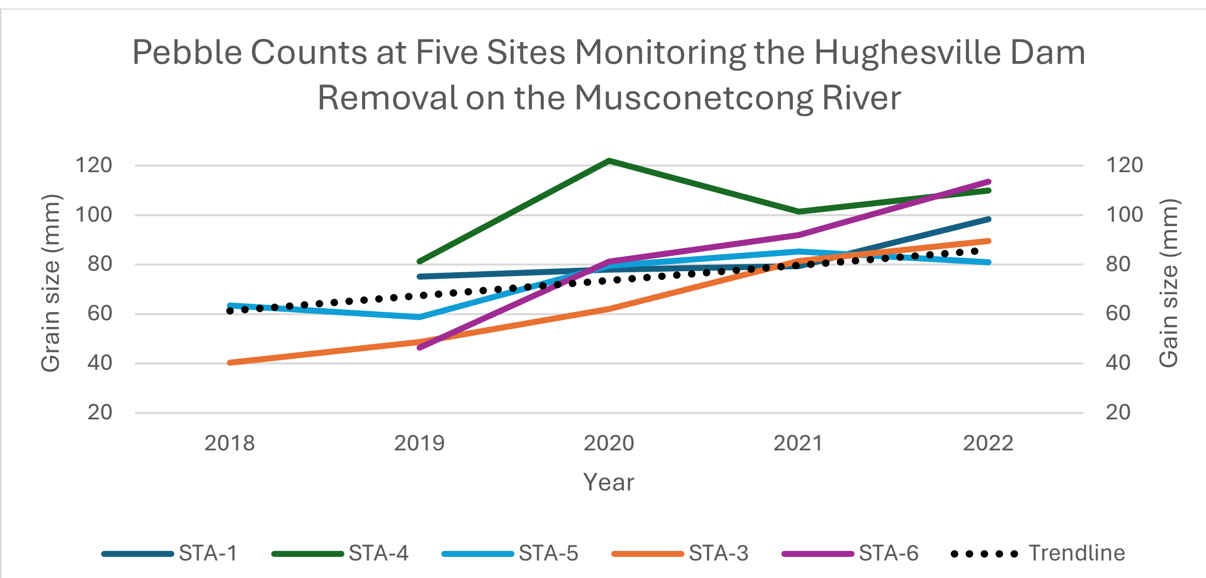

Figure: Graph of mean average grain size across time and focus area. Trendline shows the average grain size has increased as time from removal. Note that the Y-axis does not start at 0.

Macroinvertebrate Results

Macroinvertebrate assessments began two years post-dam removal, allowing the in-stream habitat to stabilize and support diverse organisms. Surprisingly, at this point, STA-3 achieved an Excellent HGMI score. Due to safety concerns from high water levels in 2019, STA-4 and STA-6 were not sampled. Nonetheless, all collected samples received a rating of Good or better (See Figure below).

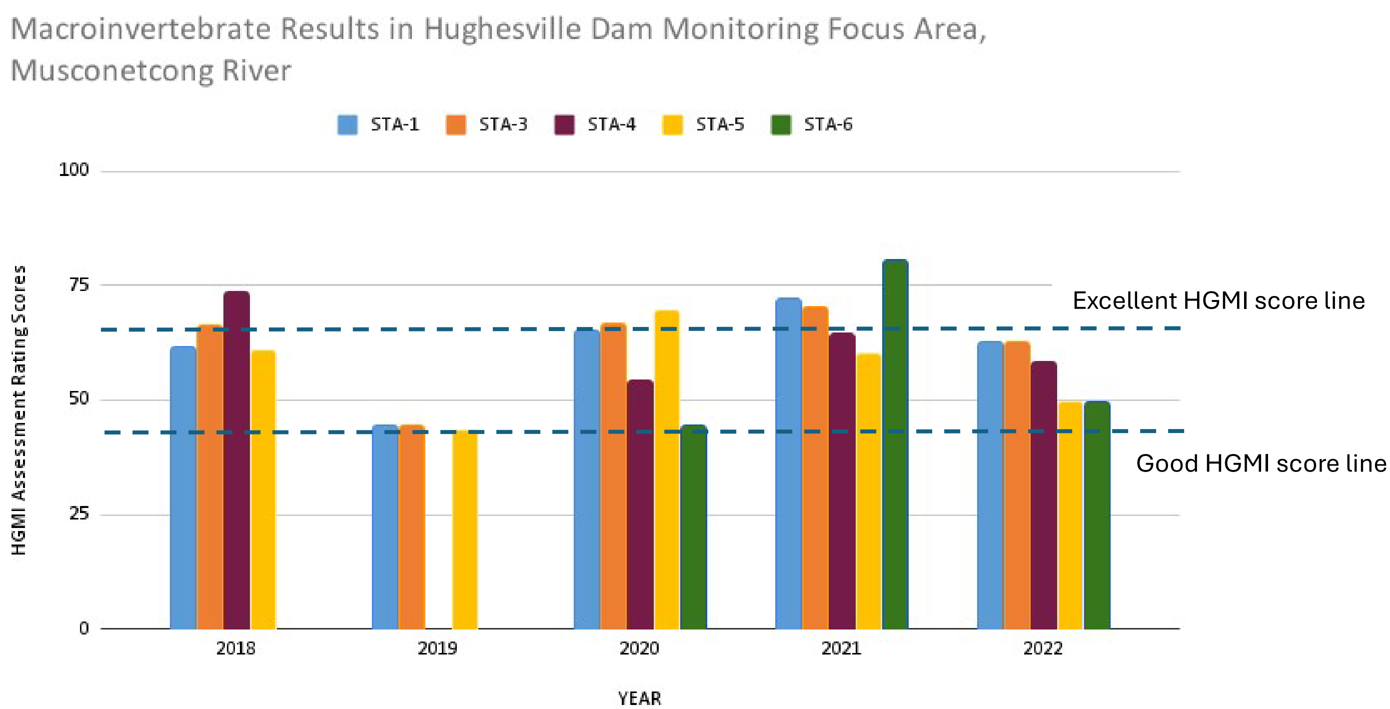

Figure: Graph depicting benthic macroinvertebrate HGMI scores. Two lines depict score limits for “Good” and “Excellent” scores.

In 2019 the taxonomic lab, Cole Ecological, informed MWA that they found an invasive species in the STA-5 sample, the New Zealand mudsnail. The Water Quality Program Manager contacted the East Coast expert, Ed Levri, at Penn State and he confirmed its presence. The New Zealand mudsnail (*Potamopyrgus antipodarum*) is a small but highly invasive aquatic snail originally native to freshwater bodies in New Zealand. It has become a problematic invasive species in the United States, first detected in the late 1980s in Idaho's Snake River. Since then, it has spread to various freshwater ecosystems across the country, including the Musconetcong River in New Jersey. The mudsnail's rapid reproduction rate, ability to thrive in diverse environmental conditions, and lack of natural predators in the U.S. allow it to dominate habitats and outcompete native species for resources. This can lead to significant disruptions in local aquatic ecosystems, impacting the food web and reducing biodiversity.

The NZM's increased presence at the surveyed sites has raised concerns due to their potential impact on native benthic macroinvertebrates and overall river health. MWA has actively responded by integrating management strategies into their monitoring programs and engaging with both local and national bodies to address the spread of this invasive species. Cole Ecological started to quantify their percentage of 100 count subsamples in 2020. In all but the most downstream site, the initial subsample contained the highest percentage of the invasive snails (see Table below).

NZM % in 100 count subsample	STA-1	STA-3	STA-4	STA-5	STA-6
YEAR					
2020	4%	11%	2%	15%	2%
2021	6%	0	1%	5%	4%
2022	12%	0	0	1%	1%

Table: Percentage of 100 count subsample from each monitoring site of the invasive New Zealand mudsnail.

The specific factors limiting the Musconetcong River's resilience against the New Zealand mudsnail invasion remain unidentified. However, the MWA has secured additional funding through a grant from the National Fish and Wildlife Foundation (NFWF) to develop a management plan and install decontamination stations at major river access points, as well as expand monitoring. The management plan is currently under final review. Additionally, these initiatives have been integrated into broader state efforts, discussed at New Jersey Water Monitoring Council meetings and within a decontamination workgroup. A state Aquatic Invasive Species (AIS) plan, which is nearing completion in the Governor's office, aims to secure federal funding for AIS management. Notably, MWA's Water Quality Program Manager contributed to the plan, focusing on decontamination strategies for New Zealand mudsnails and detailing both the background of and management strategies for this invasive species in New Jersey. In addition to the print material and decontamination station, the MWA WQ Field Specialist created a YouTube video to help others identify NZMs and decontaminate their gear. It can be viewed here:
https://youtu.be/9uGku5WnUAI?si=wOQcLjJzRSKzOcYe

Image: Decontamination station at access point to the Musconetcong River. The sign contains ID characteristics and a QR code for additional information, including a presence/absence map, can be found here: https://www.musconetcong.org/new-zealand-mudsnail

Image: Flyer created for distribution for NZM awareness.

