Restoration Monitoring of American Eel *(Anguilla rostrata)* in Three Southcentral Pennsylvania Streams in the Susquehanna River Basin: 2023 Monitoring Data Summary Update

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INTRODUCTION & BACKGROUND

The Susquehanna River Basin Commission (Commission) has been actively monitoring the restoration of American Eel (*Anguilla rostrata*) in the Susquehanna River Basin since 2015. The American eel is a catadromous fish species previously abundant throughout the basin but was effectively extirpated in the early 20th century with the construction of four river-spanning hydroelectric dams on the Lower Susquehanna River mainstem. In 2005, a basinwide reintroduction effort began with the U.S. Fish and Wildlife Service (USFWS) experimentally trapping American eel elvers at Conowingo Dam and transporting them upstream above the dams.

Through the Federal Energy Regulatory Commission's (FERC's) re-licensing of the Muddy Run Pumped Storage Project, a long-term commitment to trap and transport American eels was developed and implemented. With partial funding support from the U.S. Environmental Protection Agency (USEPA) through a Water Pollution Control (Section 106) grant, the Commission initiated a monitoring project in 2015 to investigate ecological impacts to streams receiving targeted stockings of American eel elvers in the Lower Susquehanna subbasin. The Commission began collecting fish, macroinvertebrate, and water quality data at three study sites prior to elver stocking occurring in 2016 and 2017 and has continued collecting data at these locations annually through 2023. More details regarding the first five years of this study can be found in a larger report published in October 2021 (Henning, 2021). The goal of this technical summary is to provide a summary of the results from the latest year of post-stocking monitoring conducted in 2023.

STUDY DESIGN

American eels collected at the Octoraro Creek and Conowingo Dam ramps were stocked at three sites in the Lower Susquehanna Subbasin: North Branch Muddy Creek near Brogue in York County, Conewago Creek near Aberdeen in Lancaster County, and Beaver Creek outside of Hummelstown in Dauphin County (Figure 1).

