BIOLOGICAL AND WATER QUALITY ASSESSMENT OF THE LOWER SUSQUEHANNA RIVER: NEW CUMBERLAND, PA (RM 69) TO CONOWINGO, MD (RM 10), JUNE TO AUGUST 2014

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Prepared by
Aaron Henning
Aquatic Biologist

Monitoring and Protection Program
Susquehanna River Basin Commission

INTRODUCTION

In 2014, the Susquehanna River Basin Commission (SRBC) completed a water quality and biological survey of the lower Susquehanna River from New Cumberland, Pa. (River Mile (RM) 69) to Conowingo, Md. (RM 10). The project was designed to further the understanding of this understudied portion of the Susquehanna River and supplement data collected as part of SRBC's Lower Susquehanna River Subbasin Year-2 Focused Watershed Study (Steffy, 2012). The 2012 SRBC pilot study focused on the lower 44 miles of the mainstem Susquehanna River, which is characterized by three large impoundments created by hydroelectric dams. The 2014 study included eight of the nine sites from the previous study and six additional sites between river miles 45 and 69. These additional sites bracket a fourth hydroelectric dam (York Haven) and represent a mix of true free-flowing and impounded conditions. In total, biological and water quality conditions at 14 sites on the lower 69 miles of the Susquehanna River were assessed from June through August 2014.

STUDY AREA DESCRIPTION

The lower section of the Susquehanna River consists of a variety of habitats and environmental conditions. This final 69 miles of river receives upstream inputs from over 27,000 square miles of various land uses and over 4 million residents from three states. The most upstream sampling transect was located at river mile 69, in vicinity of the town of New Cumberland, Pa. The most downstream sampling transect was located at RM 14, above Conowingo Dam, the largest dam on the mainstem river. A total of 14 sampling transects were positioned approximately every five miles from New Cumberland, Pa., to Conowingo, Md. The study area includes or is bracketed by one low-head dam, Dock Street Dam (RM 70) and four major hydroelectric dams: York Haven Dam (RM 55-57), Safe Harbor Dam (RM 33), Holtwood Dam (RM 25), and Conowingo Dam (RM 10). These dams exert varying levels of control over the natural flow regime of the river. Dock Street Dam is a low-head dam owned and maintained by the city of Harrisburg for recreational boating around the City Island Complex.

York Haven Dam

The York Haven Hydroelectric Project (RM 55-57) consists of a 20-unit powerhouse capable of producing 19.65 megawatts (MW) of electrical generation and a concrete-covered rock-fill dam extending 4,970 feet diagonally across the river. This run-of-river dam has a maximum height of 18 feet with an average of 10 feet and connects to Three Mile Island, creating an impoundment known as Lake Frederic. This project examined York Haven Dam's hydraulic control over the river flow and role in influencing water quality downstream.

The York Haven project is the smallest hydroelectric project in the study area in terms of power generation and overall dam height. York Haven Dam differs from Safe Harbor Dam, Holtwood Dam, and Conowingo Dam in that the project has a secondary dam, the East Channel Dam, through which a variable minimum flow is required to pass. The 928-ft. East Channel Dam is located two miles upstream of the York Haven Dam's powerhouse and connects the east shore of Three Mile Island with the eastern (Lancaster County) bank of the river. The main structure of York Haven Dam extends 4,970 feet from the western (York County) bank of the river to the west shore of Three Mile Island (YHPC, 2011).

The York Haven project has a hydraulic capacity of 17,000 cubic feet per second (cfs) through the powerhouse turbines. When flows are in excess of 17,000 cfs at the station, spill occurs over the dam. The persistent flow through the East Channel Dam maintains the integrity of the water quality signal along the left bank. The limited hydraulic control the project can exert at flows exceeding 17,000 cfs, coupled with the presence and minimum flow requirements of the East Channel Dam, appear to preserve the separate water quality influences observed in this study. Three Mile Island Nuclear Generating Station, a 852-MW nuclear power plant, lies in the impoundment created behind York Haven Dam. The East Channel Dam, an extension of York Haven Dam, connects the eastern edge of Three Mile Island with the eastern bank of the river. Approximately one mile downstream on the western bank (RM 54) lies the Brunner Island Steam Electric Station, a 1,567-MW coal-fired electrical generating station.

Safe Harbor Dam

Safe Harbor Dam (RM 32) is a 4,869-ft. long, 75-ft. high hydroelectric facility capable of generating 417 MW of electricity. Safe Harbor Dam creates an 11-mile long impoundment on the river extending upstream to Wrightsville, Pa., known as Lake Clarke.

Holtwood Dam

Holtwood Dam (RM 24) consists of a 55-ft. tall, 2,392-ft. long dam, and creates the eight-mile-long impoundment known locally as Lake Aldred. Holtwood Dam has recently undergone a major expansion project to increase overall electrical generating capacity to 234 MW.

Conowingo Dam

Positioned just north of Havre de Grace, Md., Conowingo Hydroelectric Station (RM 10) is the largest and most downstream dam on the mainstem Susquehanna River. Conowingo stands 94 ft. tall and extends 1,190 feet across the river and is capable of generating 573 MW of electricity. Extending 14 miles upriver and covering a surface area of 9,000 acres, the station forms Conowingo Pond, the largest of the four impoundments on the lower river.

Located directly adjacent to Conowingo Pond are two additional power-generating facilities. The Muddy Run Pumped Storage facility (RM 22) is a 1,070-MW pumped storage project which utilizes river water to fill and drain the 100-acre Muddy Run Recreation Reservoir. Peach Bottom Atomic Power Station (RM 18) is located on the western bank of the river just inside the Pennsylvania border. The station is capable of generating 1,140 MW of power and relies upon the river for cooling water.

Study Design

Figure 1 is a map of the study area in the Basin. This study and the design were influenced by the previous SRBC Lower Susquehanna River Subbasin Year-2 Focused Watershed Study (Steffy, 2012). Eight sites from that study (Table 1) were included in the 2014 study, and comparable methods were also used for collecting fish, water quality, and macroinvertebrate samples. Central to the study design is the use of three monitoring locations across a transect, denoted as A, B, and C, corresponding to the right descending bank, mid-channel, and left descending bank, respectively. Recent studies conducted on the mainstem Susquehanna River between Sunbury, Pa. (confluence with the West Branch Susquehanna River) and Duncannon, Pa. (confluence with the Juniata River) have identified varying water quality characteristics across the river channel (PADEP, 2013; PADEP, 2014).