Water Chemistry Results

In the ongoing efforts to ensure the health and sustainability of the aquatic ecosystem, monitoring nutrients, specifically nitrogen and phosphorus species, is crucial. These nutrients are fundamental in evaluating water quality as they can significantly influence algal growth and the overall biological integrity of water bodies. Excessive levels can lead to eutrophication, causing dense plant growth and death of animal life due to lack of oxygen. Total nitrogen measurements, including ammonia, nitrate, nitrite, and TKN, suggest various nitrogen sources. Sampling conditions, such as during rain or baseflow, help distinguish if results are more influenced by groundwater or stormwater. Over time, total nitrogen levels have risen across all five sites, with several readings surpassing the 2mg/L aquatic life criteria limit. Given that most samples were collected during baseflow, it suggests a significant influence from groundwater. In the river's lower section, characterized by karst geology, it is likely that deteriorating septic systems contribute to these elevated levels, rather than agricultural runoff, which would typically be indicated by increased levels during rain events. The graphs below show the increasing trend from most downstream site to the most upstream site.

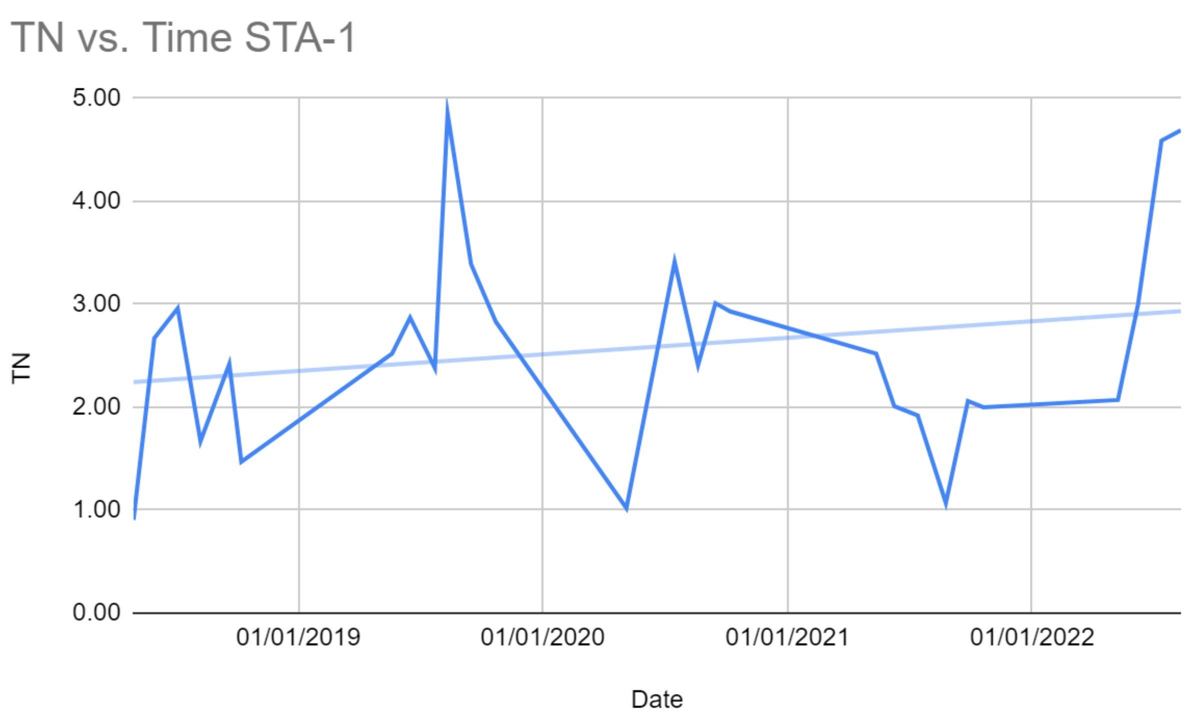

Figure: Total Nitrogen from 2018-2022 at STA-1 (Mt. Joy), the most downstream site.

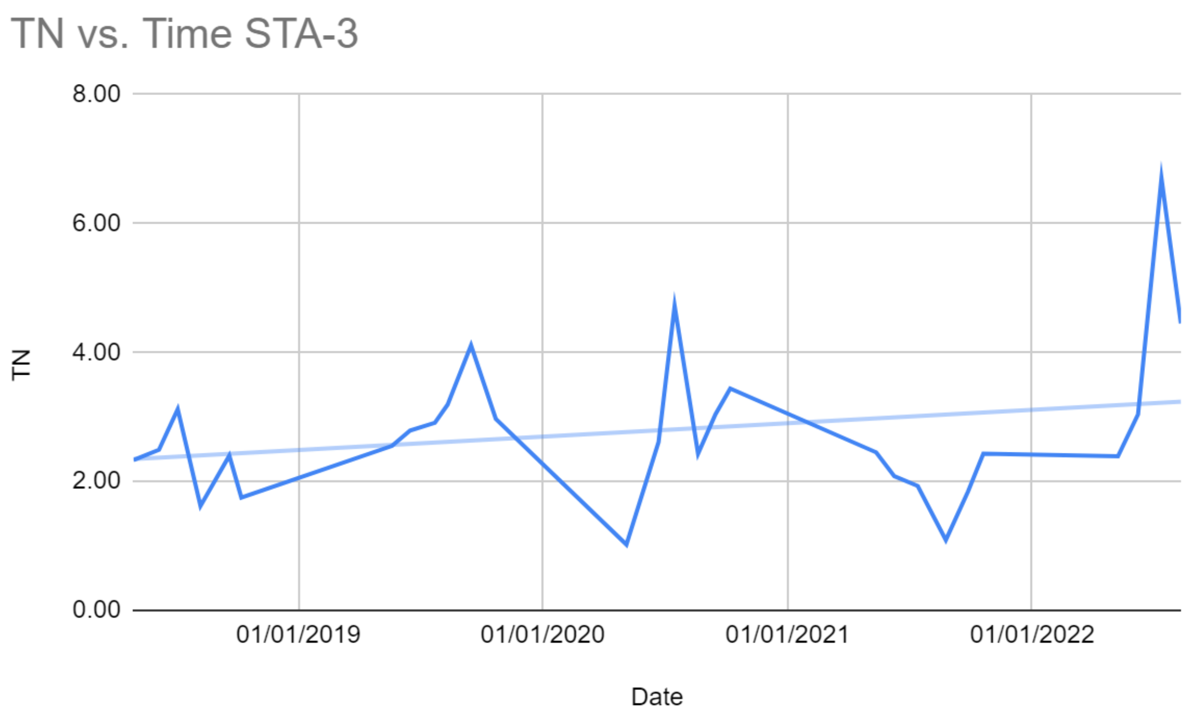

Figure: Total Nitrogen at STA-3 (Hughesville dam site) from 2018-2022.

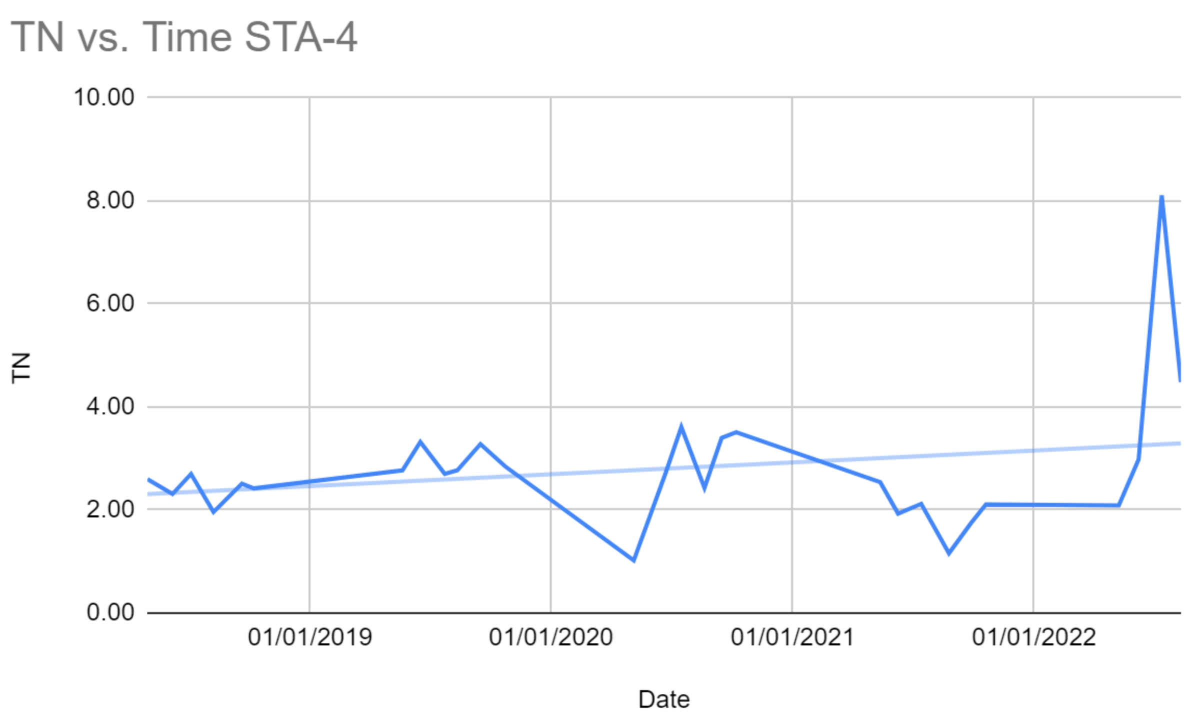

Figure: Total nitrogen at STA-4 (the Gorge) from 2018-2022.