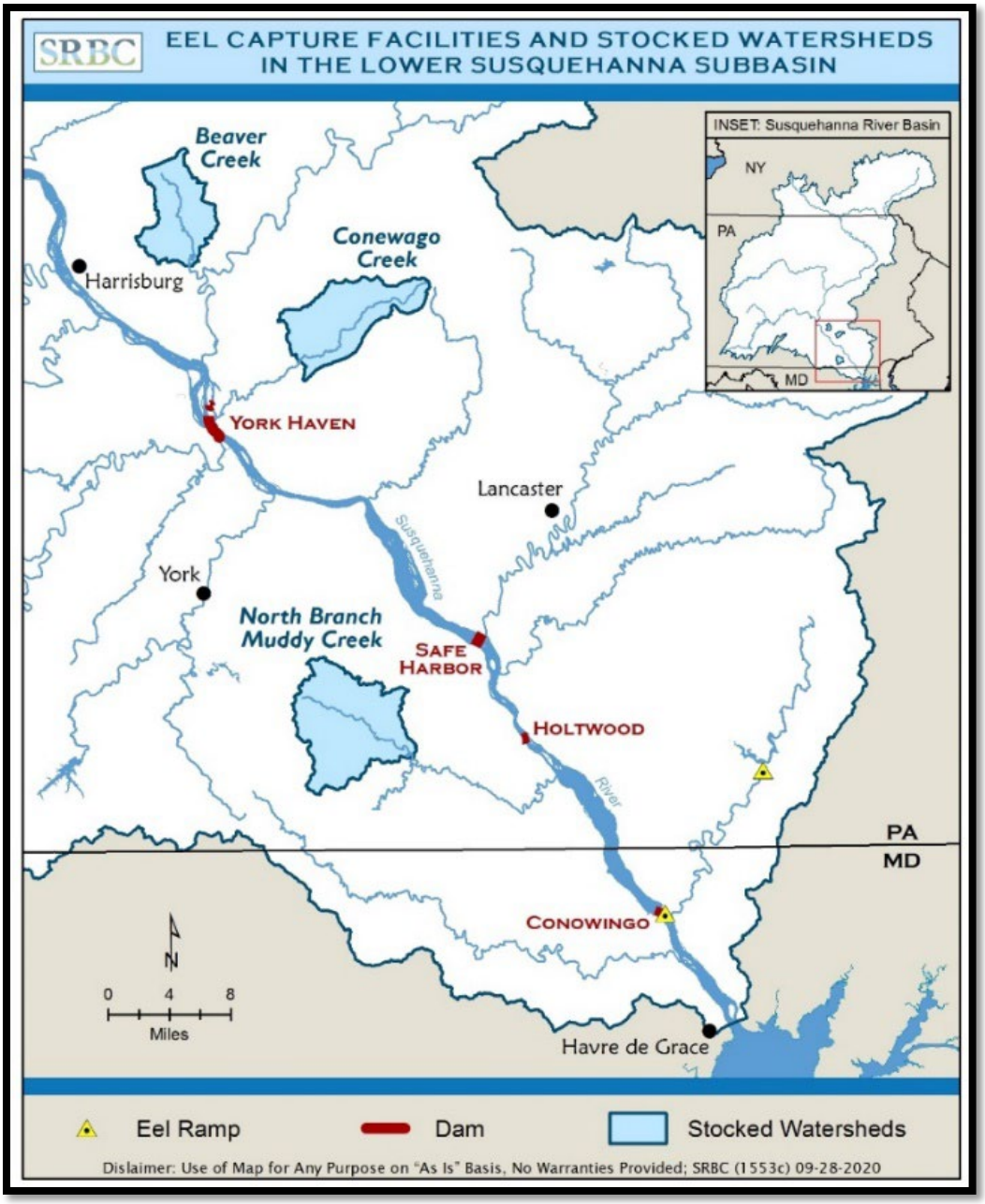

Figure 1. American Eel Stocked Watersheds and Monitoring Locations in the Lower Susquehanna Subbasin

Between May 2016 and June 2017, a total of 48,622 elvers were stocked at these sites (Table 1). Stocking occurred at a single point on each stream which continued to serve as a monitoring location for the extent of this study. Elvers were stocked within one week of capture. Stocked elvers averaged 122mm in length and 2.1g in mass (Normandeau, 2017) and were approximately 1 to 4 years old, with a mean age of 1.65 years (Normandeau, 2021).

Table 1. Cumulative American Eel Stocking by Year at Commission Study Sites

Waterbody	Stocking Goal	Stocked		
		2016	2017	Total
North Branch Muddy Creek	22,000	22,004	0	22,004
Conewago Creek	16,850	1,563	15,317	16,880
Beaver Creek	9,400	0	9,738	9,738
TOTAL	**48,250**	**23,567**	**25,055**	**48,622**

METHODS

Commission field crews followed the field methods outlined in the USEPA-approved Quality Assurance Work Plan (SRBC, 2021). Sampling occurred annually at each monitoring site and included collection of macroinvertebrates, crayfish, fish, and water samples, as well as assessments of stream characteristics.

Fish community data were collected in the summer (July and August) via electrofishing using a single-unit width based multiple pass protocol (Shank et al., 2016). All captured fish were identified to species and weighed in aggregate to attain a species level biomass value. All captured American eels were weighed and measured individually. Beginning in 2019, all American eels over 200mm were implanted with an 8-mm full duplex Passive Integrated Transponder (PIT) tag. During each subsequent sampling event, individual eels were examined for the presence of a PIT tag by using a handheld PIT tag reader.

Macroinvertebrates were collected in fall using the PA Department of Environmental Protection's (PADEP's) riffle/run freestone macroinvertebrate collection protocol, and small-stream macroinvertebrate Index of Biotic Integrity (IBI) scores were calculated (PADEP, 2013). Separate crayfish samples were collected in summer using a 1-m^2 quadrate sampler to estimate density (Larson et al., 2008). Crayfish were preserved in ethyl alcohol, identified to species, and weighed to obtain a biomass value for each species at each site.

Water quality samples were collected quarterly at each monitoring location using a handheld depth-integrated water sampler and analyzed by Pace Analytical for aluminum, iron, manganese, phosphorus, nitrate, total organic carbon, sulfate, sodium, and chloride. No storm-impacted samples were collected during water sampling. Water Quality Index (WQI) values were calculated for each sample (Berry et al., 2020).

Physical habitat was rated using the USEPA's rapid bioassessment protocol for riffle/run wadeable streams (Barbour et al., 1999). Representative site photographs were taken at least annually at each monitoring site to document changes in conditions.

RESULTS

Fish

American eels continued to be captured at North Branch Muddy Creek and Conewago Creeks (Tables 2 and 3). Consistent with previous years' monitoring observations, American eel have not yet been captured in Beaver Creek (Table 4). The number of eels caught at North Branch Muddy and Conewago creeks overall were lower than the number caught in the past few years (Figure 2).

Overall fish species richness increased slightly at all three sites compared to last year (Figure 3). In general, the rate of capture at North Branch Muddy and Conewago Creeks was similar to observations in the past couple years, while the rate of capture at Beaver Creek continued to be much more variable over time (Figure 4).

