Experimental Stocking of American eels in the Susquehanna River Watershed

2014 Annual Report

Mitigation Project for: **City of Sunbury, Riverbank Stabilization Project**
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SUMMARY

American eel (*Anguilla rostrata*) occupies a unique niche in estuarine and freshwater habitats along the Atlantic coast but have experienced a range-wide population decline during recent decades. The Chesapeake Bay watershed supports a large portion of the eel population, but a large geographic area is inaccessible due to dams on the lower part of the Susquehanna River. In 2008, USFWS began stocking eels above dams to evaluate their reintroduction. Laboratory studies conducted by the USGS indicate that eels are a good host for the common freshwater mussel, eastern elliptio (*Elliptio complanata*) in the Susquehanna River. Low abundance and lack of recruitment of eastern elliptio in the Susquehanna River, in comparison to nearby watersheds, could be related to the lack of eel passage in the Susquehanna River. Following targeted eel stocking in tributaries to the Susquehanna River in 2010, 2011, 2012, and 2013, monitoring conducted in 2014, indicates increased eastern elliptio recruitment and widespread distribution of stocked eels. The presence of healthy freshwater mussel beds provides streambed stability, water filtration, and increased macroinvertebrate biodiversity. Permanent eel passage could lead to improved ecological function in the watershed.

INTRODUCTION

American eel populations have declined along the Atlantic coast. The Chesapeake Bay and tributaries support a large portion of the remaining coastal eel population. However, a hydropower dam blocks natural eel passage at mile 10 of the Susquehanna River, the largest tributary to the Chesapeake Bay, comprising 43% of the watershed. There are three additional hydropower dams upstream of the lowermost Conowingo Dam (Figure 1). While fish passage facilities have been constructed at each of the hydropower dams, they were designed to pass migrating shad and herring and have been unsuccessful at passing young eels. Before dams were constructed, the annual harvest of silver eels in the Susquehanna River was nearly one million pounds. Although eels were stocked in the Susquehanna River and its tributaries intermittently from 1938 to 1980, at the beginning of this project there was no commercial harvest or recreational fishery for eels. Dams on the Susquehanna River not only eliminated a once abundant eel fishery; they likely had a profound effect on the way the ecosystem functions. American eels, top predators in many streams, are estimated to have once comprised almost 25%

of the fish biomass in Atlantic slope streams and rivers. Eels may also play an important role in supporting freshwater mussel populations in the Susquehanna River.

Research conducted by the U.S. Geological Survey (USGS), Northern Appalachian Research Laboratory (NARL) and the U.S. Fish and Wildlife Service (USFWS), Maryland Fishery Resources Office (MFRO) indicates that American eel is a successful host fish for the freshwater mussel, *Elliptio complanata* (eastern elliptio) (Lellis et al. 2013). The larvae (glochidia) of freshwater mussels must parasitize a host fish to complete metamorphosis to the independent juvenile life stage. Glochidia from eastern elliptio collected by NARL in the Susquehanna River had higher metamorphosis success rates on American eels (≥ 90% success) than on other fish species commonly found in the Susquehanna River. In some Atlantic draining watersheds, eastern elliptio comprise the most abundant biomass of any fauna in the watershed and can provide great filtration capacity. For example, the estimated 280 million eastern elliptio in the Delaware River have the potential to filter between 2 billion and 6 billion gallons of water and remove 78 tons of sediment from the water column each day (Spooner and Lellis 2010). However, eastern elliptio is less abundant in the Susquehanna River watershed than in nearby watersheds (Lellis 2002 and personal communication with Jim McCann, Maryland Department of Natural Resources).

In 2008 and 2009, biologists from NARL and MFRO conducted freshwater mussel surveys in the Susquehanna River watershed to assess whether reproduction was occurring in eastern elliptio populations. Biologists identified 13 sites from previous surveys as having relatively high density of eastern elliptio (≥ 30/hour). After conducting a 3.2 km snorkel survey at each site, 200 m sections with the highest density of eastern elliptio were identified. At randomly selected 0.25 m^2 quadrats within the high density sections, mussels collected from the

surface, subsurface and sediment sieved through 5 mm screen, were measured to assess the size range of mussels at the site. The two streams with the highest abundance of eastern elliptio were both tributaries to the West Branch Susquehanna River, Buffalo Creek and Pine Creek. At these and other sites above Conowingo Dam, very few small (< 40 mm) eastern elliptio were found. However at sites below Conowingo Dam, where eels were present, a number of small eastern elliptio were found. These results indicate that many of the populations at upstream sites had little or no eastern elliptio recruitment when surveyed in 2008. If eels are important to successful reproduction in eastern elliptio populations in the Susquehanna River, restoring eels could also restore mussels, which could result in improved water quality in the system.

In order to test this hypothesis and as mitigation for the City of Sunbury, Riverbank Stabilization Project, the objectives of this project are to:

1. Stock juvenile American eels (elvers) in upstream tributaries to the Susquehanna River with existing eastern elliptio populations (Buffalo Creek, Union County, PA, and Pine Creek, Tioga County, PA).
2. Monitor eel presence/absence at 2 sites in each tributary during each of the three years of stocking (2010, 2011, and 2012), year 5 (2014) and year 10 (2019) of the project.
3. Survey freshwater mussel populations in each tributary to collect baseline mussel population data and assess recruitment to the mussel populations in year 5 (2014) and year 10 (2019) of the project.

METHODS

Eel Stocking

Based on eel data (number of eels/km) collected in tributaries to the Susquehanna River and Chesapeake Bay below Conowingo Dam, a rough estimate of capacity for eels in upstream tributaries was calculated. An average density of eels was estimated at 529 eels/km using data collected by Maryland Department of Natural Resource (MD DNR), Maryland Biological Stream Survey (MBSS), in four tributaries downstream of Conowingo Dam: Big Elk Creek

(Cecil County, MD), Furnace Bay (Cecil County, MD), Little Elk Creek (Cecil County, MD), and Northeast River (Cecil County, MD). The number of eels needed to achieve a similar density of 529 eels/km at stocking sites was calculated by multiplying the number of mainstem stream kilometers above the stocking site by the average density. Based on these calculations and the projected feasibility of capturing eels for stocking, we proposed to relocate up to 60,000 eels to each of Buffalo Creek and Pine Creek over a three year period (2010 through 2012).

Eels were collected from glass eel and elver sampling sites for stocking. The MD DNR is required by the Atlantic States Marine Fisheries Commission (ASMFC) to conduct Young-of-Year (YOY) eel monitoring. Their sampling devices are located at a bridge culvert in Turville Creek (Ocean City, MD) and at the Bishopville Dam on Bishopville Prong (Bishopville, MD). Glass eels were held in captivity at the USGS lab in Wellsboro until they matured to pigmented elvers (55-94 mm). They were then stocked in Buffalo Creek and Pine Creek (Table 1). American eel elvers (90-150 mm) were collected by the USFWS using a collection device located immediately downstream of Conowingo Dam. An eel ramp consisting of covered cable tray, and lined with landscaping cloth (Enkamat), was deployed at the base of Conowingo Dam. Water from the Susquehanna River was pumped to the top of the cable tray ramp where it flowed down the Enkamat to attract elvers. Elvers crawled up the ramps and were swept by sprayed water into collection tanks. Aerated water was circulated through collection tanks to keep elvers in good health. Captured elvers were sedated, measured, and counted. Large numbers of eels were estimated volumetrically. Elvers were held in holding tanks at Conowingo Dam before being stocked in Buffalo Creek and Pine Creek (Table 1).

From 2010 through 2013, 118,642 eels were stocked in Buffalo Creek and 122,047 eels were stocked in Pine Creek. Eels were stocked in these two tributaries to the Susquehanna River

in the vicinity of eastern elliptio beds to encourage association between eastern elliptio glochidia and eels (Figure 2). The mouth of Buffalo Creek, near Lewisburg, PA is approximately 9 miles north of Sunbury, PA on the West Branch of the Susquehanna River. Eels were stocked near high densities of eastern elliptio in 3 locations: Strawbridge Rd. Bridge (40.9856 N, 76.93237 W); the footbridge on Rt. 1003 (40.98105 N, 76.95134 W); and near the U.S. Penitentiary in Lewisburg, PA (40.98078 N, 76.924114 W). Pine Creek, which has its confluence with the West Branch of the Susquehanna River at Jersey Shore, PA, has the highest density of eastern elliptio found in NARL and MFRO surveys in the Susquehanna River watershed. Eels were stocked near high densities of eastern elliptio in 4 locations: Owassee Rapids (41.71568 N, 77.45543 W); Darling Run Access (41.74368 N, 77.43394 W); Marsh Creek Boat Ramp (41.74466 N, 77.42775 W); and Ansonia Bridge, Ansonia, PA (41.73671 N, 77.43036 W). Stockings (Table 1) were documented and reported to the Pennsylvania Fish and Boat Commission as part of the requirements of the Scientific Collecting Permit Number 354, Type 2.

Fish survey

To evaluate eel stocking success, including survival, growth and habitat use, as well as to document the fish community, we conducted electrofishing surveys using 3 or 4 backpack and 1 barge electrofishing units in July of 2014. The barge electrofisher provided electricity to two attached anodes. Methods used by the MD DNR MBSS (2007) were used to quantify the catch per unit effort (CPUE), abundance, and biomass of eels. Two sites, near the eel release sites, in each stream were surveyed. At each site, 75 meters of stream was blocked off using ¼" mesh block net. In order to get a complete picture of the fish community in each stream, 2 passes with the electrofishing units were conducted and all fish collected were enumerated. Captured eels were measured to assess growth. Mass (kg) of the total catch and of eels captured was measured

to assess changes in biomass of eels over time. A subsample of eels from Buffalo Creek was returned to the lab to assess stomach contents, presence of the swim bladder parasite *Anguillicola crassus*, and remove otoliths for aging. Abundance estimates for eels in the surveyed area were calculated using the methods of Seber and LeCren (1967). Differences in eel lengths between years were determined using a two sample t- test in EXCEL.