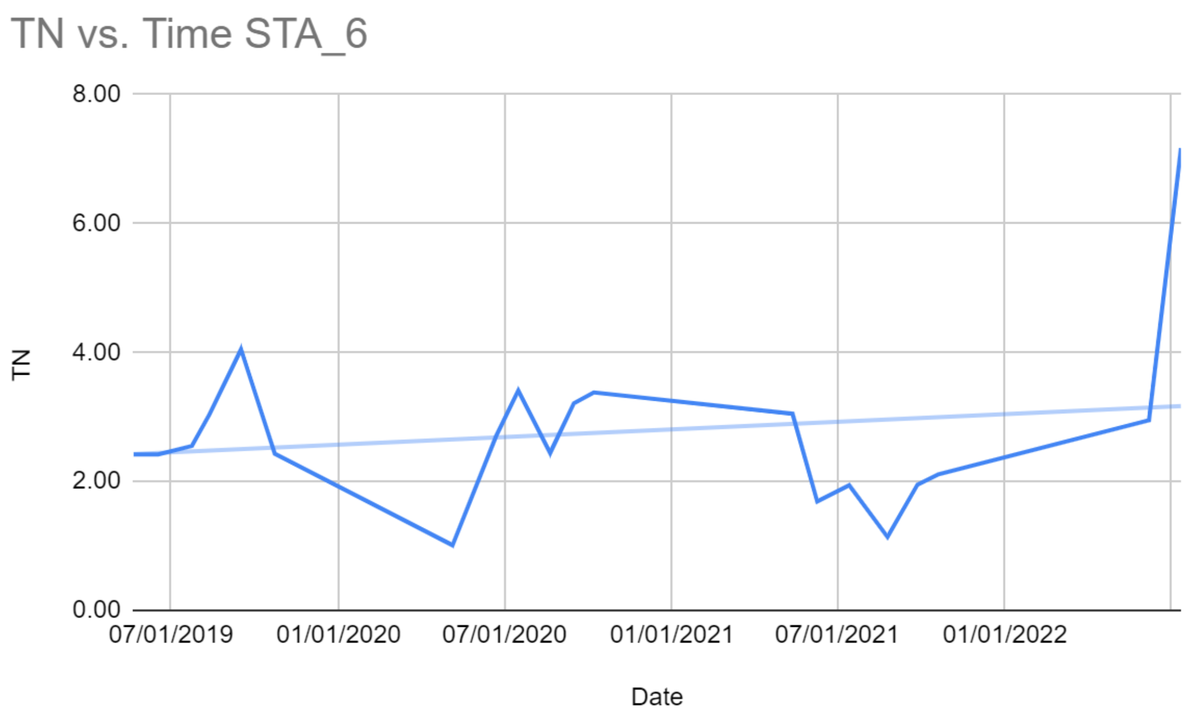

Figure: Total nitrogen at STA-6 (base of Warren Glen dam) from 2019-2022.

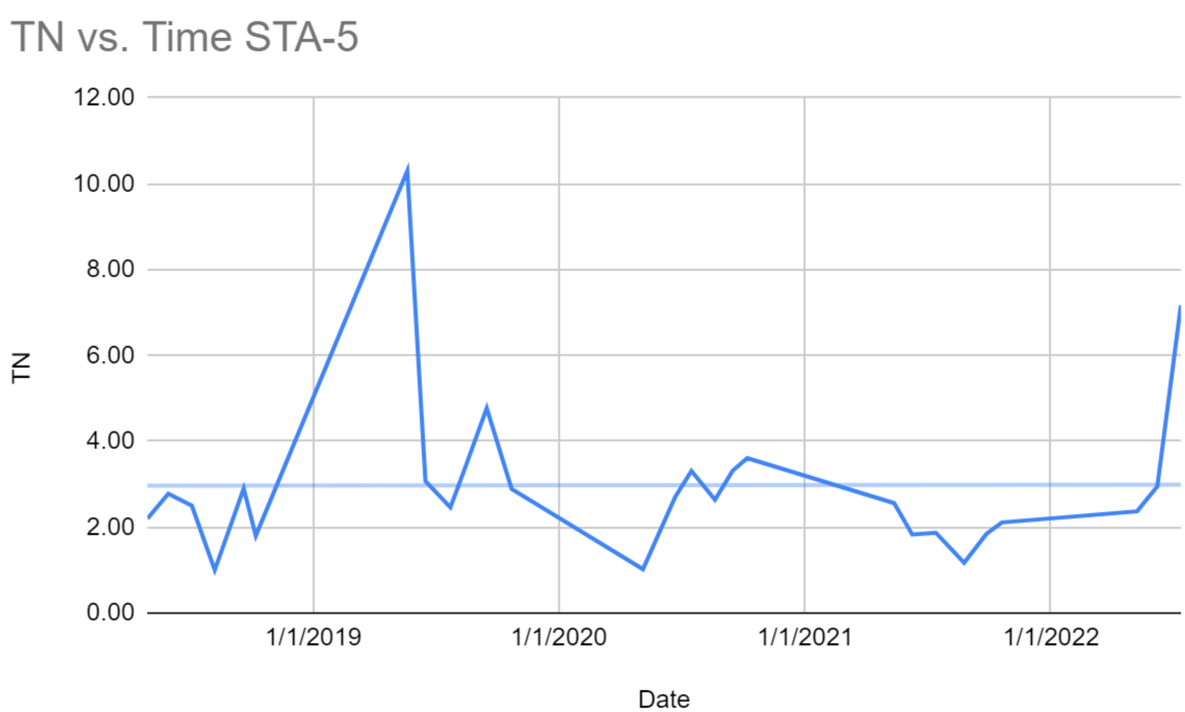

Figure: Total nitrogen at STA-5 (Bloomsbury water company) from 2018-2022.

Phosphorus in surface water can come from a variety of sources, but unlike nitrogen, it binds to the sediment and trends can be seen with the TSS measurements. Over the course of the study period, total phosphorus decreased. It exceeded the surface water criteria limit (0.1 mg/L) in only a few samples and in those instances, it was tied to an increase in TSS. The figures below show the trend over time from downstream to upstream.

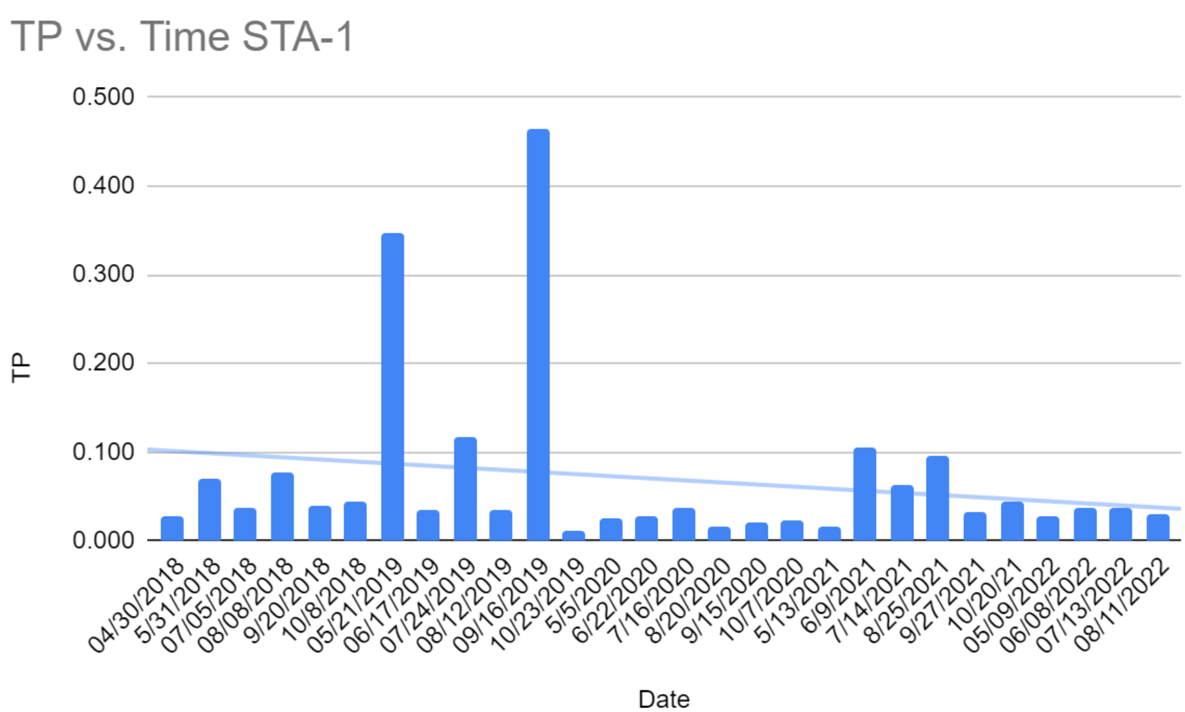

Figure: Total phosphorus at STA-1(Mt. Joy) from 2018-2022.