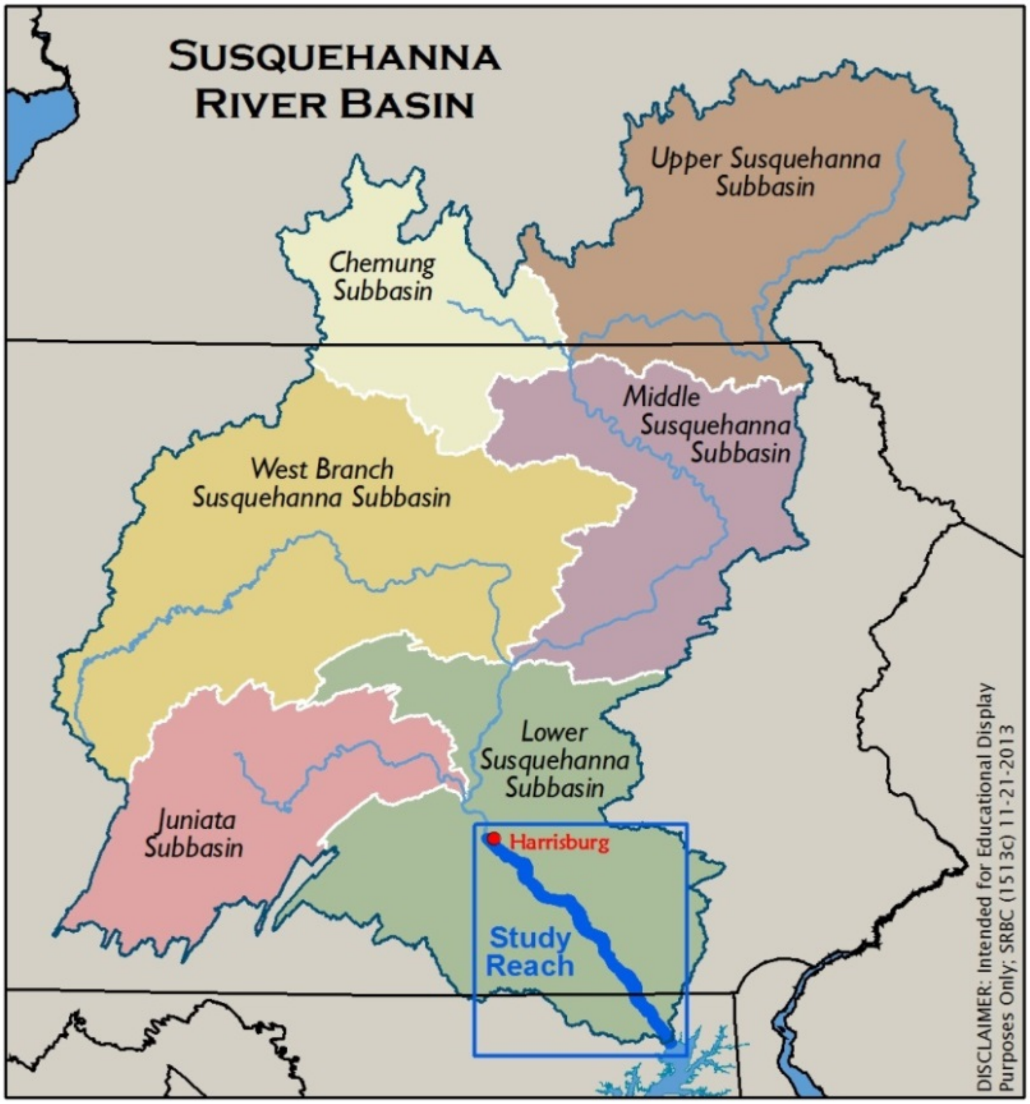

Figure 1. Map of Study Area within Susquehanna River Basin

Table 1. Sampling Sites by River Mile

River Mile	Transect Description	Latitude	Longitude	2012 site	Flow Condition
69	Redbuds Island, upstream of Steelton, Pa.	40.239117°	-76.867379°		Free-Flowing
65	Turnpike Bridge, Highspire, Pa.	40.204377°	-76.806124°		Free-Flowing
61	Poplar Island, Royalton, Pa.	40.178451°	-76.736614°		Free-Flowing
58	South end of Shelley Island, Falmouth, Pa.	40.134320°	-76.732187°		Impounded
53	Bainbridge, Pa.	40.086100°	-76.674600°		Free-Flowing
47	North Accomac, Wrightsville, Pa.	40.050150°	-76.574510°		Free-Flowing
44	Old bridge piers, Columbia, Pa.	40.028887°	-76.518915°	X	Free-Flowing
38	South end of island complex upstream of Turkey Hill, Washington Boro, Pa.	39.970419°	-76.471952°	X	Impounded
34	South Highville, Township of Manor, York Haven, Pa.	39.928689°	-76.416890°	X	Impounded
30	South end of Weise Island, Pequea, Pa.	39.886788°	-76.374618°	X	Impounded
26	South of the pinnacle, dam warning sign, Holtwood, Pa.	39.838423°	-76.347629°	X	Impounded
22	North end of Hennery Island, Drumore, Pa.	39.799696°	-76.295614°	X	Impounded
18	Downstream of Peach Bottom Atomic discharge, Peach Bottom, Pa.	39.749617°	-76.245526°	X	Impounded
14	Downstream of mouth of Broad Creek, Darlington, Md.	39.695515°	-76.221853°	X	Impounded

Figure 2. Detailed Map of Study Area Including Major Dams

METHODS

Water Quality

Water samples were collected using a 1-liter VanDorn sampler at three locations (left bank, right bank, and mid-channel) across each transect. Approximately four liters of water were collected at each transect location from throughout the water column and composited into a churn splitter. Each sampling location along the transect was treated as a distinct water quality monitoring site where in-situ field chemistry parameters were also monitored using a YSI 6820 multi-parameter meter. Discrete water quality conditions were assessed twice during this project (June and August 2014).

Continuous instream monitoring of water quality conditions was also performed at 4 sites (SUSQ 69, SUSQ 65, SUSQ 58, and SUSQ 53) during July and August 2014. Sites SUSQ 69 and SUSQ 65 were chosen for continuous monitoring based on results of prior studies performed by PADEP (PADEP, 2013a; PADEP, 2014) which documented differing water quality conditions across the river immediately upstream of the study area. SUSQ 58 and SUSQ 53 were chosen as exploratory sites to examine what, if any, influence the York Haven Hydroelectric facility had on this phenomenon. Three YSI 6600 multi-parameter data sondes were deployed across the site transect at left bank, right bank, and mid-channel locations. The data sondes recorded temperature, pH, specific conductivity, dissolved oxygen, and turbidity readings every 15 minutes for a period of two weeks at each location. Data sondes were placed in a protective, flow-through PVC housing, anchored to the river bed, and marked with a floating buoy. See Table 2 for list of site locations and descriptions of monitoring sites.