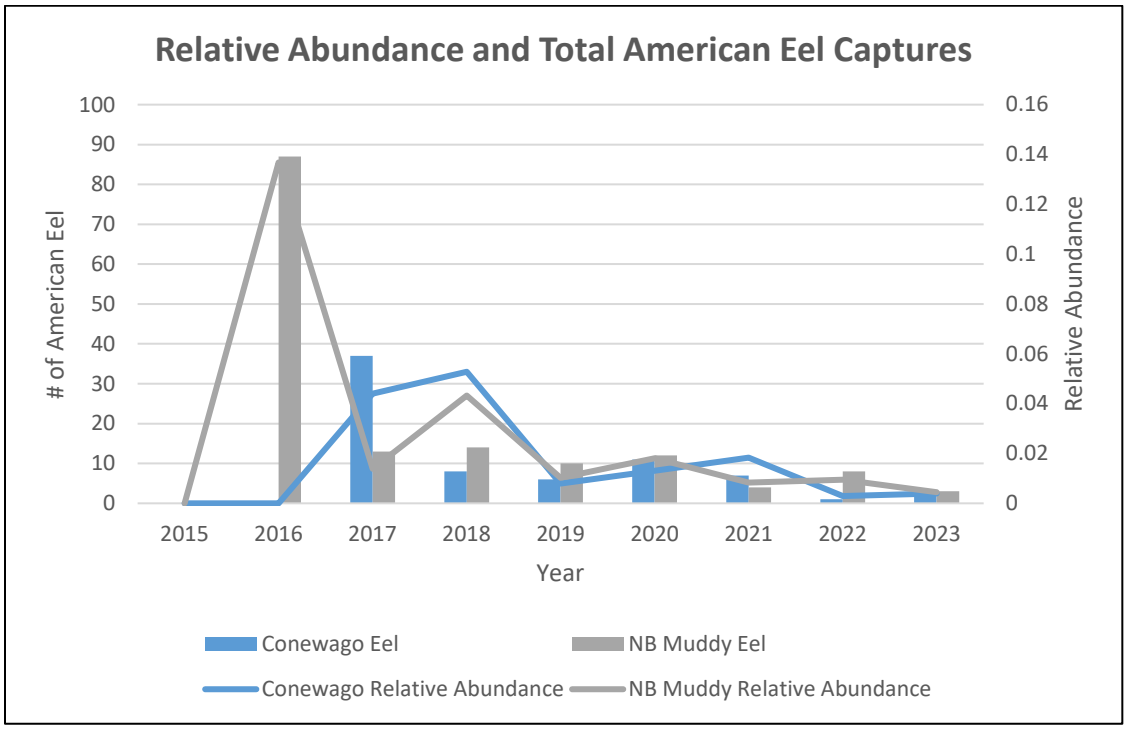

Figure 2. American Eel Capture and Relative Abundance at Beaver & North Branch Muddy Creeks (2015-2023)

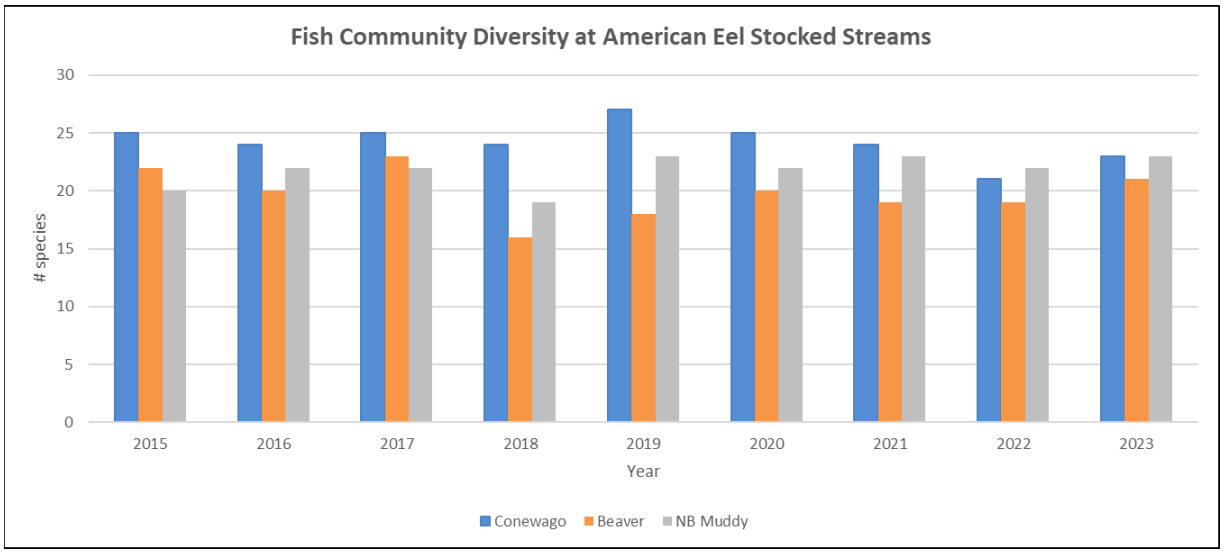

Figure 3. Annual Overall Fish Community Diversity at Eel-stocked Sites (2015-2023)