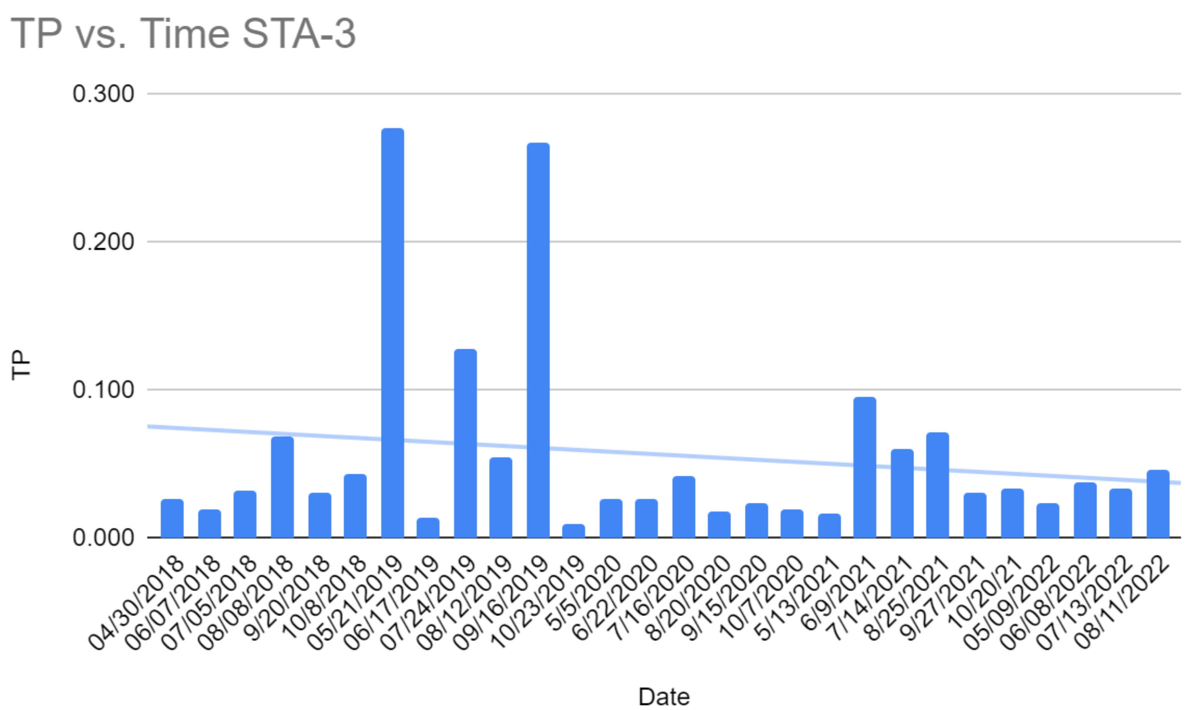

Figure: Total phosphorus at STA-3 (Hughesville dam removal site) from 2018-2022.

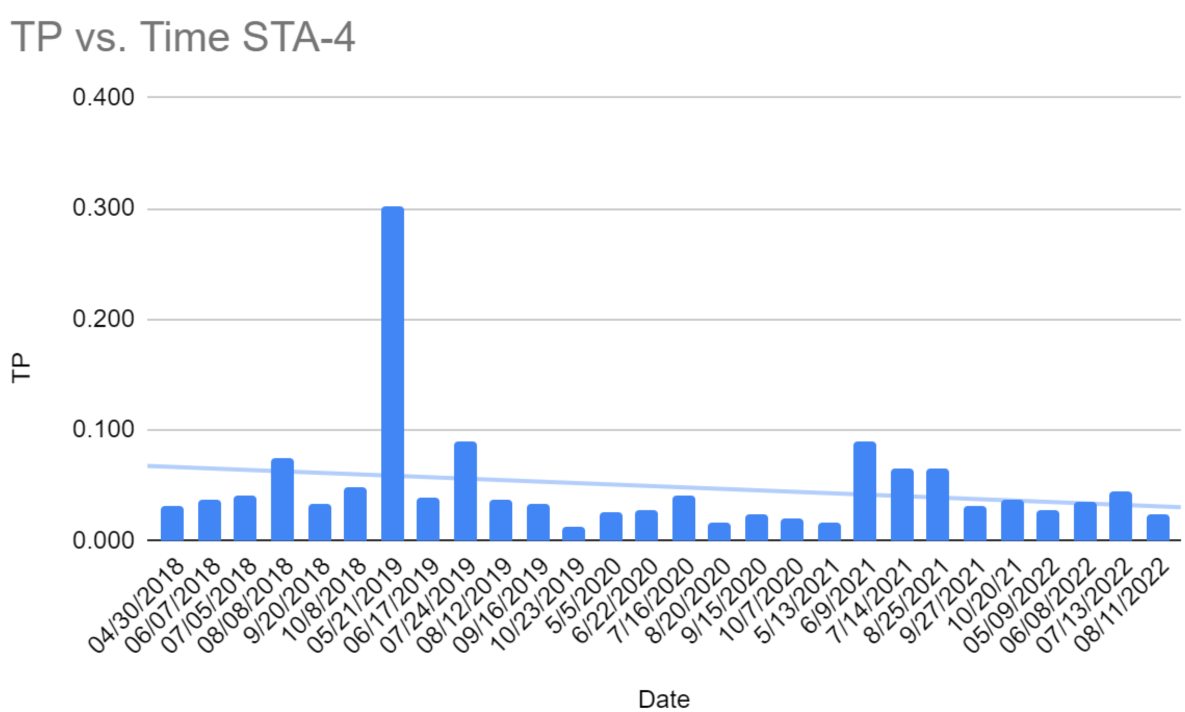

Figure: Total phosphorus at STA-4 (the Gorge) from 2018-2022.

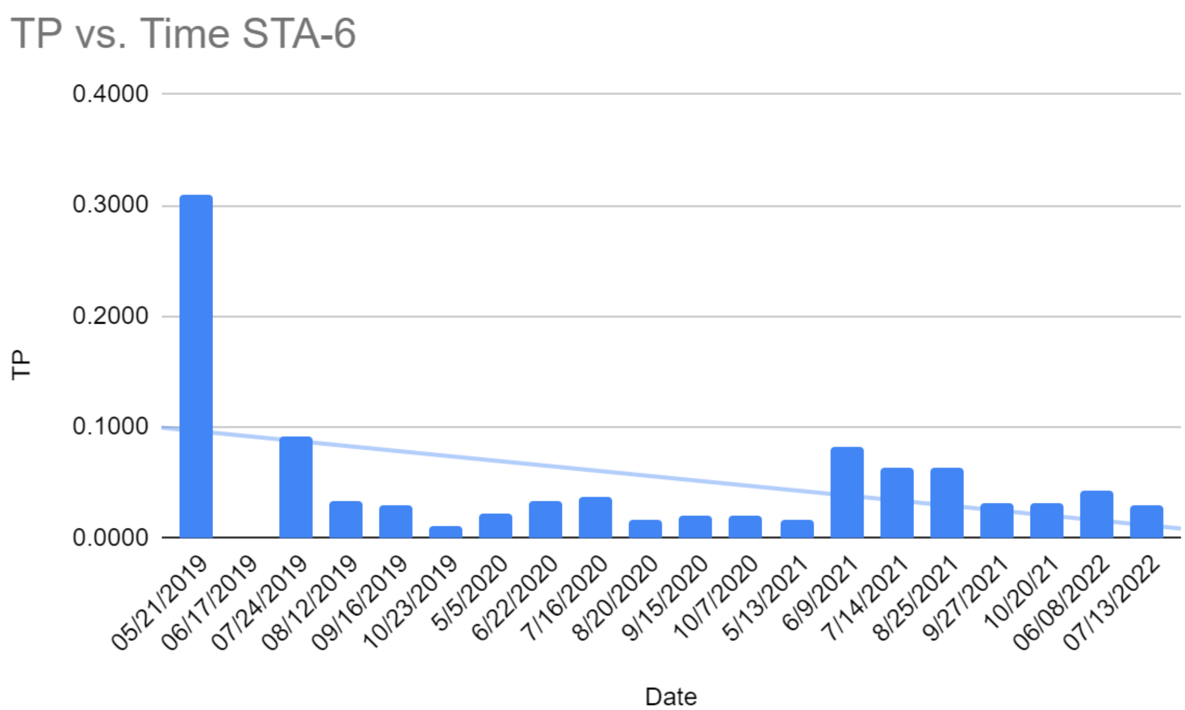

Figure: Total phosphorus at STA-6 (base of Warren Glen dam) from 2019-2022.