Table 2. Site Locations and Descriptions of Monitoring Sites

Site	Site Description	Latitude	Longitude	Site	Site Description	Latitude	Longitude
SUSQ 69A	RDB New Cumberland	40.2387	-76.8714	SUSQ 38A	RDB middle Lake Clarke	39.9631	-76.4864
SUSQ 69B	MID New Cumberland	40.2416	-76.8696	SUSQ 38B	MID middle Lake Clarke	39.9669	-76.4719
SUSQ 69C	LDB New Cumberland	40.2440	-76.8669	SUSQ 38C	LDB middle Lake Clarke	39.9700	-76.4597
SUSQ 65A	RDB Turnpike Bridge	40.2009	-76.8024	SUSQ 34A	RDB lower Lake Clarke	39.9253	-76.4206
SUSQ 65B	MID Turnpike bridge	40.2040	-76.8001	SUSQ 34B	MID lower Lake Clake	39.9289	-76.4169
SUSQ 65C	LDB Turnpike bridge	40.2076	-76.7998	SUSQ 34C	LDB lower Lake Clarke	39.9319	-76.4136
SUSQ 61A	RDB Swatara mouth	40.1782	-76.7458	SUSQ 30A	RDB upper Lake Aldred	39.8889	-76.3794
SUSQ 61B	MID Swatara mouth	40.1811	-76.7390	SUSQ 30B	MID upper Lake Aldred	39.8894	-76.3736
SUSQ 61C	LDB Swatara mouth	40.1831	-76.7324	SUSQ 30C	LDB upper Lake Aldred	39.8900	-76.3669
SUSQ 58A	RDB Three Mile Island	40.1331	-76.7377	SUSQ 26A	RDB lower Lake Aldred	39.8392	-76.3506
SUSQ 58B	MID Three Mile Island	40.1435	-76.7295	SUSQ 26B	MID lower Lake Aldred	39.8403	-76.3483
SUSQ 58C	LDB Three Mile Island	40.1649	-76.7243	SUSQ 26C	LDB lower Lake Aldred	39.8414	-76.3461
SUSQ 53A	RDB Bainbridge	40.0831	-76.6780	SUSQ 22A	RDB upper Conowingo Pond	39.7947	-76.3014
SUSQ 53B	MID Bainbridge	40.0861	-76.6746	SUSQ 22B	MID upper Conowingo Pond	39.7978	-76.2953
SUSQ 53C	LDB Bainbridge	40.0897	-76.6720	SUSQ 22C	LDB upper Conowingo Pond	39.8006	-76.2900
SUSQ 47A	RDB Accomac	40.0520	-76.5962	SUSQ 18A	RDB middle Conowingo Pond	39.7500	-76.2560
SUSQ 47B	MID Accomac	40.0538	-76.5948	SUSQ 18B	MID middle Cononwingo Pond	39.7540	-76.2470
SUSQ 47C	LDB Accomac	40.0559	-76.5943	SUSQ 18C	LDB middle Conowingo Pond	39.7590	-76.2360
SUSQ 44A	RDB upper Lake Clarke	40.0283	-76.5264	SUSQ 14A	RDB lower Conowingo Pond	39.6940	-76.2280
SUSQ 44B	MID upper Lake Clarke	40.0306	-76.5192	SUSQ 14B	MID lower Conowingo Pond	39.6970	-76.2200
SUSQ 44C	LDB upper Lake Clarke	40.0314	-76.5103	SUSQ 14C	LDB lower Conowingo Pond	39.7010	-76.2120

RDB = right descending bank, MID = mid-channel, LDB = left descending bank.

Macroinvertebrates

Macroinvertebrate assessment methods were adapted from protocols of the Ohio River Valley Water Sanitation Commission (ORSANCO, 2010) and Pennsylvania Department of Environmental Protection (PADEP, 2013b). Macroinvertebrate sampling was comprised of two separate methods of sampling based upon site characteristics. Macroinvertebrate samples were collected at each sampling transect, utilizing the method most appropriate for the flow condition (impounded or free-flowing). Transects determined to be impounded were sampled using a Hester-Dendy artificial substrate sampler, while free-flowing transects were sampled using a 500-micron D-frame net. At free-flowing transects, a sample consisted of a composite of six one-minute kicks disturbing an area equal to one-square-meter upstream of the net per kick. Kicks were performed at riffle-run locations when available or when absent, at representative habitats across the river channel transect. At impounded transects, a Hester-Dendy artificial substrate sampler was deployed in water approximately four feet deep along the shoreline at each of the eight impounded water quality sampling transects (Table 1) and allowed to colonize for at least six weeks.

The D-frame sampling was performed during the same timeframe as the Hester-Dendy retrieval and both types of samples were processed in the same way, utilizing a 200-individual subsample. In addition, at one transect, two Hester-Dendy samplers were paired and similarly composited to constitute a duplicate sample. One duplicate D-frame sample was collected at a randomly determined free-flowing transect.

Fish

Fish samples were collected by boat electrofishing a 500-meter reach of shoreline at each sampling site. Reaches were delineated prior to sampling to identify areas of adequate depth and suitable fish habitat. A single electrofishing pass was performed over the 500-meter reach while expending 2000-2500 seconds of shock time. Fish were collected in an upstream to downstream manner typically within 15 meters of shore, traveling with or slightly faster than the prevailing river current. Two netters captured all fish sighted from the bow of the boat using 8-ft. fiberglass handled nets with 1/4”-mesh openings. All game fish captured were weighed and measured and any incidence of disease, fin erosion, deformity, or tumor (DELTs) was noted. Fish unable to be positively identified in the field were preserved in 10 percent formaldehyde and later identified in the laboratory by a trained taxonomist.

RESULTS

General Water Quality

Previous studies reporting on the water quality conditions of the Susquehanna River have shown variable results dependent on a sample's position along a transect perpendicular to flow. In 2012, SRBC documented homogenous water quality conditions throughout the impounded, lower 40 miles of the river (Steffy, 2013). The Pennsylvania Department of Environmental Protection (PADEP) reported varying water quality conditions across the river at the Harrisburg sampling transect, approximately RM 80 (PADEP, 2013a).

In this study, three distinct water quality signals were consistently observed between Columbia, Pa. (RM 44) and the most upstream site at New Cumberland, Pa. (RM 69), corresponding to left bank, mid-channel, and right bank influences. These differences were apparent in both discrete water quality sampling results as well as continuous instream monitoring measurements. These water quality signals are presumed to represent the influences of the three major tributaries: the Juniata River, the West Branch Susquehanna River, and the North Branch of the Susquehanna River (mainstem). Water originating from the Upper and Chemung subbasins follows the North Branch until converging with the West Branch of the Susquehanna River entering from the northwest at Sunbury, Pa. From Sunbury, the river flows south until Duncannon, Pa., where the Juniata River enters along the western bank. The inflow from the Juniata River seems to hold along the western bank, shifting the West Branch inflow to a mid-channel position. The North Branch influence appears to maintain positing along the eastern shore until a complete mixing occurs in Lake Clarke, just south of Columbia, Pa.

Downstream of the confluence with the Juniata until the vicinity of Columbia, Pa. (RM 44), the mainstem Susquehanna exhibits horizontal stratification of water quality from the major tributaries. Within this section of the river and concordantly throughout this report, the water quality along the right bank (‘A’ or ‘RDB’ position) is driven mainly by the Juniata River, the mid-channel (‘B’ or ‘MID’ position) by the West Branch Susquehanna River, and left bank (‘C’ or ‘LDB’ position) from the North Branch of the Susquehanna River.