Eel Growth

In addition to the electrofishing surveys at the stocking locations in Buffalo Creek and Pine Creek, we conducted an electrofishing survey upstream and downstream of the Buffalo Creek stocking locations in September of 2013 and October of 2014. We used two backpack electrofishing units to capture American eels at several locations ranging from 2.4 kilometers upstream to 2 kilometers downstream of stocking locations. Captured eels were measured and those with lengths over 200 mm were tagged by inserting PIT (Passive Integrated Transponder) tags into the dorsal musculature. Captured eels were then released near their capture location. Differences in eel lengths between years were determined using a two sample t-test in EXCEL. The density of eels was calculated using the abundance estimates determined using Lincoln-Peterson in program CAPTURE.

Mussel survey

Mussel surveys were conducted in Buffalo Creek and Pine Creek in July of 2014. Qualitative searches were conducted in a 3.2 km stream reach in each of Buffalo Creek and Pine Creek using snorkeling equipment. The number of mussels and the search time were recorded after each 200 meter section to determine a CPUE. Within the surveyed area, we identified a 200 meter section of stream, approximately 6000 m^2 in area, with a relatively high mussel density. We conducted quantitative surveys in this area to estimate mussel abundance and assess

presence of juvenile mussels. The quantitative survey site was sampled using 0.25 m^2 quadrats in a systematic random design with multiple random starts (Strayer and Smith 2003). All quadrats were excavated to 10 cm or to hardpan and sifted through a 5 mm^2 mesh screen in order to detect juvenile mussels. Counts of each species and length measurement were collected for all mussels. Quantitative and qualitative survey methods followed accepted protocol developed by Strayer and Smith (2003). Results of the quantitative mussel survey were analyzed using the Mussel Estimation Program (Version 1.1.4) developed by David R. Smith (USGS, Leetown Science Center, Leetown, WV).

RESULTS

Eel Stocking

In 2013, 30,614 elvers were stocked in Buffalo Creek and no eels were stocked in Pine Creek. No eels were stocked in either Buffalo or Pine Creek in 2014. In 2013 and 2014, stocking efforts were shifted to mainstem and North Branch Susquehanna River stocking locations. In 2013, a total of 275,479 eels were stocked in the Susquehanna River above Conowingo Dam. In 2014, a total of 185,325 eels were stocked above Conowingo Dam.

Fish Survey

During electrofishing surveys in July of 2014, 162 eels were recaptured in Buffalo Creek and 61 eels were recaptured in Pine Creek (Table 2). The Pine Creek sites (Darling Run Access and Ansonia Bridge) and the Buffalo Creek sites (Strawbridge Rd Bridge and Footbridge on Rt 1003) were sampled.

Lengths of recaptured eels in Buffalo Creek were significantly larger ($p < 0.00001$) in 2014 (mean: 230 mm, S.D: ± 63) than in 2012 (mean: 196 mm S.D: ± 68 mm) and 2011 (mean: 137 mm S.D. ± 24 mm) (Figure 3). The longest eel captured in Buffalo Creek during the 2014

fish survey was 567 mm. In Pine Creek, the average length of recaptured eels was 268 mm (S.D. ± 61) which is significantly larger ($p < 0.00001$) than eel lengths in 2012, (mean: 128 mm, S.D. ± 31). The longest eel captured in in Pine Creek in 2014 was 470 mm (Figure 4). The 162 recaptured eels in Buffalo Creek had a total mass of 2.9 kg resulting in an average of 18.02 g/eel (an increase from 17.8 g/eel in 2012) and comprised 12.9% of the total biomass of captured fish. The 61 recaptured eels in Pine Creek had a total mass of 2.3 kg resulting in an average of 39.0 g/eel (an increase from 4.5 g/eel in 2012) and comprised 39.8% of the total biomass of captured fish. While density (eels/m^2) decreased at the two sites that received the largest number of stocked eels (Strawbridge in Buffalo Creek and Ansonia in Pine Creek), average length (mm) and % biomass increased from 2012 to 2014 at all sites (Table 3).

Stomach contents of the subsample of eels returned for lab dissection from Buffalo Creek (n = 38) were comprised of crayfish, water pennies, caddisfly larvae, and other unidentifiable macroinvertebrates. There was an increase in the number of eels from Buffalo Creek infected with a swim bladder parasite (*Anguillicola crassus*) from 10% in 2010 (n=30) to 34% in 2014.

In Buffalo Creek, 925 individuals of 29 fish species were collected. In Pine Creek, 676 individuals of 24 fish species were collected (Table 2). Relative abundance by family indicates that eels make up a greater proportion of the population at Buffalo Creek sampling sites (18%) in comparison with Buffalo Creek sampling sites in 2012 (9%) (Figure 5). From 2012 to 2014 relative abundance of eels increased in Buffalo Creek from 5% to 18% and in Pine Creek from 5% to 9%.

Eel Growth

During electrofishing surveys conducted in 2012, 2013, and 2014 to assess eel growth, eels were recaptured upstream and downstream of the stocking locations in Buffalo Creek.

While the CPUE was similar from 2013 (37.7 eels/hr) to 2014 (38.4 eels/hr) below Strawbridge Rd. Bridge, the CPUE above the footbridge at Rt. 1003 nearly doubled from 50.5 eels/hr in 2013 to 92.3 eels/hr in 2014 (Table 4).

We inserted PIT tags into the dorsal musculature of 174 eels in 2012, 162 eels in 2013, and 171 eels in 2014 that measured greater than 200 mm. All eels, except 3 that were returned to the lab for dissection in 2012, were returned to Buffalo Creek near their capture locations.

In 2014, 12 previously tagged eels were recaptured; 7 below Stawbridge Rd Bridge and 5 above the footbridge on Rt 1003. Of the 7 recaptured below Strawbridge, 3 were originally tagged in 2012, and the other 4 were tagged first in 2013. Of the 5 recaptured above the footbridge, 3 were first tagged in 2012, and the other 2 were tagged in 2013 (Table 5). One fish (PIT Tag num: 982000357628386) was first tagged in 2012, recaptured in 2013, and recaptured again in 2014. This fish was always caught below Strawbridge Rd Bridge and was identified as a silver male in 2014 with a total length of 371 mm. To date, no fish has been observed moving from below Strawbridge Rd. Bridge to above the footbridge on Rt 1003 (or vice versa).

Growth was similar among recaptured fish from 2012-2013 (Avg. growth = 60.1 mm/yr), 2013-2014 (Avg. growth = 60.7 mm/yr), and 2012-2014 (Avg. growth = 61.3 mm/yr) (Table 6). The average length of eels captured in 2013 (260, S.D. ± 64) was not significantly different ($p = 0.517$) from the average length of eels captured in 2014 (264, S.D. ± 71). The total length of recaptured eels ranged from 101 mm to 494 mm in 2013 and 137 mm to 610 mm in 2014 (Figure 6). Of all recaptured fish, average yearly growth is 61.7 mm/yr (S.D. ±28.7; Table 6). Range of yearly growth rates from recaptured fish is 17-136 mm/yr. The silver eel mentioned above that was recaptured twice grew 67 mm from 2012-2013 and only grew 30 mm from 2013-2014.

Mussel Survey

Buffalo Creek

In 26.3 snorkel survey hours in Buffalo Creek, 4065 eastern elliptio, 39 creeper (*Strophitus undulatus)*, 4 yellow lampmussel (*Lampsilis cariosa*), and 1 rainbow (*Villosa iris*) were detected in 3.2 km in July of 2014. Of the mussels found during the snorkel survey, 98.9% were eastern elliptio. The cumulative CPUE for eastern elliptio was 155 mussels per hour. CPUE for individual 200 meter sections ranged from 11.2 eastern elliptio per hour to 445.3 eastern elliptio per hour. The 200 meter section sampled in 2010 (407.9 mussels/hour) was chosen for the quantitative mussel survey.

During the quantitative mussel survey, 69 m^2 (276 quadrats) of the 4792 m^2 area was excavated. Three species, eastern elliptio (315 found), creeper (7 found), and rainbow (1 found) were detected during this survey. The estimated abundance (26,114, SE ± 2090.9, 90% CL 22,891-29,789) and estimated density (5.4 mussels/m^2, SE ± 0.44, 90% CL 4.776-6.215) of eastern elliptio in the survey area in 2014 were not different from the estimated abundance (27,249, SE ± 1831, 90% CL 24,397-30,434) and estimated density (5.1 mussels/m^2 SE ± 0.35, 90% CL 4.61-5.75) of eastern elliptio in the survey area in 2010 (Table 7). The average length of eastern elliptio found in quadrats in 2014 (79.1 mm, SD ± 16.9) was lower ($p < 0.02$) than the average length of eastern elliptio found in quadrats in 2010 (82.1 mm, SD ± 14.9) (Figure 7). In 2014 surveys 5 eastern elliptio, presumed to be juveniles (< 40 mm), were found in quantitative surveys. This is only slightly more than the 3 eastern elliptio juveniles found in 2010.