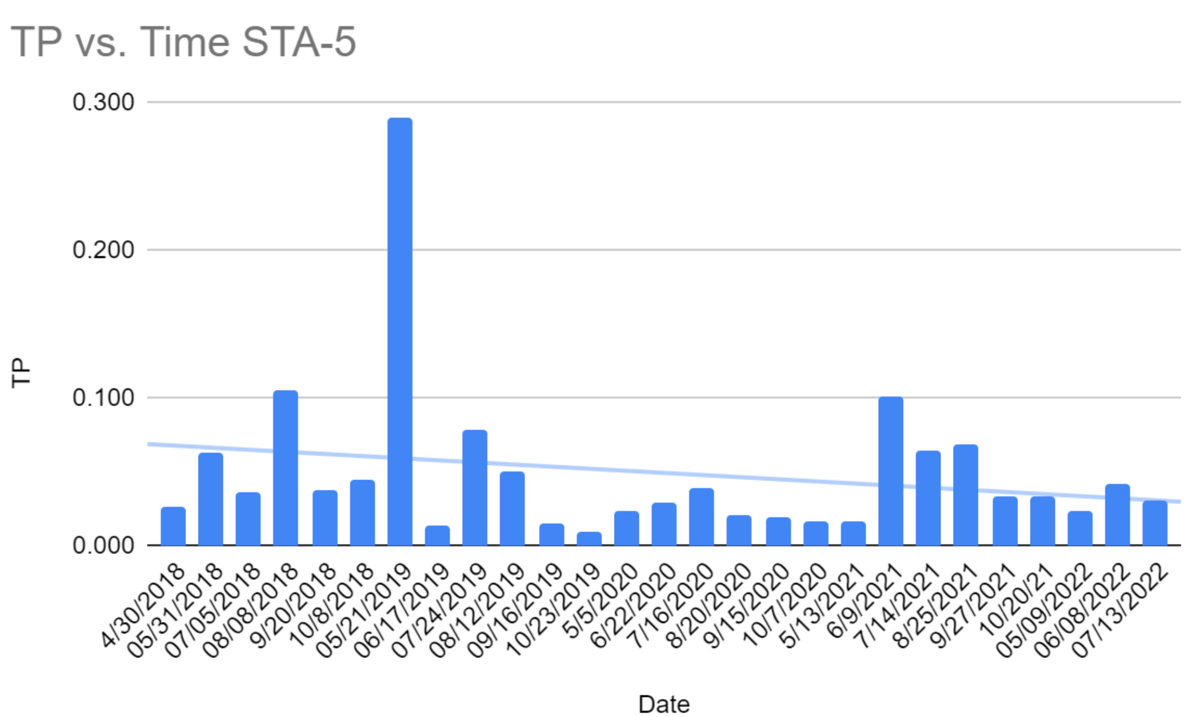

Figure: Total phosphorus at STA-5 (Bloomsbury water company), the most upstream site, from 2018-2022.

pH Results

pH in a river, such as the Musconetcong, that is geologically underlain by limestone naturally trends more alkaline. Ideal pH levels for most freshwater ecosystems range from 6.5 to 8.5, allowing a diverse range of aquatic organisms to thrive. However, readings have exceeded 8.5 on a regular basis. A connection can be seen between high nitrogen in the groundwater and higher pH readings. As this part of the river is also in agricultural cultivation, lime used on fields can runoff in stormwater, pushing the pH towards the basic side of the scale, as well. 2020 saw many of the limit exceedances, which is not surprising, since it was a significantly drier year than 2019, which was one of the highest precipitation years to date. The drought through the summer kept levels at baseflow, being mostly influenced by groundwater and hence high nitrogen and high pH.

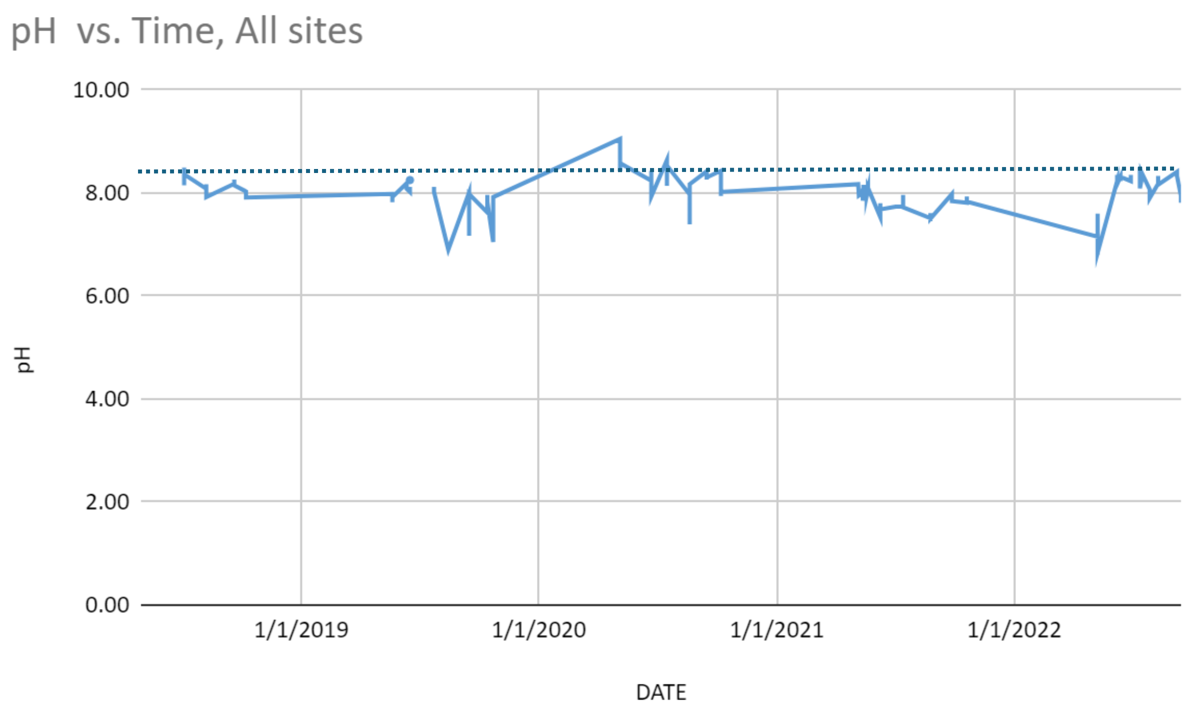

Figure: pH at all sites from 2018-2022 with criteria limit at 8.5

Specific Conductance Results

Specific conductance in rivers is a critical measure of the ability of water to conduct electrical current, which is directly influenced by the concentration of dissolved ions in the water. This parameter is typically expressed in microsiemens per centimeter (µS/cm) and serves as a general indicator of water quality. Higher values of specific conductance often indicate greater concentrations of dissolved minerals, such as salts and other ions, which can originate from natural sources like the weathering of rocks, or from anthropogenic sources such as industrial discharges, agricultural runoff, and urban stormwater.

Historical data from the late 1960s and early 1970s shows specific conductance (spC) averaging 250 µS/cm, while recent averages during this study have increased to 474 µS/cm. Notable increases in spC coincided with periods of urban and suburban expansion during the 1990s and again in the 2010s. Additional observations by the River Watchers, a volunteer community science group, during winter months linked significant spC spikes to road salt runoff near roadways and bridges. The accumulation of sodium chloride from rock salt in the soil, which releases into waterways during rain events, contributes to these spikes. This issue extends beyond the Musconetcong Watershed, prompting research into best management practices for potential implementation.

Total Suspended Solids and Turbidity Results

Total suspended solids (TSS) measure the undissolved solids or sediment in water. TSS levels typically increase during rain events due to in-stream sources and runoff. The absence of riparian buffers can further worsen these increases. For trout maintenance waters (FW2-TM), like this section of the river, the surface water quality standards set a criteria limit of 25 mg/L for TSS. It is not uncommon for TSS to be high after dam removals, as dam impoundments hold back large amounts of sediment. In fact, this part of the river was listed on the 303(d) list for TSS during this period. No trend across time appeared in the data. One of a river's primary functions is to transport sediment across the landscape, depositing it in estuaries and along coastal shorelines. Dams interrupt this natural sediment flow, leading to reduced deposition downstream. Consequently, dredging often becomes necessary to replenish shorelines, which is crucial for enhancing coastal resilience against rising sea levels and storm impacts.