Field and Laboratory Water Quality Results

Two rounds of water quality sampling were attempted during 2014. High flows and unsafe conditions were encountered in June, limiting the number of samples collected. Between August 18, 2014, and August 26, 2014, flows were manageable, all monitoring sites were visited, and water samples were collected and analyzed for numerous chemical constituents.

Results varied considerably and were dependent upon the position along the transect from which the sample was taken as well as the monitoring point along the river. Samples collected from sites designated as free-flowing showed considerably greater variation across the transect than those designated as impounded. In general, the water quality of the impounded sites was nearly identical across the sampling transect. Those samples collected from the free-flowing sites typically exhibited characteristics more similar to their corresponding transect position (A, B, or C) either upstream or downstream than adjacent points along the same transect. The horizontal stratification of water quality signals was exhibited from RM 69 to RM 44. The RM 44 sampling transect represents a transitional position along the river at which a more thorough mixing of the water stratification begins to occur.

Among free-flowing sites where the horizontal separation was observed (RM 69 through RM 47), greater chemical similarity was noted between the B (MID) and A (RDB) samples than between B (MID) and C (LDB) or between C (LDB) and A (RDB) (Table 3, Figures 3 and 4).

Within this portion of the study area, samples collected along the A (RDB) transect position on average exhibited higher concentrations of nutrients as measured by total nitrogen and total organic carbon (Table 3, Figures 3a and 3b). Samples collected along the C (LDB) transect typically contained the highest concentrations of bromide, chloride, total suspended, and total dissolved solids.

As in the 2012 study, nutrients were the principal water quality concern encountered in this study. Of the 42 samples drawn from the river, 26 contained nitrate concentration in excess of 0.6 mg/L, generally accepted as the natural ‘background level’ (USGS, 1999). Additionally, 13 of 14 samples from the A (RDB) transects possessed nitrate concentrations in excess of 0.6 mg/L, suggesting increased nutrient loading from the Juniata River. Along the B (MID) and C (LDB) transects, nitrate concentrations increased as sampling proceeded downriver, whereas along the A (RDB) transect, nitrate concentrations decreased. This observation supports the homogenization of water quality from three separate influences to one as the river becomes impounded.

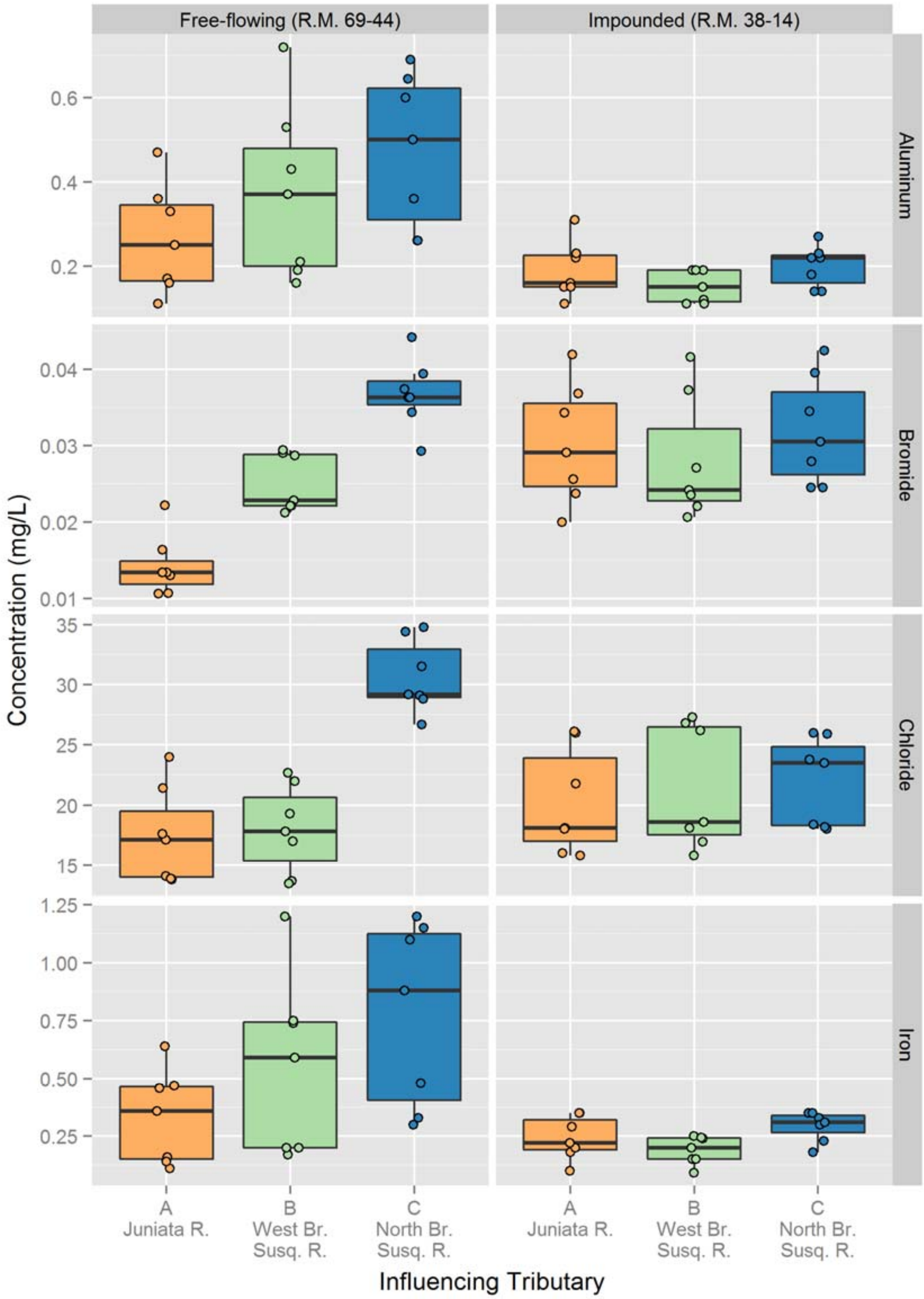

Figure 3a. Box Plots of Water Quality Parameters Sampled by Transect Categorized by River Mile