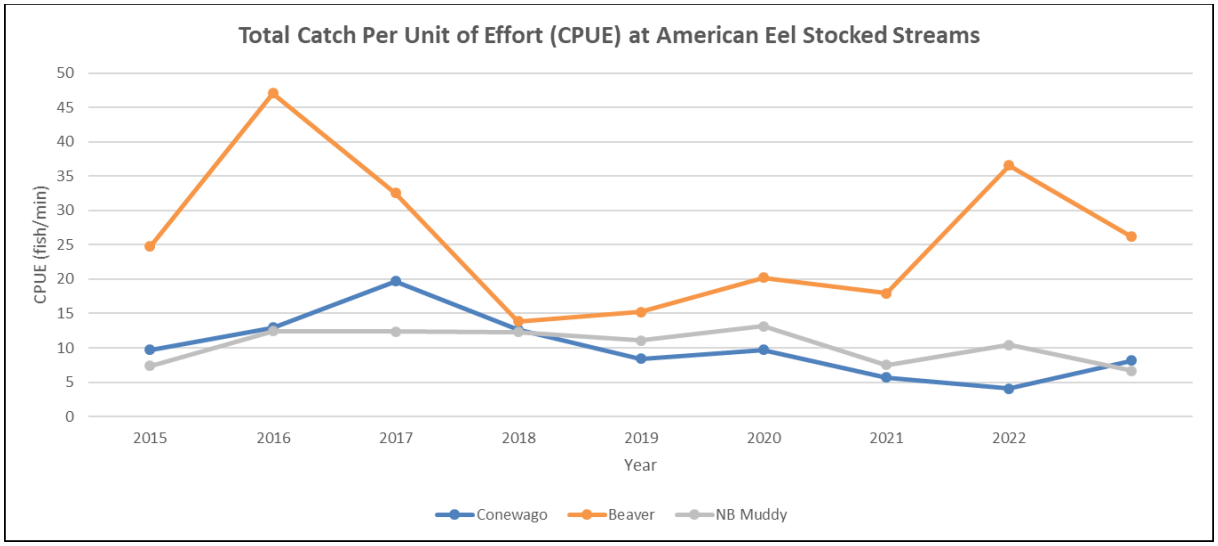

Figure 4. Annual CPUE of All Fish Species at Eel-stocked Streams (2015-2023)

The results of the 2023 eel sampling are listed in Tables 2, 3, and 4, which are broken down by individual site. Details regarding each of the sites are included in the Appendix.

North Branch Muddy Creek

Table 2. Annual American Eel Results at North Branch Muddy Creek

NB Muddy Creek					
Year	**n**	**avg. length (mm)**	**avg. mass (g)**	**CPUE (n/min)**	**Eel biomass (g/min)**
2016	87	130	NA	1.7	9.3
2017	13	205.1	19.3	0.17	3.31
2018	14	349	85.2	0.21	17.54
2019	10	384	120.9	0.11	13.59
2020	12	465.8	244	0.17	42.12
2021	4	523	293	0.06	18.3
2022	8	555.5	392	0.09	38.6
2023	3	535.7	315	0.04	16.7

Conewago Creek

Table 3. Annual American Eel Results at Conewago Creek

Conewago Creek					
Year	**n**	**avg. length (mm)**	**avg. mass (g)**	**CPUE (n/min)**	**Eel biomass (g/min)**
2016	0	NA	NA	NA	NA
2017	37	156.8	6.1	0.88	4.8
2018	8	297.9	52	0.11	5.64
2019	6	362.3	72.5	0.07	4.98
2020	11	424.9	156.2	0.18	27.4
2021	7	459	211	0.11	22.2
2022	1	450	175	0.02	2.1
2023	2	565.6	367.5	0.04	10.8

Beaver Creek

Table 4. Annual American Eel Results at Beaver Creek

Beaver Creek					
Year	**n**	**avg. length (mm)**	**avg. mass (g)**	**CPUE (n/min)**	**Eel biomass (g/min)**
2016	0	NA	NA	NA	NA
2017	3	139.6	5	0.03	0.06
2018	0	NA	NA	0	0
2019	0	NA	NA	0	0
2020	0	NA	NA	0	0
2021	0	NA	NA	0	0
2022	0	NA	NA	0	0
2023	0	NA	NA	0	0

Macroinvertebrates

The macroinvertebrate health of Conewago and Beaver Creeks has been on a general upswing since the beginning of post-stocking monitoring, but that does not correlate with the presence of eels (Figure 5). North Branch Muddy experienced an unexplained drop in macroinvertebrate score.