Turbidity is a measurement of water clarity and when paired with TSS measurements, a rating curve can be constructed, and grab samples don't need to be taken with a robust R^2. A continuous turbidity sensor was installed on the most downstream EnviroDIY and a YSI sensor was used at the Bloomsbury/STA-5 and Hughesville dam removal site/STA-3 to calibrate the curve to site specific conditions. This also allowed for the correlation to be seen on Monitor My Watershed as rain events came through the focus area.

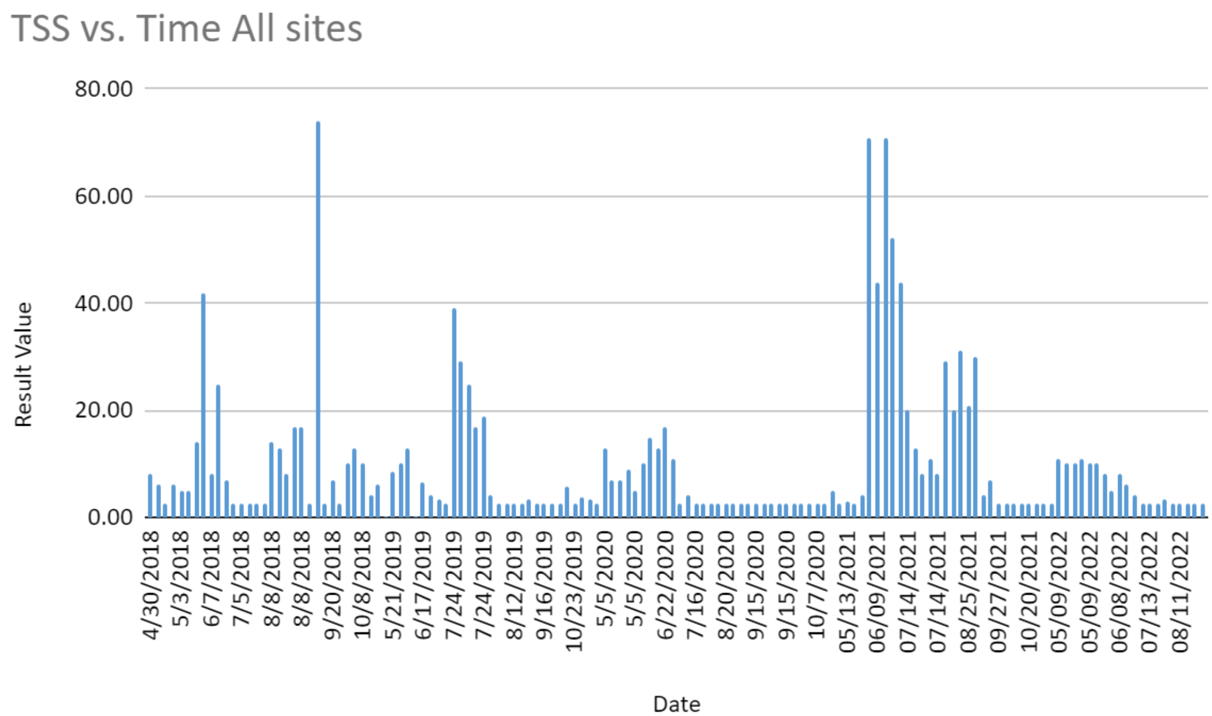

Figure: Total suspended solids for all 5 monitoring sites from 2018-2022.

Dissolved Oxygen Results

Low dissolved oxygen (DO) levels are a common issue behind dams, where water tends to be slower, warmer, deeper, and nutrient-rich. DO is essential for the health of aquatic ecosystems, especially for species like trout that need colder, oxygen-rich environments. According to NJDEP surface water quality standards for trout maintenance, the 24-hour average should not fall below 6.0 mg/L, and levels should never be less than 5.0 mg/L at any time. From April to October, the average dissolved oxygen (DO) level across all sites was 9.87 mg/L, significantly surpassing the minimum required levels. Throughout the summer, no exceedances were observed, and DO levels consistently remained above 7.5 mg/L, indicating healthy oxygenation throughout the river system.

Flow and Continuous Monitoring Results

The MWA has effectively integrated the use of EnviroDIY sensor stations in its ongoing monitoring and research efforts. These sensors collect continuous data on key environmental parameters such as specific conductance, temperature, depth, and turbidity. The real-time data generated by these sensors are crucial for understanding the dynamic changes in the river ecosystem, particularly following interventions like dam removals. These sensor stations have been installed at strategic locations along the river, enhancing the MWA's ability to monitor water quality and sediment transport continuously. The data collected helps in making informed decisions regarding river management and in assessing the impacts of restoration activities on river health. Moreover, the data visualization projects associated with these sensors allow for more accessible communication of complex data, supporting community engagement and educational outreach.

Photo: EnviroDIY live continuous sensor station and it’s components. On the left, the in-stream sensors are fixed to rebar. Center, the electronic components, seen in detail on the right, are fixed to galvanized pipe and powered by a small solar panel.

One of the parameters that the EnviroDIY measures is temperature. In NJ, surface water quality standards state, “Temperatures shall not exceed a daily maximum of 25 degrees Celsius or rolling seven-day average of the daily maximum of 23 degrees Celsius, unless due to natural conditions”. The fact that the sensor station takes reading every 5 minutes allows for fine detail in the monitoring and management of the river. Dam impoundments are notorious for slowing and warming water behind the impoundment. The EnviroDIY shows a cooling trend, as demonstrated in the graph below. Data previous to the removal of the dam showed that the temperature behind the dam regularly exceeded the rolling 7-day limit of 25 degrees Celsius. As the trees in the restoration site grow and provide canopy cover, the temperature is expected to continue its cooling trend.

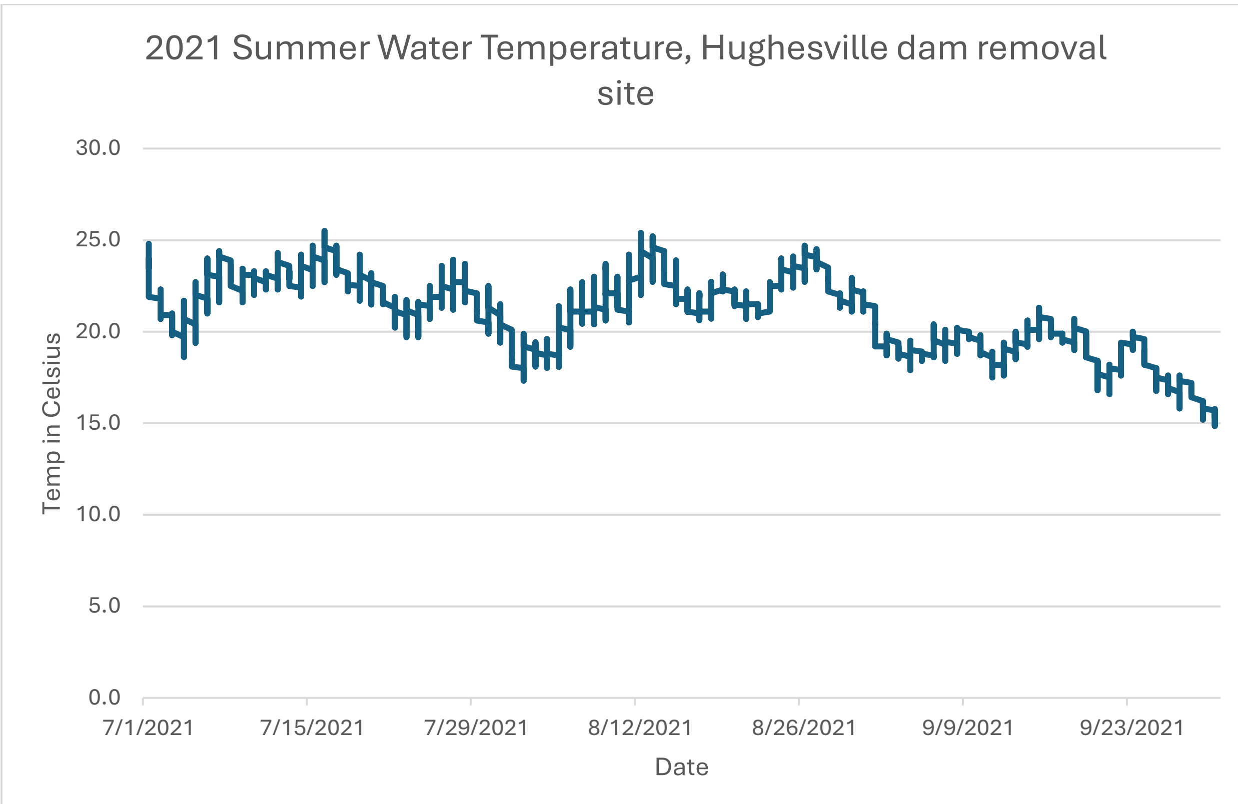

Figure: EnviroDIY temperature data from the summer of 2021. This station data can be viewed here - https://monitormywatershed.org/sites/NHML13S/

Depth and Discharge Results

The Musconetcong River, as the largest tributary to the Delaware River, presents complex hydrological data due to other dams and tributaries upstream. The use of EnviroDIY stations facilitated continuous depth and discharge measurements, allowing for the development of accurate rating curves. This detailed understanding of river dynamics greatly enhanced the timing of water quality sampling and provided valuable information for recreational activities like kayaking and fishing. It proved particularly crucial for planning precise electrofishing efforts, which require specific water depths to be effective.