Pine Creek

In the summer of 2014, qualitative surveys were conducted in 3.2 km of Pine Creek. In the 32.5 survey hours spent in this 3.2 km section, 4990 individuals of 5 species were detected:

4414 eastern elliptio; 267 creeper; 290 brook floater (*Alasmidonta varicosa*); 4 green floater (*Lasmigona subviridis*); and 15 elktoe (*Alasmidonta marginata*). Of the mussels found during the survey, 88% were eastern elliptio. The cumulative CPUE for eastern elliptio was 136 mussels per hour. CPUE for individual 200 meter sections ranged from 1.4 eastern elliptio per hour to 701.1 eastern elliptio per hour. The 200 meter section sampled in 2008 (701.1 mussels/hr) was not chosen for the quantitative mussel survey due to high water. Instead, a shallower section (277.2 mussels/hr) approximately 400 m upstream was chosen.

An area of 6084 m^2 was quantitatively surveyed in Pine Creek. In the quadrats excavated for the survey, totaling 97.5 m^2 (390 quadrats), 454 eastern elliptio were detected. The estimated density (4.6 mussels/m^2, SE ± 0.18) and abundance (28,257, SE ± 1114) of eastern elliptio in the surveyed area in 2014 was less than the estimated density (5.9 mussels/m^2, SE ± 0.64) and abundance (60,615, SE ± 6578) of eastern elliptio in 2008 (Table 7). However, a site with a lower CPUE during the qualitative survey was chosen. The average length of eastern elliptio found on the surface and in excavated quadrats in 2014 was 73.0 mm (SD ± 35.6) which was significantly lower ($p < 0.0001$) than the average length of eastern elliptio found in 2008 (93.1 mm, SD ± 8.2) (Figure 8). In 2008 during quantitative surveys in Pine Creek, there were no juvenile (< 40 mm) elliptio complanata detected during quantitative surveys. In contrast, during 2014 quantitative surveys, 30% of the eastern elliptio found (134 eastern elliptio) were juveniles (Figure 8).

DISCUSSION

In Buffalo Creek, an additional 30,614 eels were stocked in 2013, bringing the number of eels stocked since 2010 to 118,742. The number of eels stocked in Buffalo Creek and Pine Creek (122,049) is nearly double the proposed stocking goal of 60,000 in each creek. In 2014

we completed electrofishing surveys and mussel surveys in both Pine Creek and Buffalo Creek. Our success in recapturing over 162 eels in Buffalo Creek and 60 eels in Pine Creek indicates that the stocked eels are surviving and growing well near the stocking sites. During mussel surveys in Buffalo Creek, there was an increase in juvenile eastern elliptio from 3 in 2010 to 5 in 2014. More significantly, there was an increase in juvenile eastern elliptio found in Pine creek from 0 in 2008 to 134 in 2014. However, due to high water conditions, a different 200 meter section was surveyed in 2014 than the baseline survey site in 2008. An additional survey at the 2008 survey site is needed to determine if there is an increase in juvenile eastern elliptio at that site as well.

As expected, average length and weight of eels increased from 2012 to 2014. A larger increase in mean eel length was found in Pine Creek (from 128 mm in 2012 to 268 mm in 2014) than in Buffalo Creek (from 196 mm in 2012 to 230 mm in 2014). This is likely due to the large number of small eels stocked in Pine Creek in 2012, and the additional stocking in Buffalo Creek in 2013 which decreased the mean length in 2014. The % biomass of eels also increased at all sites from 2012 to 2014. Ansonia Bridge, in Pine Creek, had the highest % biomass of eels and also had the longest average eel length of all of the sample sites.

Relative abundance of eels also increased in both creeks and at all sites sampled. While it is possible that eels are starting to become large enough to eat fish, the lower number of all fish species captured in 2014 was likely due to high water level conditions during 2014 electrofishing surveys, allowing fish to disperse and not be limited to the deeper areas included in the survey.

The largest eel captured during the summer electrofishing surveys near stocking locations was 567 mm in length. However, during fall electrofishing surveys upstream and downstream of stocking locations, an eel, 610 mm in length, was captured in Buffalo Creek. The reason larger

eels are captured during the eel growth study than the summer electrofishing survey is likely that surveyors target preferred eel habitat (deep crevices and root overhangs).

Average annual growth in this study (61.7 mm/year) was similar to studies conducted in South Carolina which found a maximum growth rate of 69 mm/year (Hansen and Eversole 2011) and exceeds average growth rates found in a study conducted in Maine of 30 mm/year (Oliveira and McCleave 2002). Average growth rates in Buffalo Creek are higher than those at the base of Conowingo Dam of 43 mm/year (USFWS, unpublished data). Abundant food resources are likely driving growth rates in Buffalo Creek. Average growth rate may also differ by age and length range. The silver male mentioned above that was recaptured twice grew 67 mm from 2012-2013 and only grew 30 mm from 2013-2014. As expected for silvering males, growth slows as the fish prepares for downstream migration. Average growth rates for eels, which likely vary in accordance with water temperature and latitude, need to be further studied by sex and length range in the mid-Atlantic region.

During fish surveys conducted by other agencies since 2010, eels have been captured over 50 km from eel stocking sites (Figure 9). Eels have been captured by other agencies both upstream and downstream of Buffalo and Pine Creek stocking sites. The Susquehanna River Basin Commission has detected eels at many of their study sites. Additional sampling will likely provide more information about eel dispersal throughout the watershed.

Similar to previous studies (Ogden 1970, Lookabaugh and Angermeier 1992) and stomach content analysis conducted in 2012, stomach contents of eels collected in 2014 consisted of aquatic macroinvertebrates. A comprehensive assessment of stomach contents for eels of various lengths would be useful to determine the impact of eels on the macroinvertebrate community.

The most interesting finding in 2014 was evidence of recruitment in the eastern elliptio population in Pine Creek (Figure 8). The large number of juveniles less than 40 mm coupled with the small number or absence of mid-length mussels (50 – 80 mm) signifies that there is now recruitment of juveniles into the eastern elliptio population where there had been little in recent years. There may be two contributing factors to this increase in juvenile eastern elliptio. The highest CPUE of eastern elliptio recently found in the Susquehanna River watershed (701 mussels/hr) is approximately 400 m downstream of the sample site. This is the highest CPUE of eastern elliptio found in the Susquehanna River watershed to date and is similar to CPUE of eastern elliptio found in the Delaware River (Lellis 2002). This site is likely a huge source of freshwater mussel larvae each spring. The second factor is that the quantitative survey site is between two of the Pine Creek eel stocking sites: Darling Run is approximately 200 m downstream and Ansonia Bridge is approximately 1000 m upstream. The results of the quantitative survey provide more evidence that American eels may be a limiting factor in eastern elliptio recruitment.

In coming years, the USFWS plans to continue eel growth studies in Buffalo Creek. In addition, because a different quantitative survey site was chosen in Pine Creek in 2014 due to high water conditions, we plan to conduct an additional quantitative mussel survey to assess juvenile recruitment of eastern elliptio at the 2008 site if lower water conditions are available in 2015. Final monitoring of fish and mussel populations will occur in 2019.

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Table 1. Eels stocked in Buffalo Creek (Union County, PA), Pine Creek (Tioga County, PA) and Conowingo Creek (Lancaster County, PA) in 2010, 2011, 2012, and 2013.

Date	# Stocked	Location	Mean Length (mm)	Origin
		Pine Creek		
June 9, 2010	3,000	Darling Run Access	56.3*	Turville Creek
June 9, 2010	3,000	Ansonia Bridge	56.3*	Turville Creek
June 9, 2010	3,000	Owassee Rapids	56.3*	Turville Creek
June 21, 2011	10,666	Darling Run Access	80.1 ± 16.0	Turville Creek
June 21, 2011	10,666	Ansonia Bridge	80.1 ± 16.0	Turville Creek
June 21, 2011	10,668	Owassee Rapids	80.1 ± 16.0	Turville Creek
June 30, 2011	7,222	Marsh Creek Boat Ramp	127 ± 16.9	Conowingo Dam
August 22, 2011	1,528	Ansonia Bridge	127 ± 16.9	Conowingo Dam
August 31, 2011	8,940	Ansonia Bridge	127 ± 16.9	Conowingo Dam
September 2, 2011	8,084	Ansonia Bridge	127 ± 16.9	Conowingo Dam
September 7, 2011	12,205	Ansonia Bridge	127 ± 16.9	Conowingo Dam
May 24, 2012	15,237	Darling Run Access	67.4 ± 10.0	Bishopville Prong
June 6, 2012	16,241	Ansonia Bridge	121.0 ±16.5	Conowingo Dam
June 20, 2012	11,592	Ansonia Bridge	121.0 ±16.5	Conowingo Dam
Total	**122,049**			
		Buffalo Creek		
June 10, 2010	8,084	Strawbridge Rd. Bridge	127.7	Conowingo Dam
June 10, 2010	4,500	Strawbridge Rd. Bridge	56.3*	Turville Creek
June 10, 2010	4,500	Footbridge on Rt. 1003	56.3*	Turville Creek
June 21, 2010	7,790	Strawbridge Rd. Bridge	127.7	Conowingo Dam
June 21, 2011	16,219	Strawbridge Rd. Bridge	80.1 ± 16.0	Turville Creek
June 21, 2011	16,000	Footbridge on Rt. 1003	80.1 ± 16.0	Turville Creek
July 14, 2011	6,326	Strawbridge Rd. Bridge	127 ± 16.9	Conowingo Dam
July 18, 2011	4,390	Strawbridge Rd. Bridge	127 ± 16.9	Conowingo Dam
July 28, 2011	3,603	Strawbridge Rd. Bridge	127 ± 16.9	Conowingo Dam
May 24, 2012	8,526	Strawbridge Rd. Bridge	67.4 ± 10.0	Bishopville Prong
May 31, 2012	7,122	Strawbridge Rd. Bridge	121.0 ±16.5	Conowingo Dam
August 7, 2012	1,068	Strawbridge Rd. Bridge	121.0 ±16.5	Conowingo Dam
June 26, 2013	7,908	Strawbridge Rd. Bridge	127 ± 16.9	Conowingo Dam
August 22, 2013	22,706	Penetentiary	127 ± 16.9	Conowingo Dam
Total	**118,742**			

* length (mm) of glass eels was estimated using regression

Table 2. Number and catch per unit effort (CPUE, #/hour) of fish species captured in Buffalo Creek and Pine Creek during electrofishing surveys conducted in July of 2014.