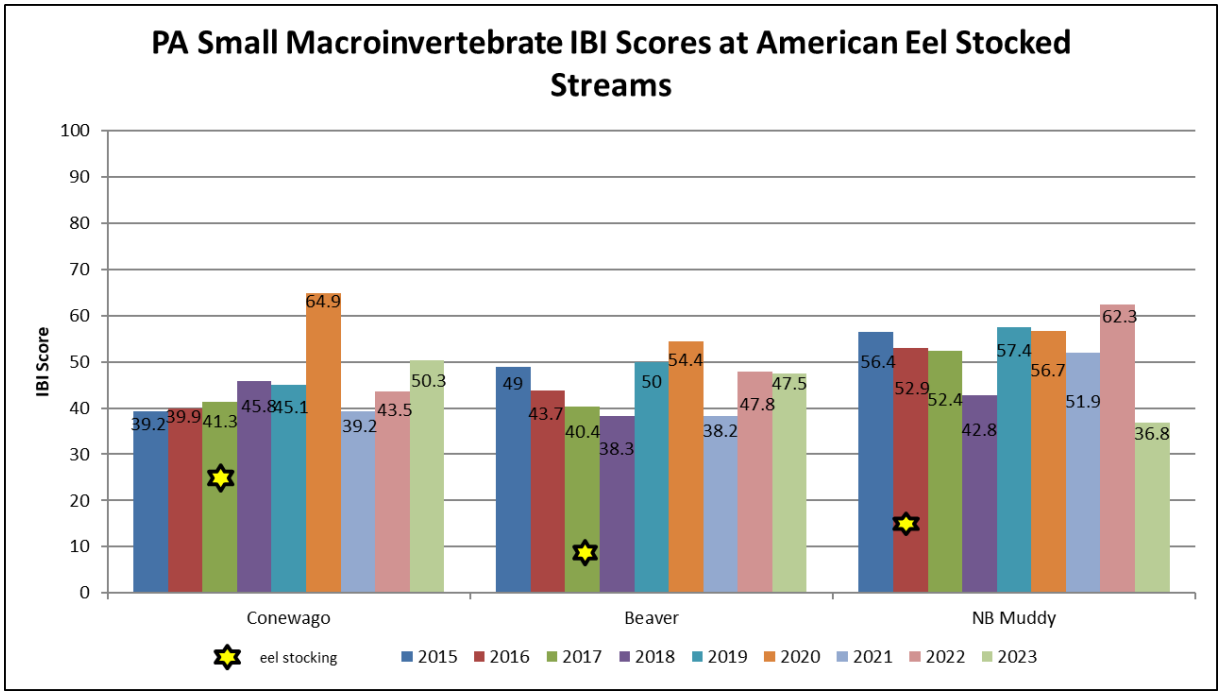

Figure 5. Macroinvertebrate IBI Scores at Eel-stocked Streams (2015-2023)

Crayfish

The crayfish populations of the three receiving streams have remained relatively consistent since the onset of monitoring. Beaver Creek routinely possessed the greatest overall population with counts typically exceeding the combined totals of North Branch Muddy and Conewago Creeks. The Beaver Creek population, however, is comprised entirely of the non-native rusty crayfish *(Faxonius rusticus),* whereas North Branch Muddy and Conewago Creeks exhibit a more balanced mix of native Allegheny crayfish *(Faxonius obscurus)* and the Appalachian Brook crayfish *(Cambarus bartonii).*

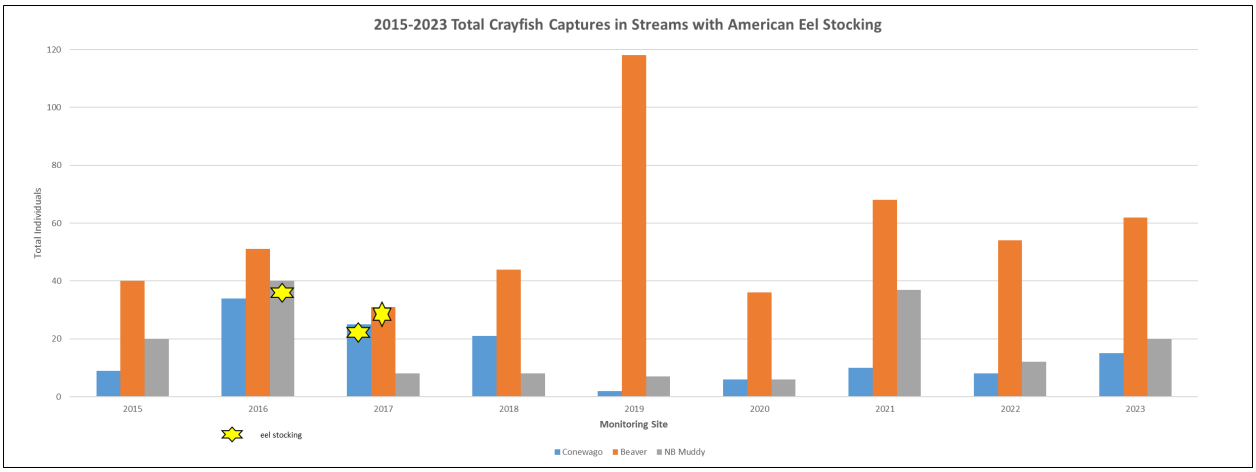

Figure 6. Crayfish Abundance at American Eel-stocked Streams (2015-2023)

Habitat

The physical habitat variables assessed at the eel stocking sites have been rated fair to good consistently throughout this study. Minor site level changes to instream cover and epifaunal substrates account for annual variation in scores but overall functionality remains intact at these locations. Increased developmental pressures on each watershed remain as the greatest limiting factor to net improvement.