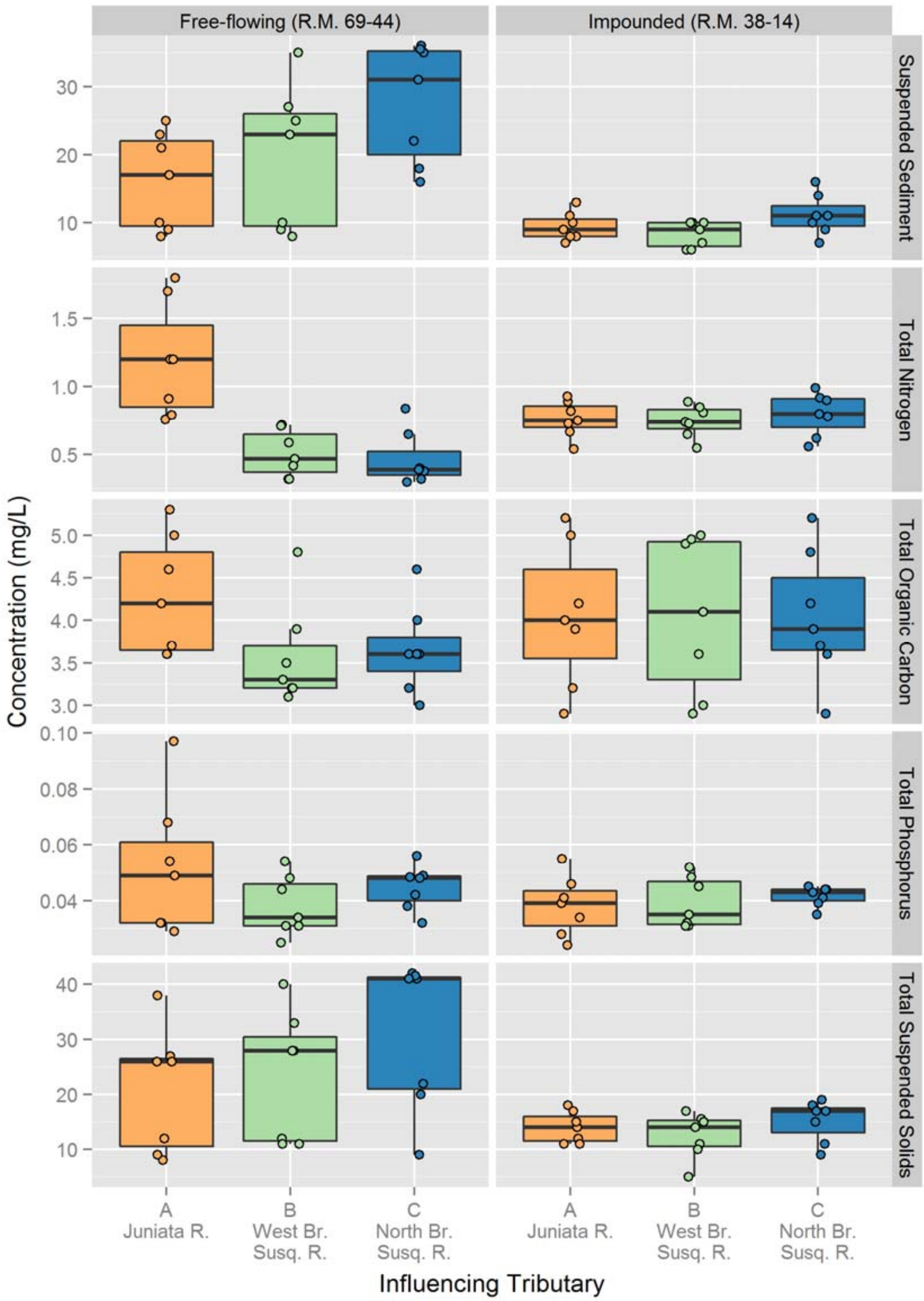

Figure 3b. Box Plots of Water Quality Parameters Sampled by Transect Categorized by River Mile

Table 3. Average Concentrations of Measured Water Quality Parameters by Transect Position

	Transect Position	Orthophosphate (mg/L)	Alkalinity (mg/L)	Biochemical Oxygen Demand (mg/L)	Total Nitrogen (mg/L)	Nitrite-N (mg/L)	Nitrate-N (mg/L)
River mile 69 - 44	A (RDB)	0.02	67.86	2.29	1.19	0.10	1.09
	B (MID)	0.02	50.00	2.19	0.51	0.10	0.41
	C (LDB)	0.02	64.57	2.41	0.47	0.10	0.37
River mile 38 - 14	A (RDB)	0.02	62.57	3.24	0.76	0.10	0.66
	B (MID)	0.02	62.57	2.61	0.75	0.10	0.65
	C (LDB)	0.02	65.57	2.38	0.80	0.10	0.70

	Transect Position	Sulfate (mg/L)	Total Suspended Solids (mg/L)	Total Organic Carbon (mg/L)	Bromide (ug/L)	Total Dissolved Solids (mg/L)	Ammonia-N (mg/L)
River mile 69 - 44	A (RDB)	27.13	20.86	4.29	14.24	145.00	0.02
	B (MID)	37.34	23.29	3.57	25.04	152.57	0.01
	C (LDB)	37.01	30.93	3.66	36.75	156.79	0.03
River mile 38 - 14	A (RDB)	33.00	14.00	4.06	30.20	168.29	0.04
	B (MID)	32.67	12.50	4.06	28.05	150.07	0.03
	C (LDB)	33.43	15.14	4.04	31.97	180.57	0.05

	Transect Position	Chloride (mg/L)	Phosphorus (mg/L)	Aluminum (mg/L)	Iron (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Suspended Sediment (mg/L)
River mile 69 - 44	A (RDB)	17.41	0.05	0.26	0.33	1.04	16.14
	B (MID)	18.00	0.04	0.37	0.55	1.03	19.57
	C (LDB)	30.64	0.04	0.47	0.78	1.21	27.64
River mile 38 - 14	A (RDB)	20.26	0.04	0.19	0.24	1.00	9.43
	B (MID)	21.39	0.04	0.15	0.19	1.02	8.29
	C (LDB)	21.97	0.04	0.20	0.29	1.03	11.14

Continuous Instream Monitoring

Results of continuous instream monitoring provided useful data to supplement discrete water quality samples. Continuous instream water quality monitoring data sondes were deployed at four sampling transects between June 26, 2014 and August 21, 2014 (Table 4 and Figure 4). Data sondes recorded water temperature, pH, dissolved oxygen, specific conductance, turbidity, and depth every 15 minutes for a period of two weeks at four transect locations. Over 13,000 observations were made throughout the course of the monitoring, yielding over 53,000 individual data points comprised of pH, conductivity, turbidity, dissolved oxygen, and temperature. The data sonde deployed at site 58C was unable to be recovered, providing no data. Sonde 54 deployed at SUSQ 69C experienced an internal programming error and stopped logging data on June 30, 2014 at 09:15.