	Buffalo Creek				**Pine Creek**			
	Strawbridge Rd Bridge		Footbridge on Rt 1003		Darling Run Access		Ansonia Bridge	
Shock time (hours)	3.5		4.2		3.1		2.4	
Common name	#	CPUE	#	CPUE	#	CPUE	#	CPUE
American eel	54	15.3	108	25.9	25	7.9	35	14.3
creek chubsucker	0	0.0	0	0.0	0	0.0	9	3.7
northern hogsucker	4	1.1	8	1.9	4	1.3	2	0.8
white sucker	2	0.6	52	12.5	5	1.6	5	2.0
rockbass	27	7.7	20	4.8	7	2.2	1	0.4
redbreast sunfish	12	3.4	5	1.2	12	3.8	0	0.0
green sunfish	1	0.3	0	0.0	0	0.0	0	0.0
pumpkin seed	0	0.0	2	0.5	0	0.0	0	0.0
bluegill	3	0.9	4	1.0	0	0.0	0	0.0
smallmouth bass	9	2.6	30	7.2	6	1.9	1	0.4
mottled sculpin	0	0.0	2	0.5	0	0.0	0	0.0
central stoneroller	2	0.6	0	0.0	1	0.3	5	2.0
cutlips minnow	15	4.3	18	4.3	56	17.8	34	13.9
pearl dace	29	8.2	3	0.7	3	1.0	30	12.3
river chub	0	0.0	0	0.0	0	0.0	8	3.3
rosyface shiner	13	3.7	0	0.0	59	18.7	3	1.2
mimic shiner	56	15.9	59	14.1	0	0.0	62	25.4
bluntnose minnow	1	0.3	0	0.0	0	0.0	1	0.4
blacknose dace	0	0.0	1	0.2	1	0.3	3	1.2
longnose dace	30	8.5	0	0.0	0	0.0	1	0.4
creek chub	0	0.0	0	0.0	1	0.3	0	0.0
fallfish	4	1.1	27	6.5	1	0.3	1	0.4
chain pickerel	3	0.9	0	0.0	1	0.3	0	0.0
banded killifish	0	0.0	1	0.2	0	0.0	0	0.0
yellow bullhead	2	0.6	1	0.2	0	0.0	0	0.0
margined madtom	20	5.7	21	5.0	23	7.3	40	16.4
greenside darter	15	4.3	24	5.7	26	8.3	5	2.0
fantail darter	2	0.6	0	0.0	0	0.0	0	0.0
tessellated darter	26	7.4	66	15.8	91	28.9	20	8.2
banded darter	11	3.1	30	7.2	21	6.7	11	4.5
shield darter	18	5.1	60	14.4	12	3.8	13	5.3
brown trout	1	0.3	1	0.2	0	0.0	0	0.0

Table 3. Density (# eels/m^2) of eels, estimated abundance (Seber and Le Cren 1967) (± S.E.) of eels in a 75 meter length of stream, average length (± S.D.) and % biomass of captured fish that were eels during 2011, 2012, and 2014 electrofishing surveys in Buffalo Creek and Pine Creek.

2011

	Buffalo Creek		**Pine Creek**	
	Strawbridge Rd Bridge	Footbridge on Rt 1003	Darling Run Access	Ansonia Bridge
Density (# eels/m^2)	0.17	n/a	0.004	0.003
Abundance	480.3 (± 14)	n/a	12.5 (± 1)	n/a
Ave. Length (mm)	137 (± 24)	193 (± 21)	161 (± 37)	118 (± 28)
% Biomass	10.1	6.1	1.2	0.6

2012

	Buffalo Creek		**Pine Creek**	
	Strawbridge Rd Bridge	Footbridge on Rt 1003	Darling Run Access	Ansonia Bridge
Density (# eels/m^2)	0.03	0.04	0.008	0.07
Abundance	72 (± 6)	160 (± 41)	28 (± 9)	302 (± 37)
Ave. Length (mm)	154 (± 41)	223 (± 68)	167 (± 46)	124 (± 26)
% Biomass	3.8	9	2.7	4.8

2014

	Buffalo Creek		**Pine Creek**	
	Strawbridge Rd Bridge	Footbridge on Rte. 1003	Darling Run Access	Ansonia Bridge
Density (# eels/m^2)	0.03	0.05	0.03	0.02
Abundance	62 (± 6)	131 (± 13)	65 (± 85)	54 (± 21)
Ave. Length (mm)	215 (± 58)	236 (± 65)	262 (± 67)	272 (± 58)
% Biomass	21.1	10.2	29.2	52.8

Table 4. Density of eels (95% CI range) using Lincoln-Peterson estimated abundance, average length (± S.D.), and CPUE (eels/hr) of eels captured during 2013 and 2014 electrofishing pit tag surveys below Strawbridge Rd. Bridge and above the footbridge at Rt. 1003 in Buffalo Creek.

2013

	Buffalo Creek	
	Strawbridge Rd Bridge	Footbridge on Rt 1003
Density (# eels/m^2)	0.068	0.25
Ave. Length (mm)	263 (± 81)	258 (± 49)
CPUE (eels/hr)	37.7	50.5

2014

	Buffalo Creek	
	Strawbridge Rd Bridge	Footbridge on Rt 1003
Density (# eels/m^2)	0.13 (0.08-0.22)	0.28 (0.17-0.48)
Ave. Length (mm)	255 (± 83)	270 (± 60)
CPUE (eels/hr)	38.4	92.3

Table 5. Number of recaptured pit tagged American eels from two sites within Buffalo Creek.

Below Strawbridge	Recapture Year		
Tagging Year	2012	2013	2014
2012	0	4	3
2013	--	0	4
2014	--	--	0

Above Footbridge	Recapture Year		
Tagging Year	2012	2013	2014
2012	0	9	3
2013	--	0	2
2014	--	--	0

Table 6. Average yearly growth (in mm/yr) of recaptured fish from Buffalo Creek from 2012-2014 at two sites, below Strawbridge Rd. bridge and above the footbridge on Rt. 1003.

Site	2012-2013	2012-2014	2013-2014	**Site Avg.**
Strawbridge	65.5	72.0	73.5	**70.2**
Footbridge	57.0	50.5	43.7	**53.1**
Yearly Avg.	**60.1**	**61.3**	**60.7**	**61.7**

Table 7. Relative abundance, density (± SE and 90% Confidence), and abundance (± SE and 90% Confidence), estimated using the Mussel Estimation Program (Smith 2007), of mussels found during quantitative surveys below the footbridge at Rt 1003 in Buffalo Creek and at Darling Run in Pine Creek.

Species	Relative Abund.	Density Est.	SE	90% CL	Abund. Est.	SE	90% CL
				Pine Creek			
				2008			
ALL		6.121	0.6449	5.147-7.279	62432	6578.38	52497-74246
Brook floater	0.44	0.027	0.0194	0.008-0.088	275	198.08	84-899
Eastern elliptio	97.09	5.943	0.6439	4.973-7.102	60615	6567.67	50720-72440
Creeper	2.48	0.152	0.0448	0.093-0.246	1546	456.56	951-2513
				2014			
ALL		5.432	0.2558	5.027-5.87	33050	1556.25	30586-35711
Brook floater	9.23	0.501	0.1012	0.36-0.699	3050	615.53	2188-4251
Eastern elliptio	85.5	4.645	0.1831	4.353-4.956	28257	1114.03	26483-30150
Green floater	1.32	0.072	0.0244	0.041-0.126	436	148.69	249-764
Creeper	3.95	0.215	0.0343	0.165-0.279	1307	208.45	1005-1699
				Buffalo Creek			
				2010			
ALL		5.44	0.3743	4.858-6.092	28788	1980.93	25708-32238
Eastern elliptio	94.65	5.149	0.3461	4.61-5.751	27249	1831.36	24397-30434
Creeper	5.35	0.291	0.0323	0.242-0.349	1539	171	1282-1848
				2014			
ALL		5.586	0.4141	4.945-6.311	26775	1984.92	23701-30247
Eastern elliptio	97.53	5.448	0.4362	4.776-6.215	26114	2090.85	22891-29789
Creeper	2.16	0.121	0.0328	0.077-0.189	578	157.28	370-905
Rainbow	0.31	0.017	0.0171	0.003-0.088	83	82.14	16-424