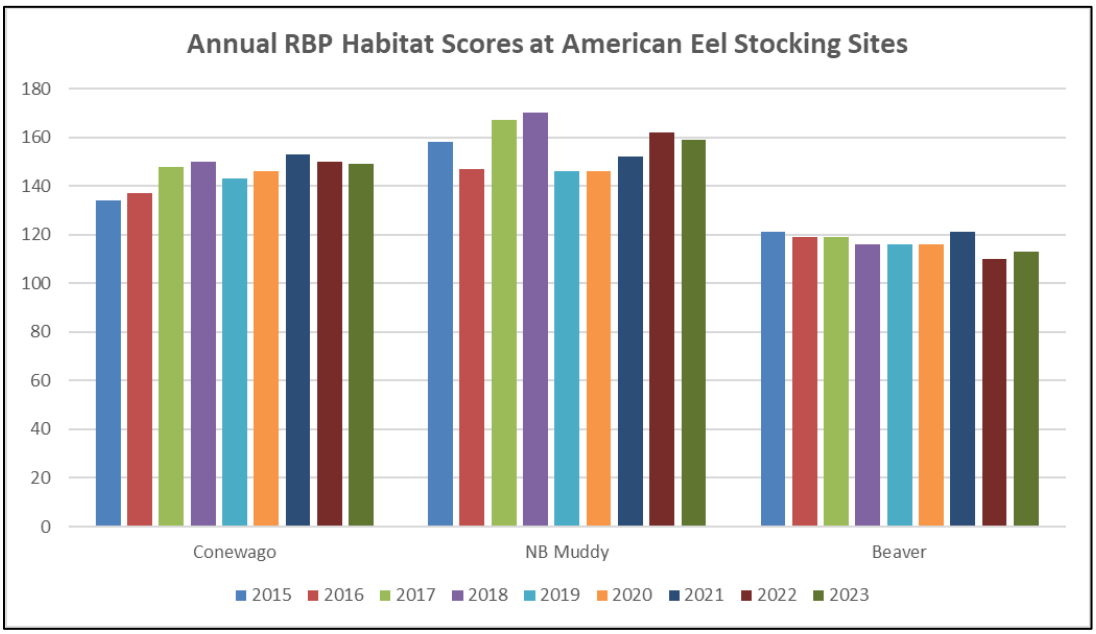

Figure 7. Habitat Scores at American Eel-stocked Streams (2015-2023)

Water Quality

Quarterly samples were analyzed using the Commission's Water Quality Index and showed great variation in the overall water quality of each stream. Conewago Creek routinely scored the lowest of three with high levels of nutrient enrichment, which is not unique to the region but attributed to the intense agricultural production (row crops, poultry farming) with the watershed. Conversely, North Branch Muddy Creek, also an agriculturally dominated catchment, possessed the best water quality of the three. Beaver Creek scored intermediately amongst the monitoring locations with consistently fair water quality.

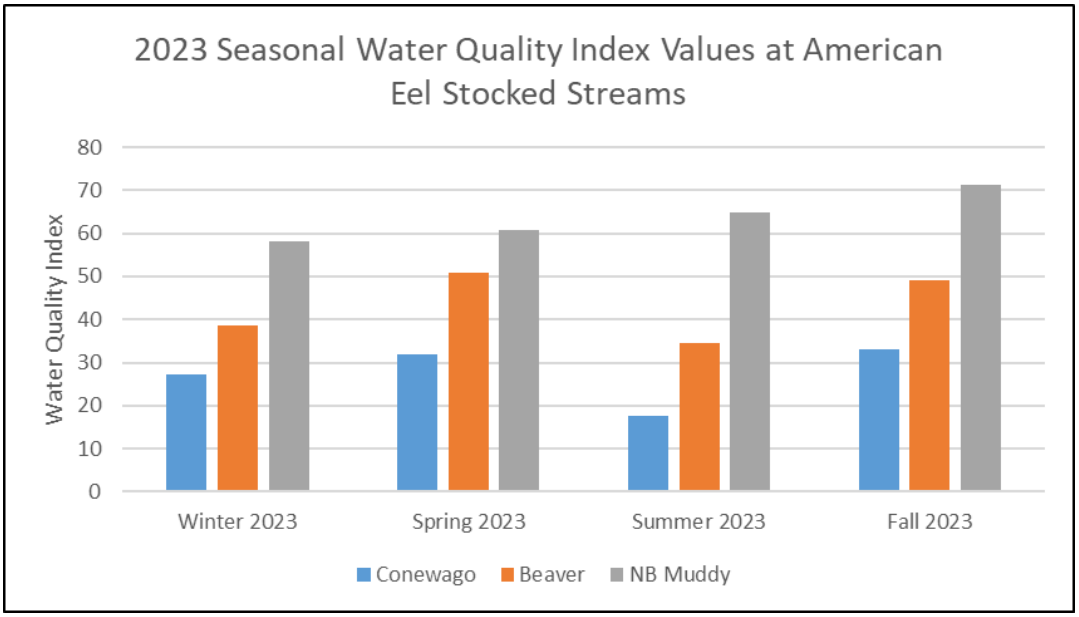

Figure 8. Water Quality Index Scores at American Eel-stocked Streams (2015-2023)

DISCUSSION/CONCLUSIONS

The 2023 season concluded the eighth consecutive year of post-stocking American eel ecological monitoring at North Branch Muddy Creek and the seventh consecutive year at Beaver and Conewago Creeks. The data gathered from this effort have directly informed and supported the management of American eel within the Susquehanna River Basin. All three study streams continue to exhibit stable, functional ecological states and have not experienced any observable detrimental impacts following American eel reintroduction. The receiving streams' biological conditions, as measured by macroinvertebrate IBI, have slightly improved through time at Conewago and Beaver Creeks while North Branch Muddy Creek exhibited a marginal decline.

Annual captures of American eel at each site have declined as expected; however, a consistent low density population exists within two of three receiving watersheds. No additional stocking has occurred in these watersheds since the initial 2016 and 2017 stockings.