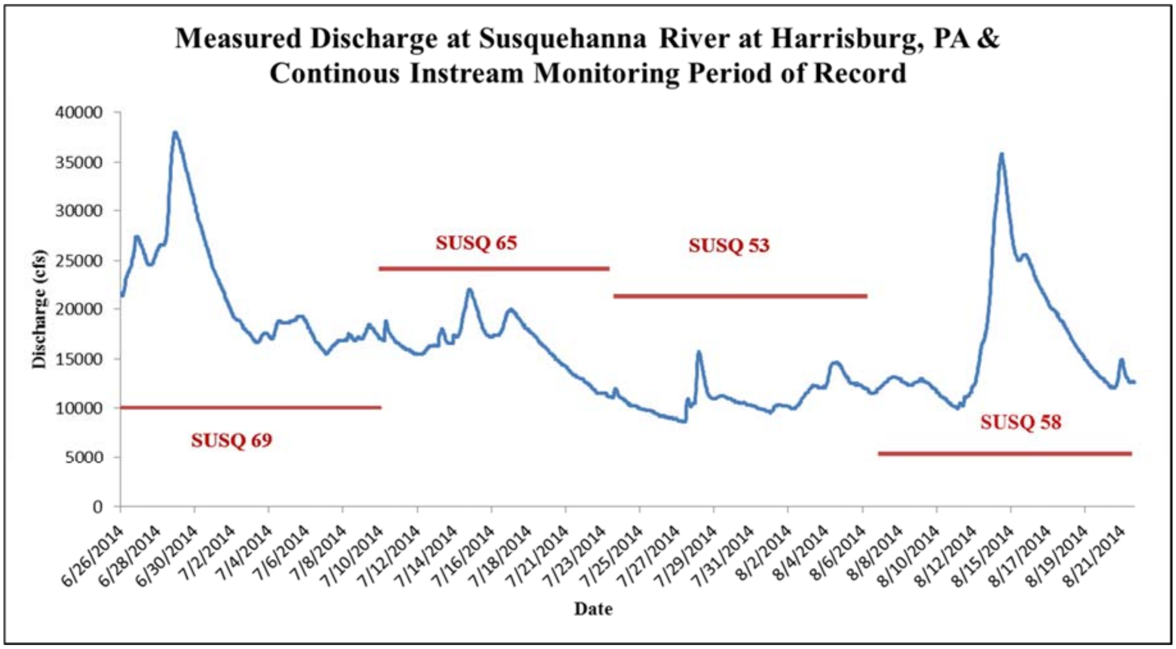

Figure 4. ***Measured Discharge at Susquehanna River at Harrisburg, Pa., Through Project Monitoring Period, June – September 2014 (The blue line denotes river discharge (cfs) and the red line denotes the period of time when instream monitors were deployed at the site.)***

Pennsylvania's accepted water quality standard for pH is a range of 6.0 – 9.0 standard units. A total of 13,533 pH observations were recorded with 107 (0.7 percent) of the observations exceeding 9.0 and zero observations falling below 6.0. Violations for pH occurred at two monitoring transects, SUSQ 58 and SUSQ 65. The sonde positioned at SUSQ 58B made 15 observations in excess of 9.0 on 8/19/14 between 15:45 and 19:30. Excessive pH values were more commonly encountered along the A (RDB) transects. Seventy-two observations (5.5 percent) at SUSQ 65A were made over three consecutive days (July 18-20, 2014) where pH exceeded 9.0. These elevated values were documented between 11:30 and 18:30 on July 18, between 10:45 and 17:00 on July 19 and from 10:15 to 13:00 on July 20. An additional 20 readings (1.5 percent) exceeding the standard were noted on July 12, 2014 between the hours of 16:15 and 21:15. These results support observations made by PADEP indicating an elevated pH contribution stemming from the Juniata River (PADEP, 2014).

The variable and flashy discharge of the river throughout the course of the study impacted results. Measured discharge during the study period was above the median average daily flow almost every day (Figure 5). The scheduled June water quality sampling event was not completed due to atypically high flows and adverse weather conditions. The high flow events increased turbidity to 25-30 NTUs, which decreased water column visibility to < 0.5 meters as measured by a secchi disc.

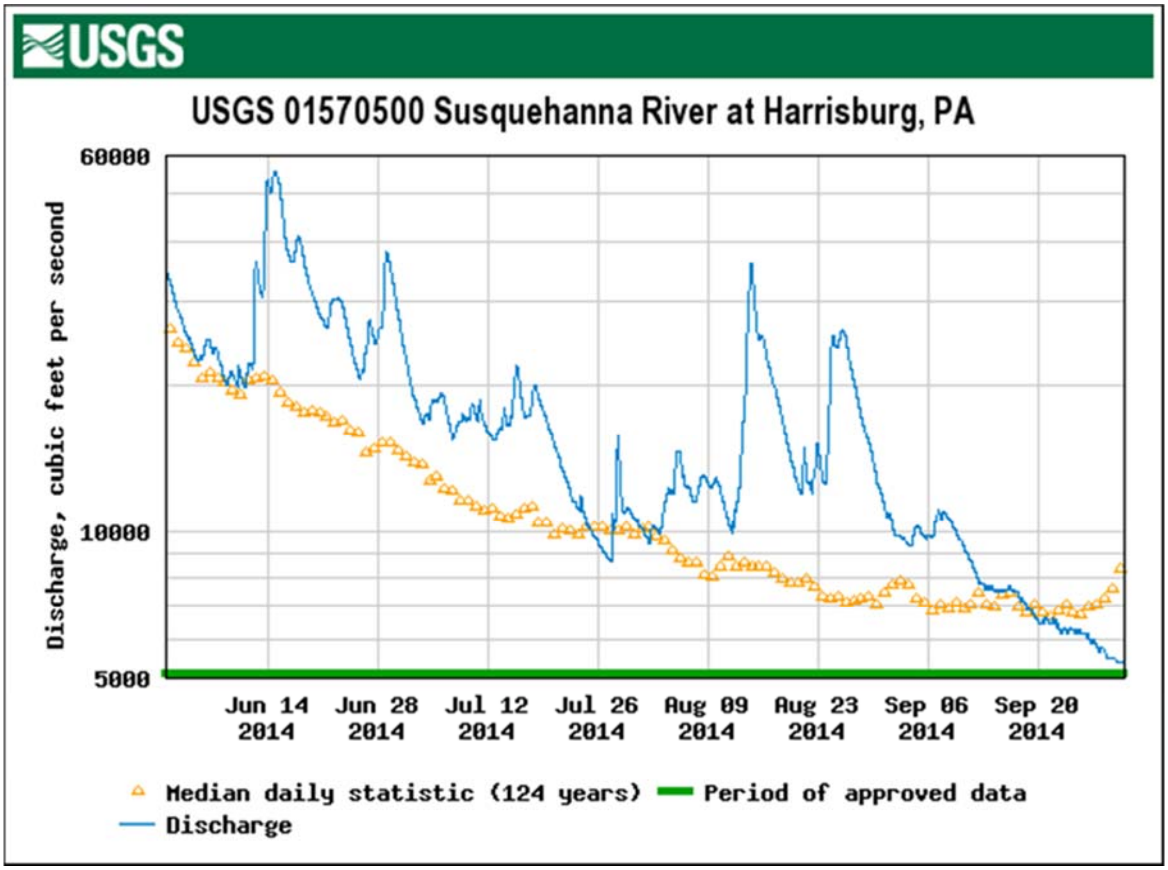

Figure 5. Measured Discharge at USGS Harrisburg Gage (RM 71) during Sampling Period

Table 4. Date, Time, and Locality of Continuous Instream Water Quality Monitoring Sondes