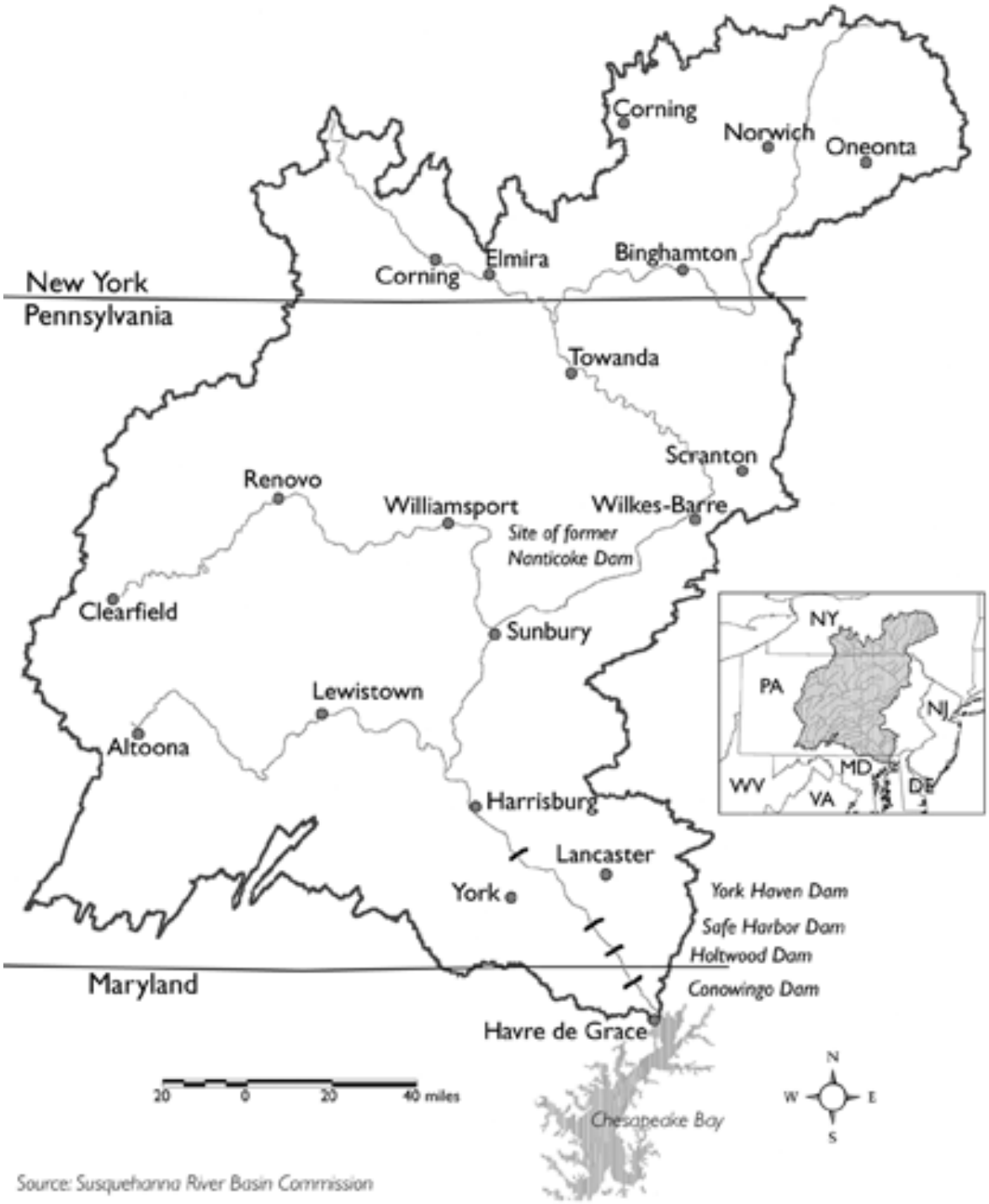

Figure 1. Susquehanna River watershed with the locations of the 4 hydroelectric dams, York Haven, Safe Harbor, Holtwood Dam, and Conowingo Dam denoted by straight lines across the mainstem Susquehanna River.

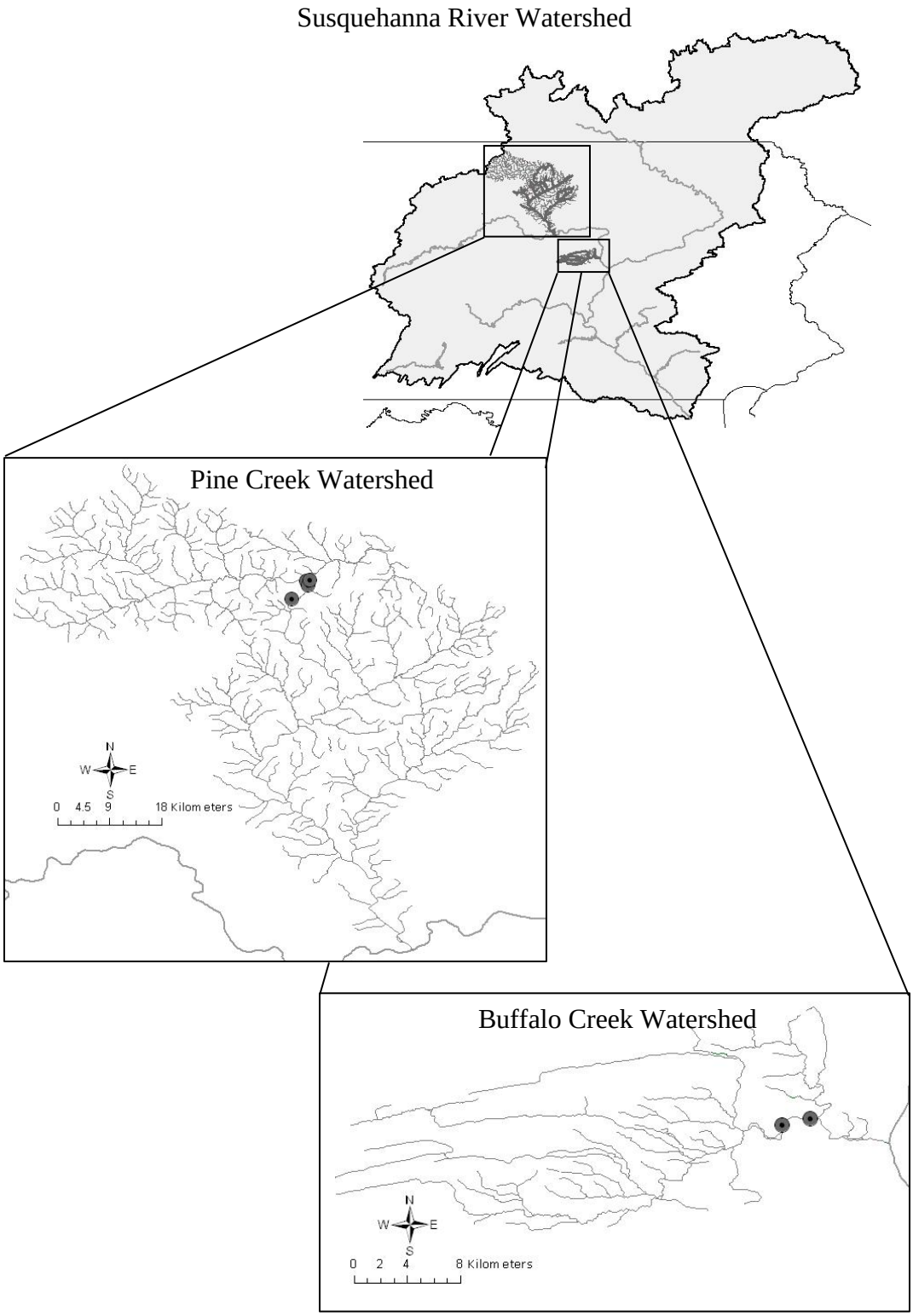

Figure 2. Eel stocking sites (indicated by dots) at Owassee Rapids, Darling Run Access, Marsh Creek, and Ansonia Bridge in Pine Creek (Tioga County, PA) and Strawbridge Rd. Bridge and the footbridge at Rt. 1003 in Buffalo Creek (Union County, PA) in the Susquehanna River drainage.