The persistent lack of observations of American eel within the Beaver Creek Watershed following reintroduction in 2017 has lacked suitable explanation. Periodic evaluations of Beaver Creek stream segments performed by Normandeau Associates in 2018, 2021, and 2024 failed to detect presence of American eel at locations upstream and downstream on the original stocking site at each survey (Normandeau Associates 2018, 2021, 2024 unpublished data). The combined effort represents 15 unique surveys at three locations spanning eight years within the watershed. In August 2023, the Commission conducted a multi-site investigation into the occupancy of American eel within this watershed utilizing environmental DNA (eDNA) methodologies. Samples were collected from nine locations on Beaver Creek, Mill Race and Nyes Run and tested for the presence of American eel DNA. Initial, unpublished results indicated American eel DNA was present at eight of the nine sampling locations, suggesting contrary to electrofishing data, that the Beaver Creek Watershed is in fact widely occupied by American eel. This finding demonstrates the utility obtained through passive monitoring via eDNA methodologies to detect rare, low density populations of American eel.

Since the inception of the restoration program, over 3 million American eel elvers have been translocated to locations within the Susquehanna River Basin. Dispersal throughout all of the major subbasins of the Susquehanna have been documented (Figure 9). Results of this monitoring effort are presented annually to the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC) and the Eel Passage Advisory Group (EPAG) to guide and inform ongoing and future restoration work.