Site	Position	Sonde	Date Set	Time Set	Date Retrieved	Time Retrieved	Observations
SUSQ 69A	RDB	3	6/26/2014	14:15	7/10/2014	8:15	1337
SUSQ 69B	MID	2	6/26/2014	14:30	7/10/2014	8:30	1335
SUSQ 69C	LDB	54	6/26/2014	15:15	7/10/2014	9:00	360*
SUSQ 65A	RDB	3	7/10/2014	14:00	7/24/2014	7:45	1315
SUSQ 65B	MID	2	7/10/2014	14:00	7/24/2014	8:00	1321
SUSQ 65C	LDB	T2	7/10/2014	14:15	7/24/2014	9:15	1325
SUSQ 53A	RDB	30	7/24/2014	14:00	8/7/2014	9:15	1327
SUSQ 53B	MID	2	7/24/2014	14:15	8/7/2014	9:30	1326
SUSQ 53C	LDB	T2	7/24/2014	14:30	8/7/2014	10:45	1329
SUSQ 58A	RDB	D-04	8/7/2014	13:30	8/21/2014	8:00	1323
SUSQ 58B	MID	D-10	8/7/2014	13:45	8/21/2014	7:45	1320
SUSQ 58C	LDB	9	8/7/2014	14:00	N/A	N/A	N/A

Fish

A total of 38 unique fish species representing seven families were encountered during sampling. All 14 sites were sampled between August 18 and August 26, 2014, registering a total shock time of 6.93 hours or approximately 30 minutes per site. Gizzard shad *(Dorosoma cepedianum)* were frequently encountered in large numbers in the impounded portions of the river but became increasingly scarce upstream of RM 38. Gizzard shad were encountered in excess of 1,000 per site throughout Conowingo Pond and Lake Aldred. Abundance decreased slightly, but gizzard shad were encountered frequently in Lake Clarke. Gizzard shad were not included in analysis of fish data as they represented an irruptive species. Irruptive species are those found locally abundant or in ‘patches’ and can skew calculations of relative abundance within a reach (USEPA, 2013). Catch per unit effort (CPUE), excluding gizzard shad, varied by site and generally decreased as sampling progressed downriver (Figure 6). When sites were classified by flow condition (free-flowing or impounded), the CPUE for impounded sites was different from CPUE of free-flowing sites but within one standard deviation (S.D. 372). On average, the six sites considered free-flowing yielded a CPUE of 756 fish/hour compared to eight impounded sites where overall CPUE was 468 fish/hour.

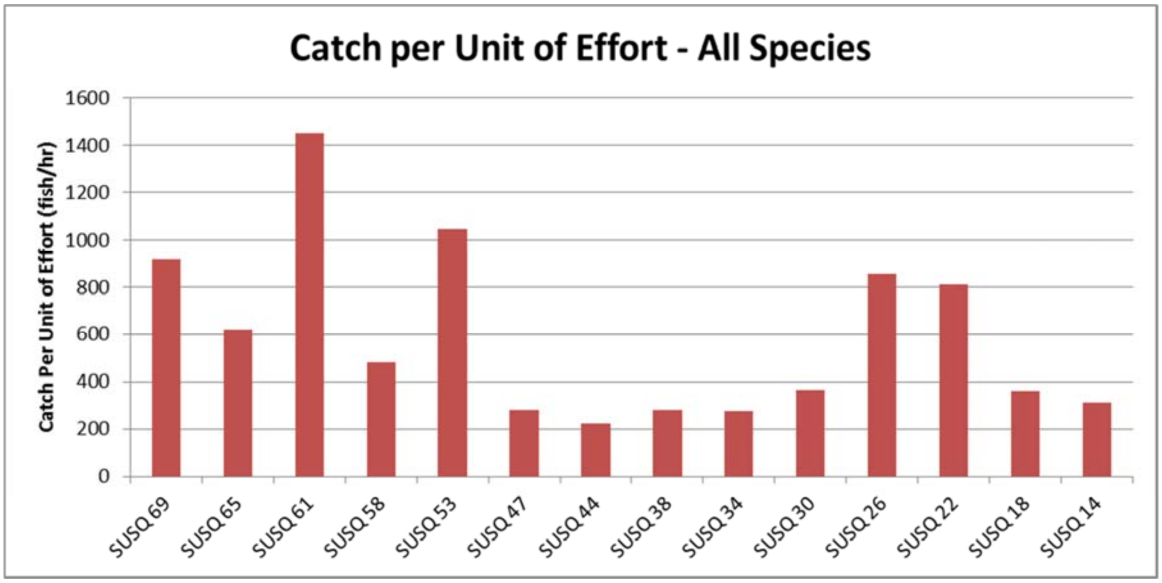

Figure 6. Overall Catch per Unit of Effort (Fish/hour) by Site, Excluding Gizzard Shad

Nonmetric multidimensional scaling (NMDS) analysis of fish communities was applied to allow for visual comparison of similarity of samples (Figure 7). NMDS utilizes the Bray-Curtis similarity index to compare common taxa and their relative abundance amongst samples (SIMPER, Field, 1982; Clarke, 1993). Fish samples from sites described as free-flowing were significantly different from impounded sites (ANOSIM, $p = 0.04$). Free-flowing sites showed 36.91 percent similarity between fish communities while impounded sites possessed 36.79 percent similarity. Overall average dissimilarity between free-flowing and impounded sites was 70.22 percent. Thirty-three percent of the cumulative dissimilarity in fish communities between site classifications is explained by the mimic (*Notropis volucellus)* and comely shiners (*Notropis amoenus)* (SIMPER). Comely shiners, a native minnow species preferring large water, were more common in the impounded sites while mimic shiners, a recently introduced non-native minnow, were more common at free-flowing sites. Sites SUSQ 44 and SUSQ 58 had fish communities more closely resembling impounded and free-flowing sites, respectively, despite their contradicting a priori designations. SUSQ 58, located in the impoundment behind York Haven Dam, possessed a fish community more similar to sites immediately upstream and downstream than those located in other impoundments. Additionally, the fish community of SUSQ 44 bore greater resemblance to the adjacent sites SUSQ 38 (impounded) and SUSQ 47 (free-flowing) than other true free-flowing or impounded sites.