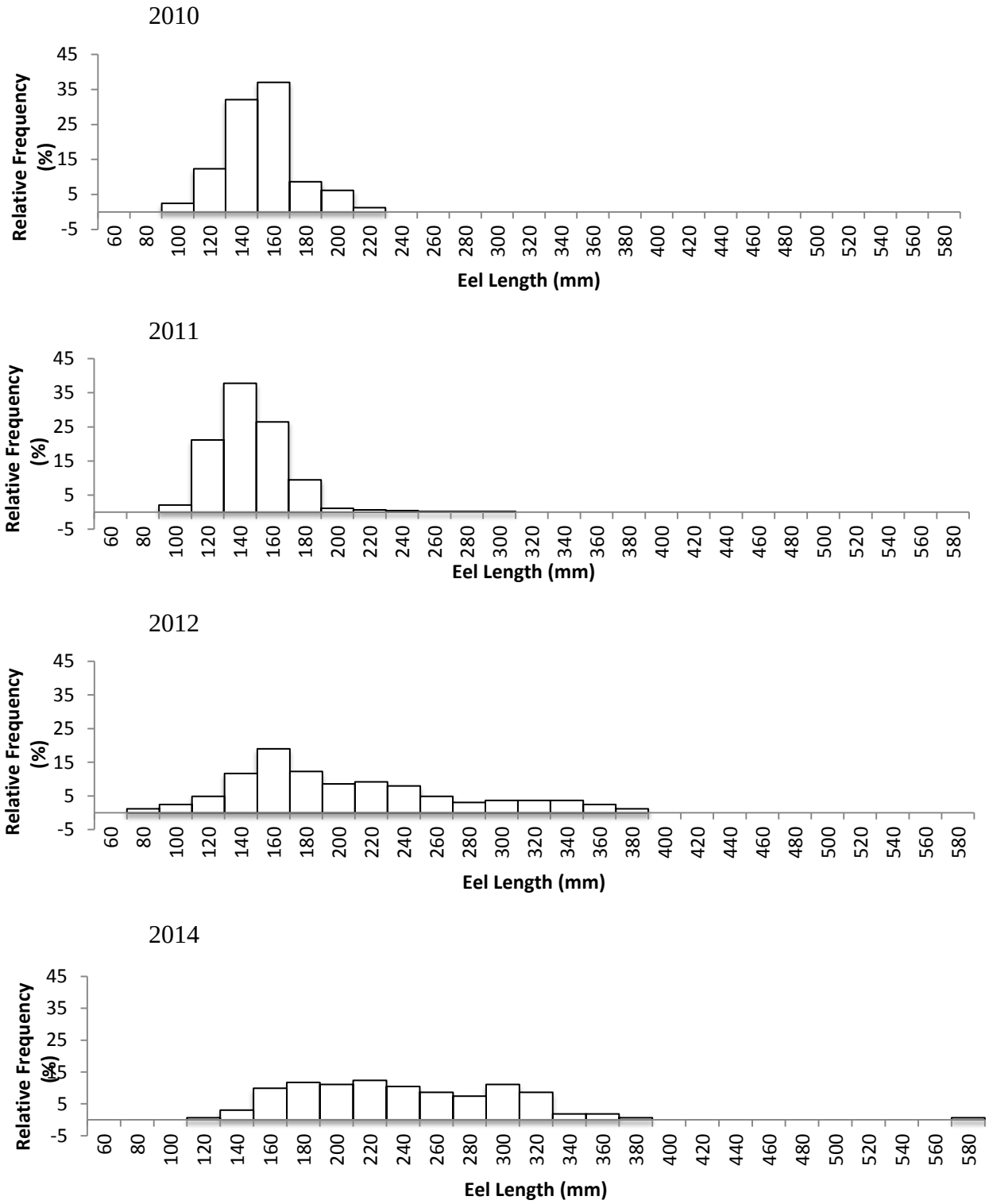

Figure 3. Relative length frequency (expressed as percentage) of eels captured during monitoring surveys in Buffalo Creek in 2010 (n = 81), 2011 (n = 434), 2012 (n = 163), 2014 (n=162).

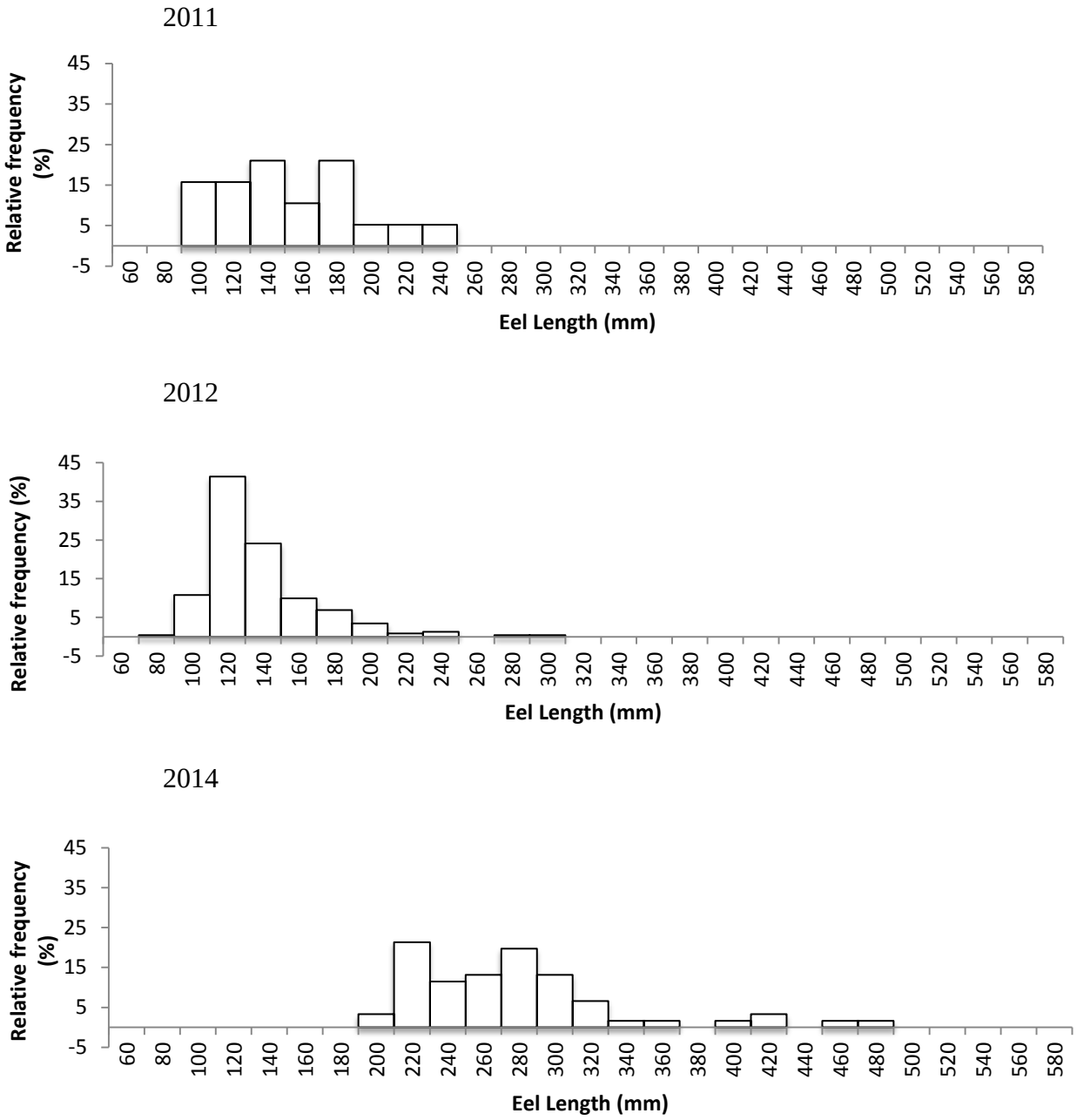

Figure 4. Relative length frequency (expressed as percentage) of eels captured during monitoring surveys in Pine Creek in 2011(n = 20), 2012 (n = 232), 2014 (n = 61).

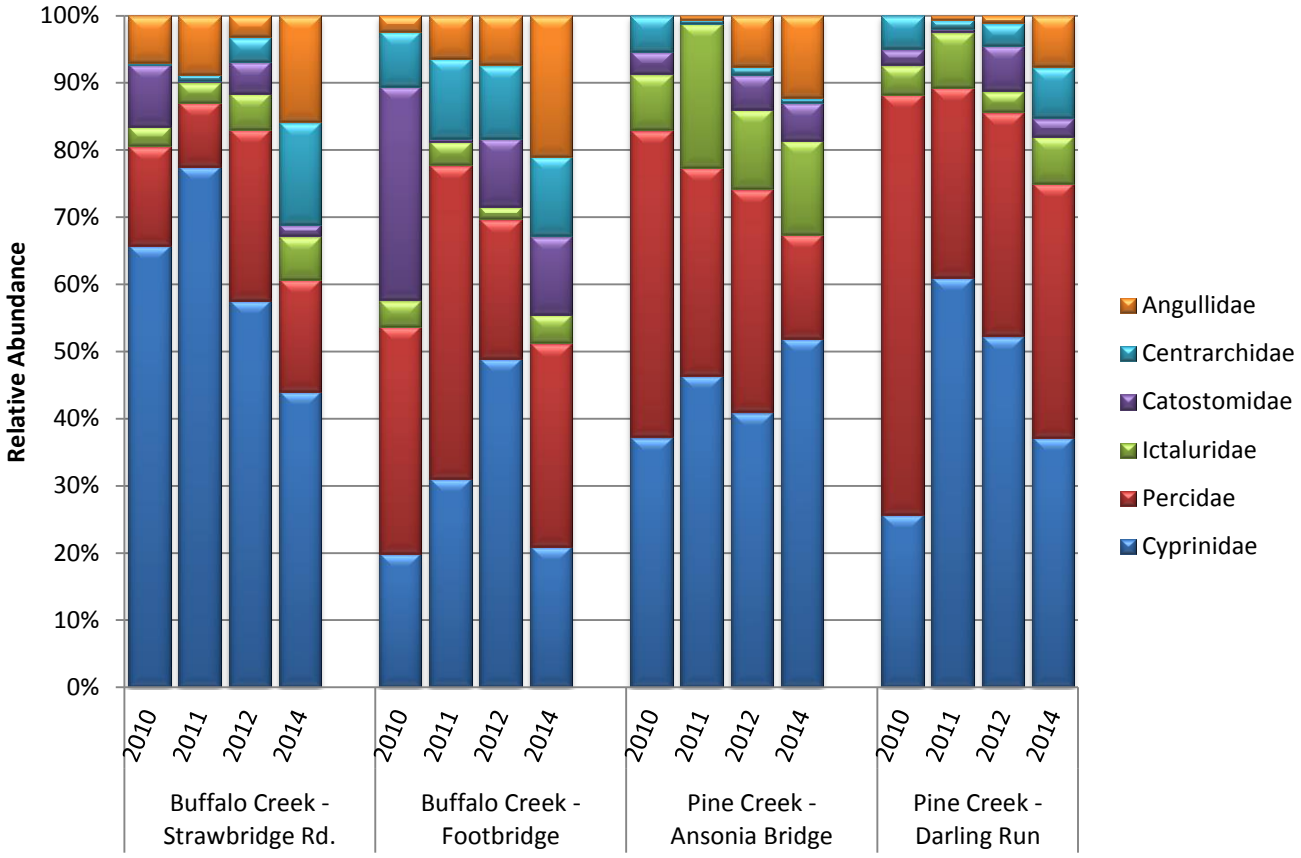

Figure 5. Relative abundance expressed as a percentage of 6 families of fish, Anguillidae (eels), Centrarchidae (sunfish and bass), Catastomidae (suckers), Ictaluridae (catfish and madtoms), Percidae (perch and darters), and Cyprinidae (minnows and shiners), caught in Buffalo and Pine Creeks during backpack electrofishing in July and August, 2010, 2011, 2012 and 2014.