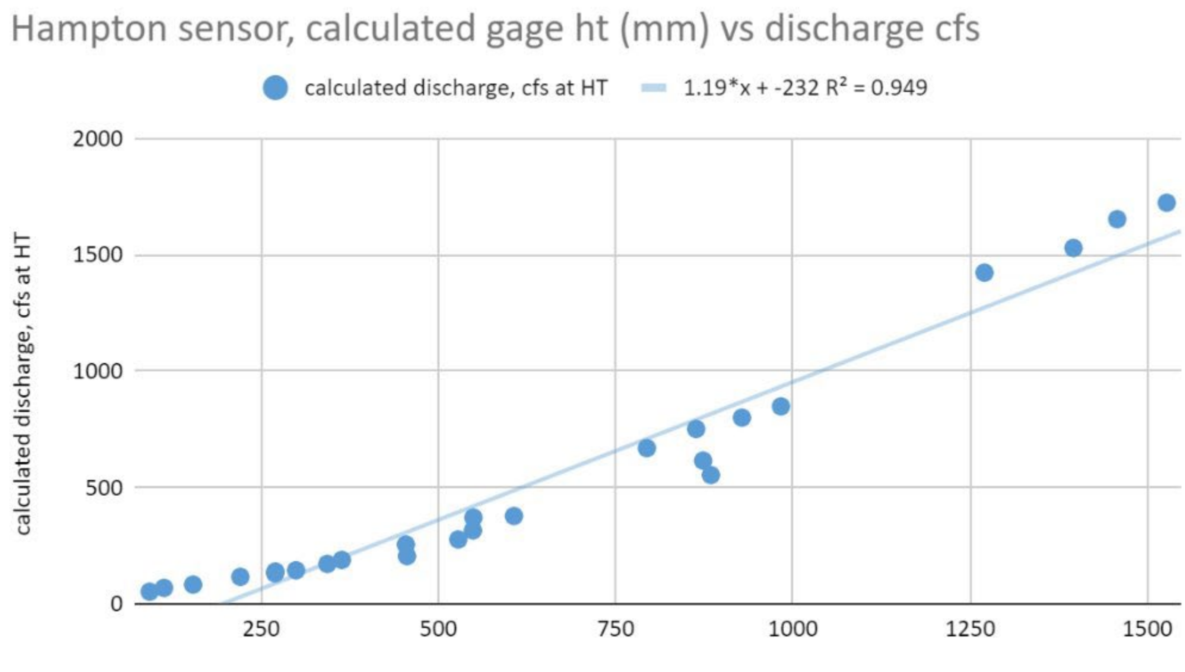

Figure: Depth to discharge plot to obtain equation. Depth is in mm from EnviroDIY sensor station and discharge was obtained with an OTT MF Pro, measured in cubic feet per second. The sensor depicted here is installed at Hampton Park.

Fish Survey Results

The contractor for the fish surveys at the outset of this project was Princeton Hydro. Their electrofishing efforts were conducted once in spring and once in summer at all sites, minus STA-6. The spring session recorded a significant catch of 248 American eels, notably at STA-4, and a diverse range of species across the sites. The summer session showed a decrease in American eels but included catches like brown trout and walleye at STA-3. Overall, 536 and 342 individuals were collected during the spring and summer surveys, respectively, reflecting varied species richness across the sessions. No American shad were caught in these sessions. During the 2018 season an American shad was caught with a fishing pole at the base of the Warren Glen dam, signaling the return of this anadromous fish.

The 2019 season was plagued by high waters and no surveys were performed. 2019 had the highest recorded rainfall in the region for over 100 years. It was also determined that Princeton Hydro was not well positioned to carry out the surveys with the protocols outlined. NJDFW was contacted and workplans overlapped to enable them to perform the surveys moving forward. Then Covid canceled the surveys scheduled for 2020. Electrofishing is a personnel intensive activity, requiring people to be in close proximity to one another. The surveys were expected to resume in 2021. At this time, the WQ Program Manager started to research other possibilities to accomplish this part of the monitoring. eDNA technology was making positive advances and prices were becoming more affordable. Contact was made with several labs and the Program Manager at USFWS, and the decision was made to adaptively manage the methods used and eDNA protocols were researched and equipment was purchased.

eDNA is particularly beneficial for assessing the presence and distribution of species in a less invasive manner, making it an effective method for environmental monitoring and conservation efforts. This approach has been highlighted as part of broader strategies to manage aquatic habitats and track the impact of restoration activities. Not only does it only require two people to gather the data that uses 12-15 people per electrofishing effort, but there is also no mortality with the smaller and less resilient fish species, like with electrofishing. This method involves analyzing water samples for traces of DNA shed by organisms in the water and can capture fish that are wily and able to avoid the electricity and nets, such as American shad and trout.

Photo: MWA and NJDFW crews electrofishing at the Mt.Joy/STA-1 site, with barge.

The eDNA protocols called for a series of presence/absence runs for the American shad and 1 full round of metabarcoding to determine assemblages. The timing of the sampling was aimed to capture young of the year shad, seeing as how the adults presence was established in 2018. Positive hits were seen at STA-1. While it can' be known for certain, the positive hit and the time of year suggest American shad are breeding in the Musconetcong River.

Photo: Sam Johnson and Craig Fleming collecting eDNA samples a the Hughesville dam removal site/STA-3.

The metabarcoding was paired with an electrofishing effort performed by MWA and NJDFW. The Covid restrictions had been lifted by the time the metabarcoding samples were gathered making for a robust data set and advances to the eDNA method and resulting analysis done by biologists at Montclair State University. The survey showed expected results alongside surprising findings such as the significant presence of American eels and traces of European and Japanese eel DNA. The unexpected presence of Japanese eel DNA was linked to local sushi restaurant waste entering the river, while the occurrence of European eel DNA raised questions about potential hybridization and migration patterns, previously unconsidered. The study underscores the complexity of aquatic ecosystems and the unexpected consequences of human activity, highlighting the need for thorough monitoring and analysis of aquatic species to understand ecological changes fully.

Photo: Fish sorting and assessment from 2022 electrofishing effort at Mt.Joy/STA-1.

The 2022 electroshocking survey identified 14 different fish species, compared to 18 in the 2015 survey. The observed decrease in diversity is attributed more to sampling challenges and the river's high flow conditions rather than the removal of the Hughesville Dam. Notably, two species of special interest due to their scarcity and specific habitat needs—Shield Darter and Northern Hog Sucker—were detected. Although American Shad wasn't found in the July survey, they have been seen upstream, suggesting potential, though currently minimal, reproduction in the river. Concerns remain about invasive species, such as Northern Snakehead and Flathead Catfish, potentially accessing new areas post-dam removal, although they haven't yet been documented in the Musconetcong River.