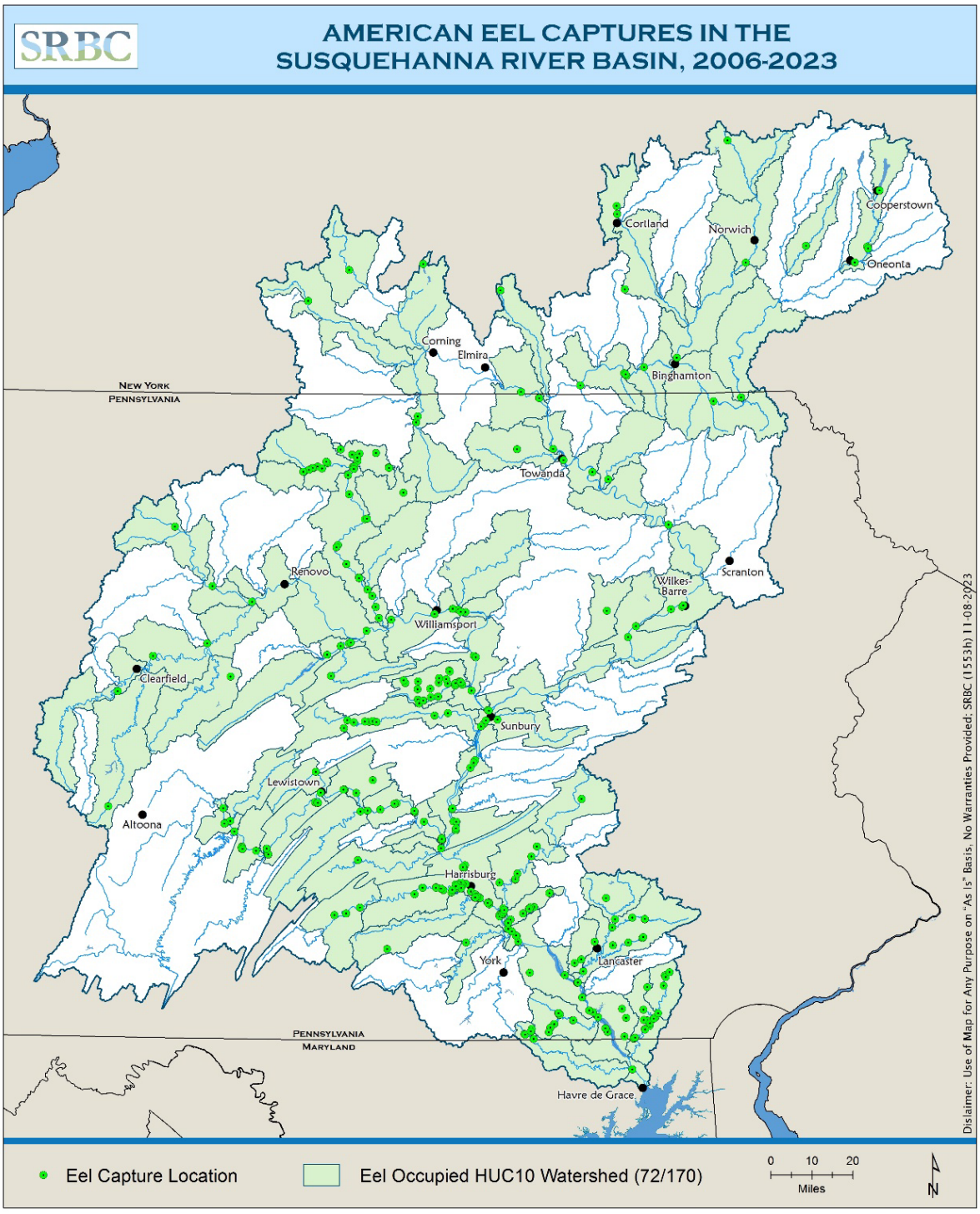

Figure 9. Documented American Eel Captures Across the Susquehanna River Basin

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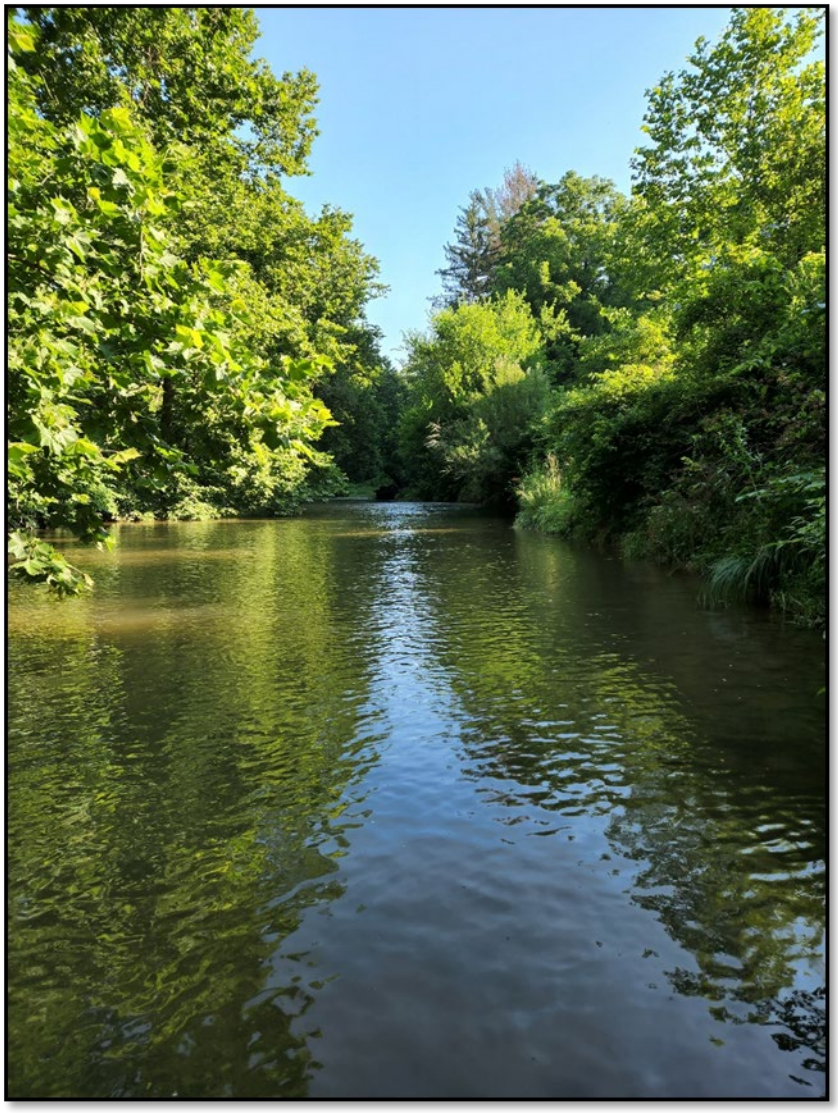
APPENDIX: INDIVIDUAL SITE INFORMATION

North Branch Muddy Creek at Muddy Creek Forks, PA

North Branch Muddy Creek drains 43 square miles of northern and eastern York County. This site is located just upstream of the confluence with South Branch Muddy Creek at Muddy Creek Forks, PA. The watershed's land use is primarily agricultural crop land (52%), followed by forests and development.

Between May and August of 2016, about 22,000 American eel elvers were stocked at this site. Supported by annual club stockings, North Branch Muddy Creek also supports a naturally reproducing brown trout population.



View looking upstream of North Branch Muddy Creek at Muddy Creek Forks

Conewago Creek at Old Hershey Road (Elizabethtown, PA)

Serving as the border between Dauphin and Lancaster Counties, Conewago Creek flows 23 miles from the headwaters in Lebanon County to the mouth at the Susquehanna River in Falmouth, PA. The primary land use in the watershed is agriculture (53%), followed by forest and development. The watershed benefits from the Conewago Creek Initiative, a public-private partnership that has organized restoration efforts to improve water quality through implementation of various best management practices.

View looking upstream of Conewago Creek at Old Hershey Road

Beaver Creek at Nyes Road (Harrisburg, PA)

Located in southern Dauphin County, PA, Beaver Creek is an 11-mile long tributary to Swatara Creek. The 27.2-square-mile watershed drains primarily agricultural and increasingly developed lands just east of Harrisburg, PA, before joining the Swatara Creek in Hummelstown, PA.

Just over 9,700 American eel elvers were stocked over the course of two separate events in June 2017. No eels were collected again this year. Beaver Creek is also the only one of the three study sites to have a crayfish community comprised entirely of non-native rusty crayfish (*Faxonius rusticus*). Beaver Creek also possessed the poorest physical habitat of the three sites. A lack of epifaunal substrates and associated fish cover (large woody debris, large boulders) were persistent characteristics of this stream and a presumed contributing factor leading to unsuccessful eel colonization.

View looking upstream of Beaver Creek at Nyes Road