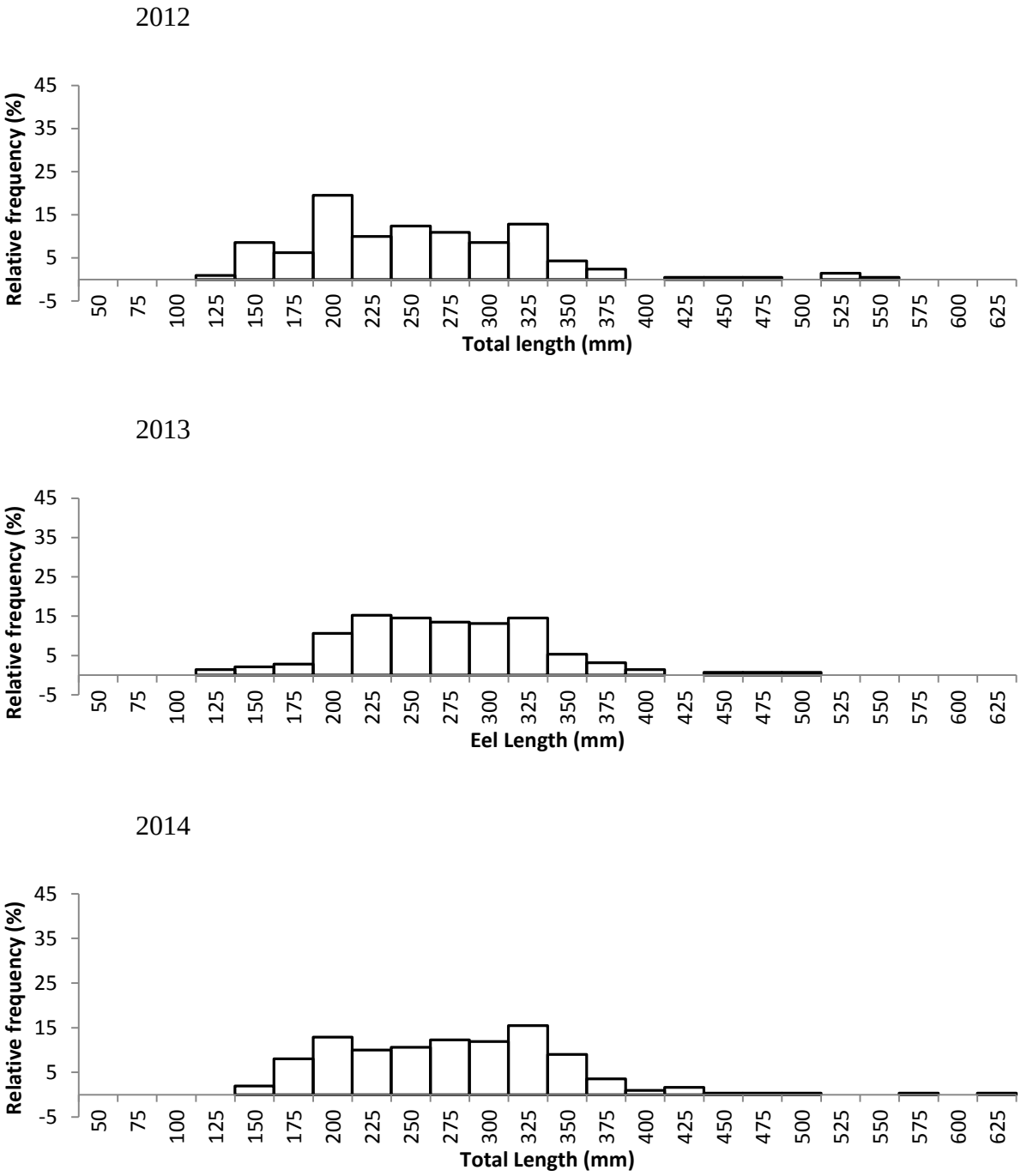

Figure 6. Relative length frequency (%) of eels captured during pit tagging study in Buffalo Creek in 2012 (n = 210), 2013 (n = 282), and 2014 (n = 410).

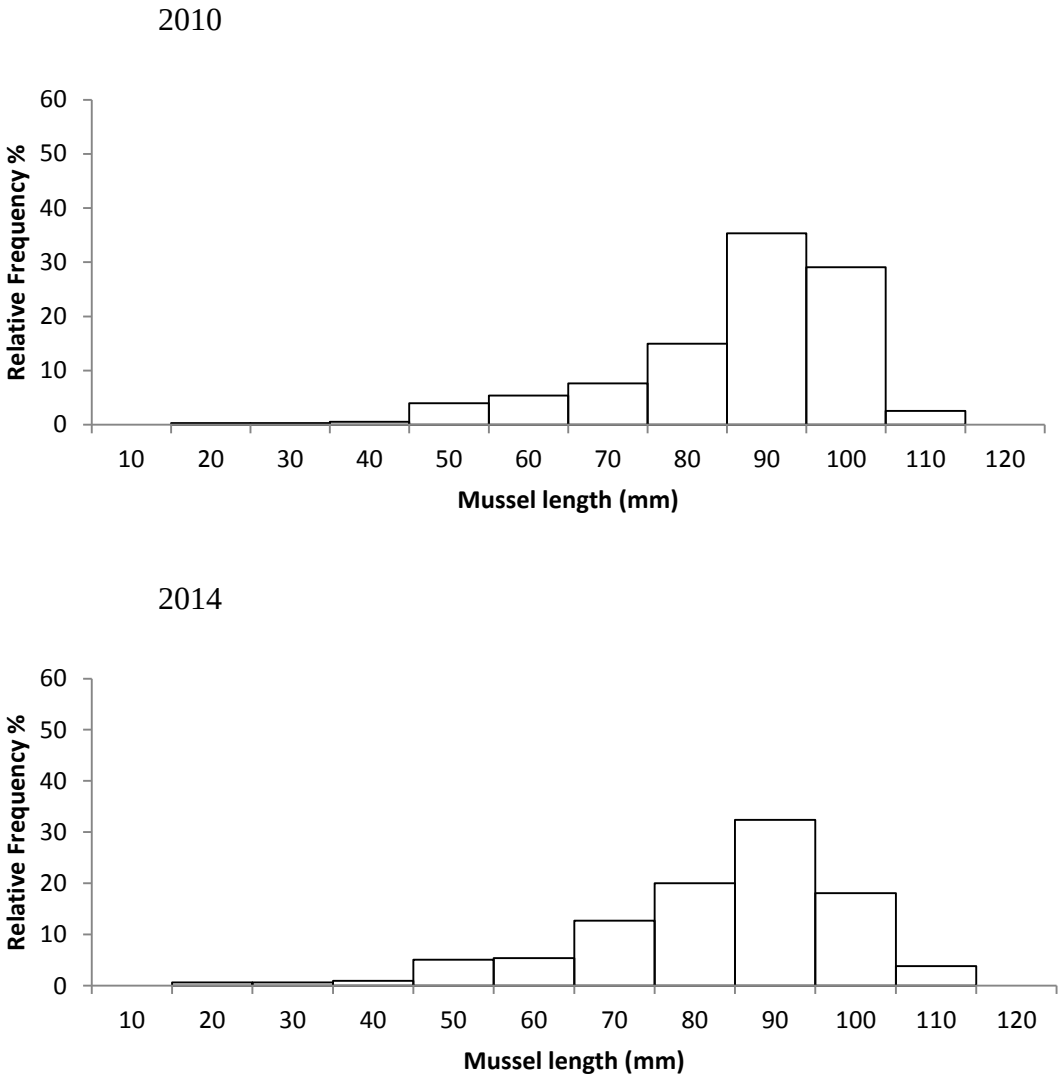

Figure 7. Relative length frequency (%) of mussels found during the quantitative survey in Buffalo Creek in 2010 (n = 354) and 2014 (n = 315)