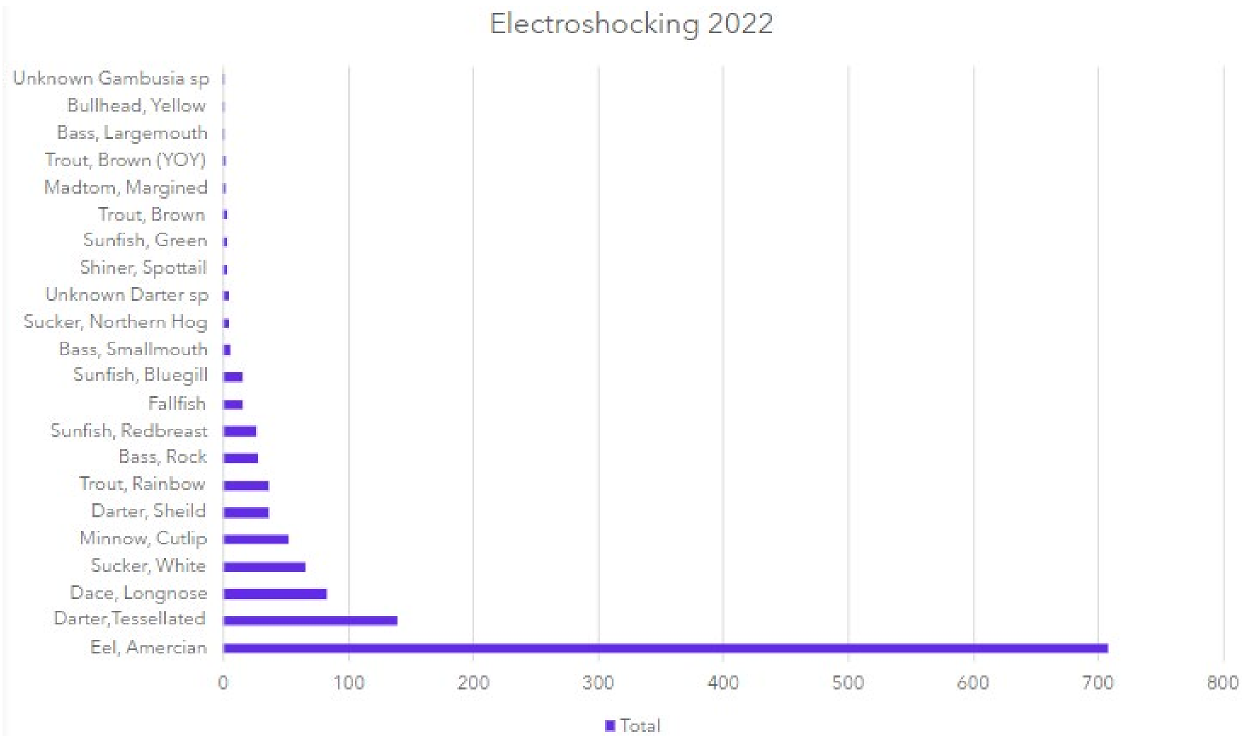

Figure: Fish species found in the 2022 electroshocking effort. The X-axis shows the totals.

The metabarcoding analysis identified 25 species, including Japanese and European eels, as well as sea lamprey. Notably, brown trout DNA was highly prevalent, despite their minimal appearance in the electroshocking data. This discrepancy may be due to a school of brown trout near the sampling site, skewing the DNA results. Discussions with biologists and bioinformatics technicians suggest that while eDNA is excellent for detecting presence or absence, it is less reliable for determining species abundance due to these potential anomalies.

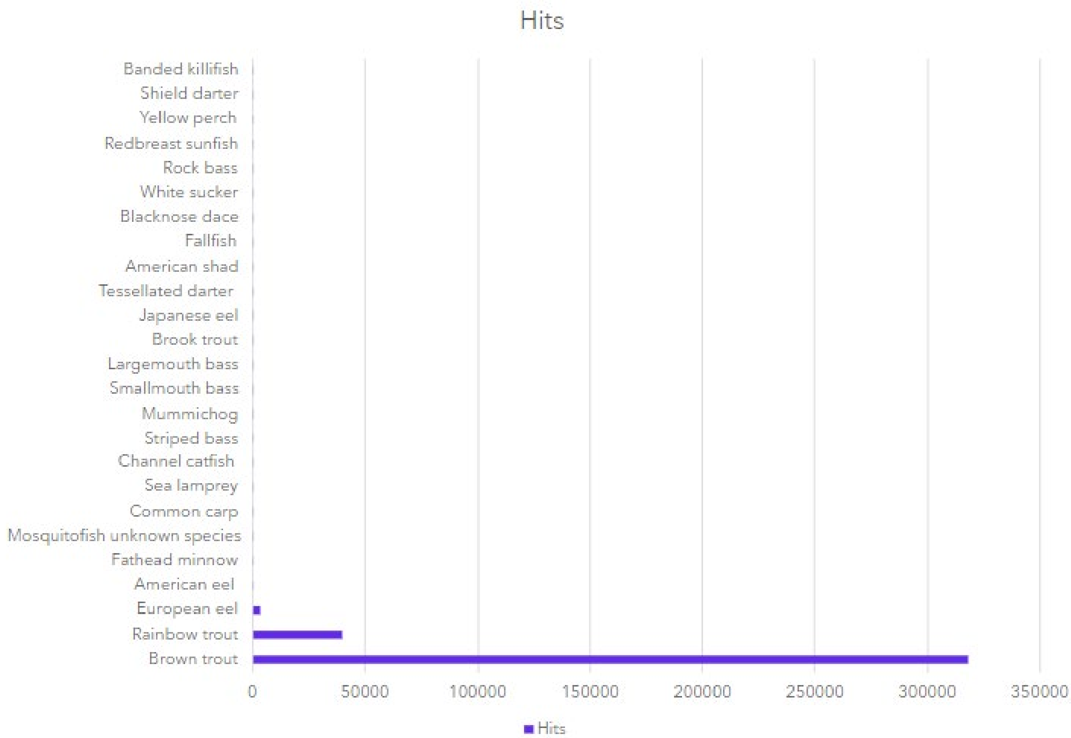

Figure: Hits from the eDNA water samples and species present. The abundance of Brown and Rainbow trout skews the graph.

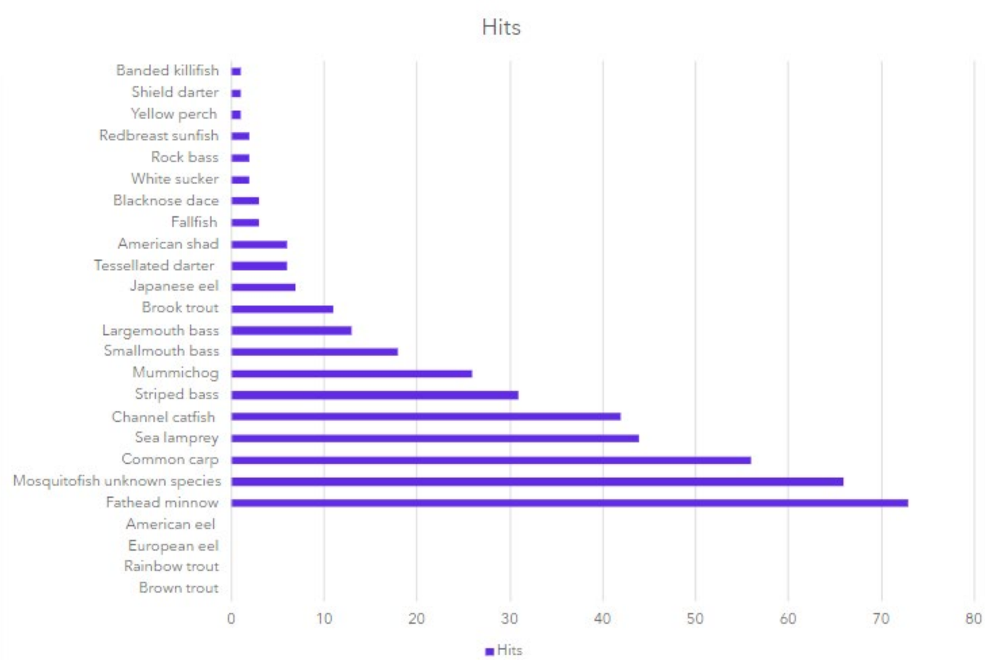

Figure: Graph showing eDNA results when Brown and Rainbow trout as well as eels are removed to visualize the other hits.

Conclusion

It is assumed that dam removals provide ecological uplift, but it is important to define what that means and the time in which things take place. The monitoring efforts detailed in this report exemplify the comprehensive approach taken to evaluate the ecological recovery of the Musconetcong River following the removal of the Hughesville Dam. These efforts were supported by a variety of advanced monitoring techniques including habitat assessments, which focused on streamside conditions and substrate changes, and macroinvertebrate sampling, which provided insights into the biological health of the river. Fish surveys, including innovative eDNA analyses, helped track species diversity and detect the presence of both migratory and resident fish species.

Furthermore, the application of continuous sensor monitoring facilitated real-time data collection on water quality parameters such as depth, temperature, specific conductance and turbidity, essential for adaptive management. This holistic monitoring framework not only underscores the ecological benefits of dam removal but also enhances community engagement and supports ongoing conservation efforts. The collaboration among government agencies, local communities, and environmental organizations through the Musconetcong River Management Council exemplifies a model for sustainable watershed management aimed at preserving river health and biodiversity. This project serves as a benchmark for similar ecological restoration efforts, emphasizing the importance of thorough pre-and post-removal studies to optimize restoration strategies and ensure the resilience of river ecosystems.

Links and References

EnviroDIY Sensor stations

Bloomsbury/STA-5: https://monitormywatershed.org/sites/NHML14S/

Hughesville/STA-3: https://monitormywatershed.org/sites/NHML13S/

Confluence: https://monitormywatershed.org/sites/1-1-BL/

Outreach and Education

New Zealand mudsnail: https://www.musconetcong.org/new-zealand-mudsnail

Blog and Newsletter articles: https://www.musconetcong.org/blog

Facebook page: https://www.facebook.com/search/top?q=musconetcong%20watershed%20association

Instagram page: https://www.instagram.com/muskywatershed?igsh=dGt5YWY3YWoxbGNh

News articles: https://www.musconetcong.org/mwa-in-the-news

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