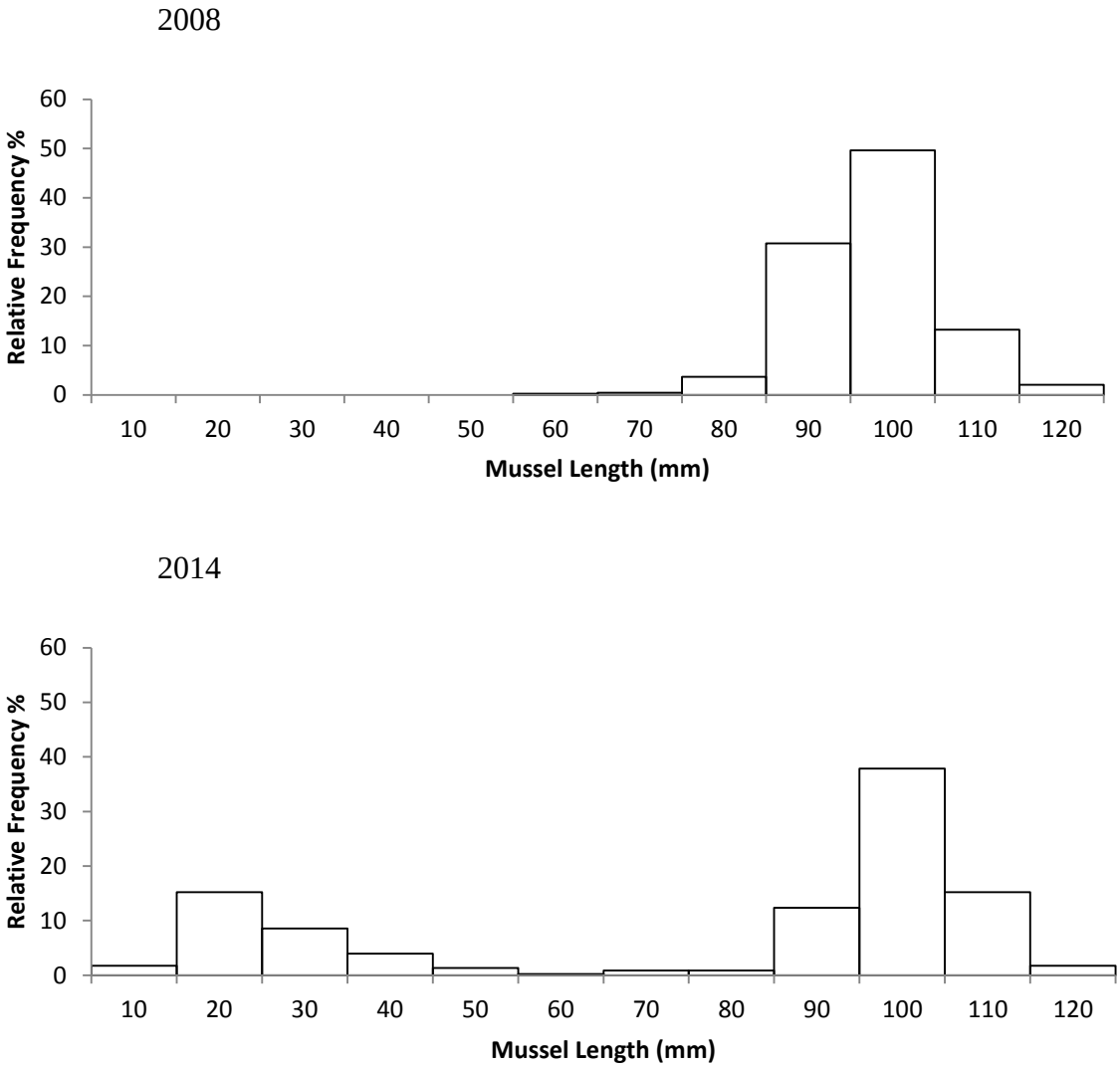

Figure 8. Relative length frequency (%) of mussels found during the quantitative survey in Pine Creek in 2010 (n = 439) and 2014 (n = 454)

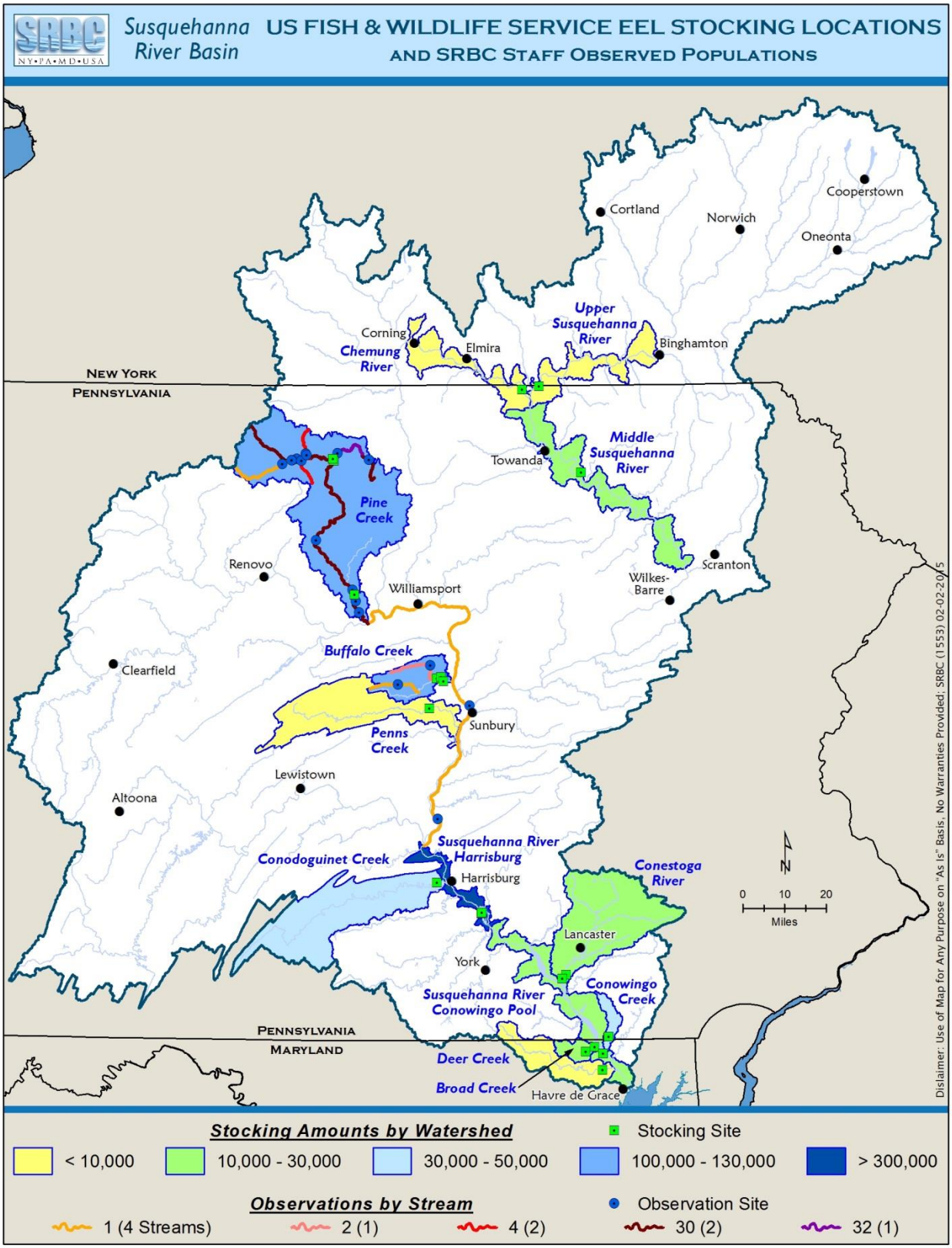

Figure 9. American eel stocking and recapture locations in the Susquehanna River Watershed from 2008 to 2014. Map courtesy of the Susquehanna River Basin Commission (Henning et al. 2015)

Appendix 1. CPUE (#/hour) of fish species captured in Buffalo Creek and Pine Creek during electrofishing surveys conducted in 2010, 2011, 2012, and 2014.

	Buffalo Creek								Pine Creek							
	Strawbridge Rd. bridge				Footbridge at Rt. 1003				Ansonia Bridge				Darling Run			
	2010	2011	2012	2014	2010	2011	2012	2014	2010	2011	2012	2014	2010	2011	2012	2014
American eel	33	73	15	15	8	10	19	26	0	2	31	`	0	2	4	8
Banded darter	9	26	34	3	13	9	12	7	44	39	63	5	29	27	19	7
Banded killifish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Blacknose dace	1	2	0	0	0	0	0	0	10	2	0	1	11	12	0	0
Bluegill	0	0	0	1	7	2	2	1	3	0	0	0	2	0	0	0
Bluntnose minnow	0	93	6	0	1	8	2	0	0	10	3	0	0	14	26	0
Brown trout	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Central Stoneroller	4	10	0	1	0	0	0	0	4	1	12	2	2	0	8	0
Chain Pickerel	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
Common carp	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
Common Shiner	0	6	0	0	1	0	0	0	0	4	10	0	0	3	0	0
Creek chub	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0
Creek chubsucker	0	0	0	0	2	0	0	0	0	0	0	4	0	0	0	0
Cutlips Minnow	1	10	8	4	11	16	6	4	2	18	27	14	15	33	31	18
Fallfish	8	9	21	1	6	9	12	6	19	59	16	0	5	23	21	0
Fantail darter	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0
Green sunfish	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Greenside darter	18	7	31	4	8	8	10	6	12	15	24	2	33	22	24	8
Largemouth bass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Longnose dace	9	8	19	9	0	1	3	0	15	2	7	0	0	6	0	0
Margined madtom	13	26	24	6	11	3	4	5	19	68	48	16	9	38	13	7
Mimic shiner	0	25	181	16	0	9	94	14	0	0	49	25	0	3	69	0
Mottled sculpin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern hogsucker	14	24	5	1	0	22	6	2	5	4	4	1	3	7	12	1
Pearl dace	0	0	0	8	0	0	0	1	0	0	0	12	0	0	0	1
Pumpkinseed	0	4	0	0	2	8	1	0	0	0	0	0	0	0	0	0

Redbreast sunfish	0	1	3	3	0	0	7	1	0	0	1	0	0	0	2	4
River chub	0	0	0	0	0	0	0	0	0	0	19	3	0	0	9	0
Rockbass	0	1	5	8	15	7	8	5	9	0	0	0	8	0	7	2
Rosyface shiner	0	18	20	4	0	0	5	0	8	50	22	1	14	176	41	19
Rosyside dace	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Shield darter	6	10	13	5	23	27	18	14	17	13	18	5	22	23	11	4
Shiner sp.	283	464	2	0	49	2	1	0	23	2	1	0	6	9	4	0
Shorthead redhorse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Smallmouth bass	1	2	6	3	5	2	11	7	0	1	4	0	0	6	4	2
Spotfin Shiner	0	1	3	0	1	1	5	0	0	0	0	0	0	0	0	0
Tessellated darter	36	36	35	7	74	30	14	16	30	32	31	8	44	58	80	29
White sucker	29	8	16	1	108	8	21	12	3	0	17	2	2	1	15	2
Yellow bullhead	0	0	0	1	2	2	1	0	0	0	0	0	0	0	0	0