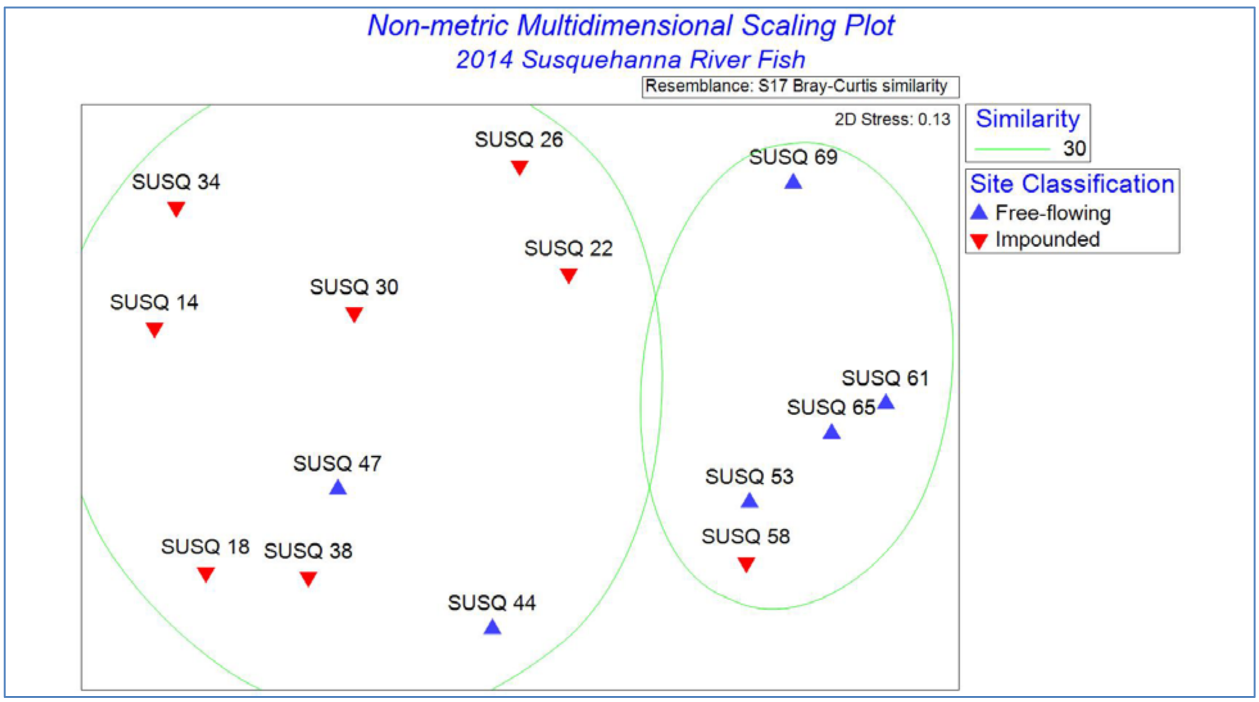

Figure 7. NMDS Plot of Fish Communities (2014)

Results from fish data collected during the 2012 SRBC study were compared to results from the 2014 effort at four sites (SUSQ 14, SUSQ 22, SUSQ 30, and SUSQ 34). Figure 8 shows a NMDS plot of fish communities sampled identical locations in 2012 and 2014. These shared sites possessed 45.3 percent similarity between years (SIMPER). Greater similarity of samples was observed among sites within the same year than across years at the same sites (Figure 8). This pattern was also observed in macroinvertebrate samples collected in 2012 and 2014.

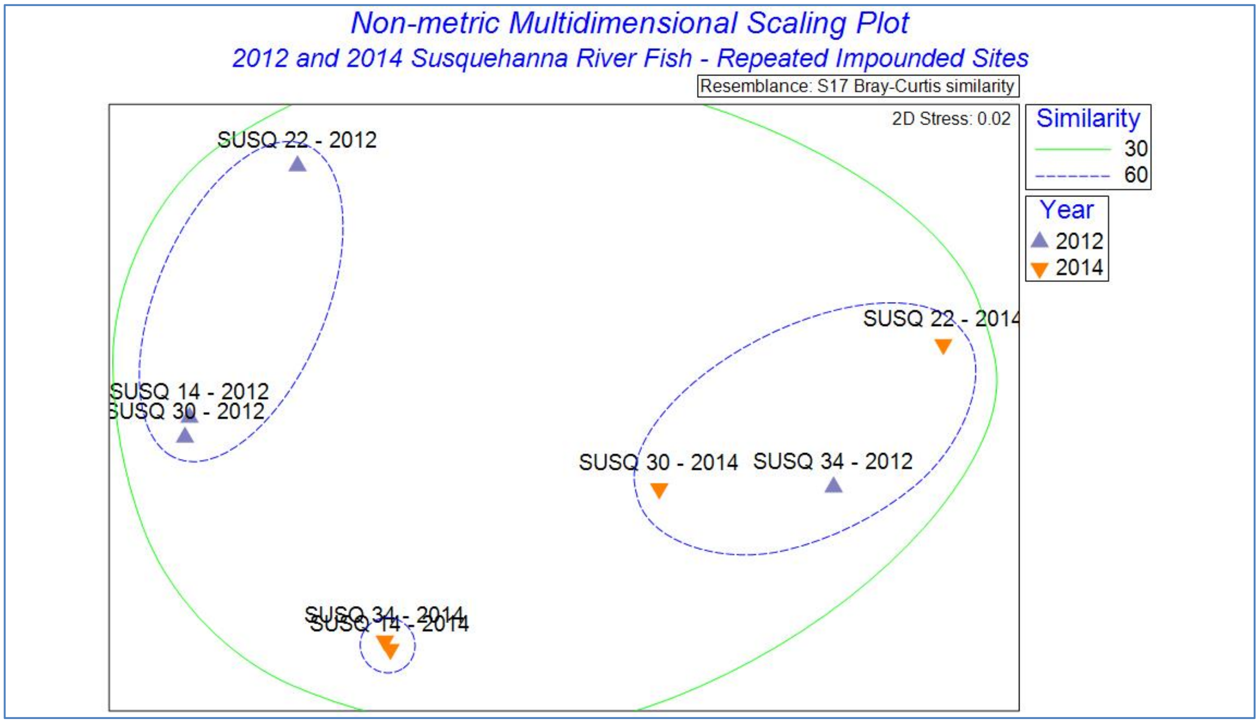

Figure 8. NMDS Plot of 2012 and 2014 Fish Communities at Repeated Impounded Sites

Smallmouth Bass

Smallmouth bass have been a species of concern in the Susquehanna River since 2005 when anglers and biologists began noticing dying and distressed fish. All smallmouth bass captured during this study were visually examined for any signs of deformities, eroded fins, lesions, or tumors, commonly referred to as DELTs. The presence of one or more DELT on a fish is an indication of poor health of the individual fish. An overall percentage of fish exhibiting some form of DELT (typically expressed at %DELT) is a common metric used to evaluate fish community health. Figure 9 shows smallmouth bass CPUE, number of smallmouth bass exhibiting DELTs per unit of effort, and an overall proportion of smallmouth bass showing at least one DELT.

Multiple age classes of smallmouth bass were encountered at every site. Average CPUE of smallmouth bass was 31.5 fish/hour across all sites. No difference in smallmouth bass CPUE was noted between impounded (31.35 fish/hour) and free-flowing sites (31.55 fish/hour). Smallmouth bass showing some type of DELT were encountered at 11 of 14 sites. The overall proportion of bass per site exhibiting a form of DELT ranged from 0 percent to 37 percent per site. Smallmouth bass displaying some form of DELT were more commonly encountered at free-flowing sites (26.4 percent) than impounded sites (9.2 percent). The overall proportion of smallmouth bass across all sites that possessed some form of DELT was 16.1 percent –a slight increase from the 2012 study where the proportion was 13 percent (Steffy, 2013).

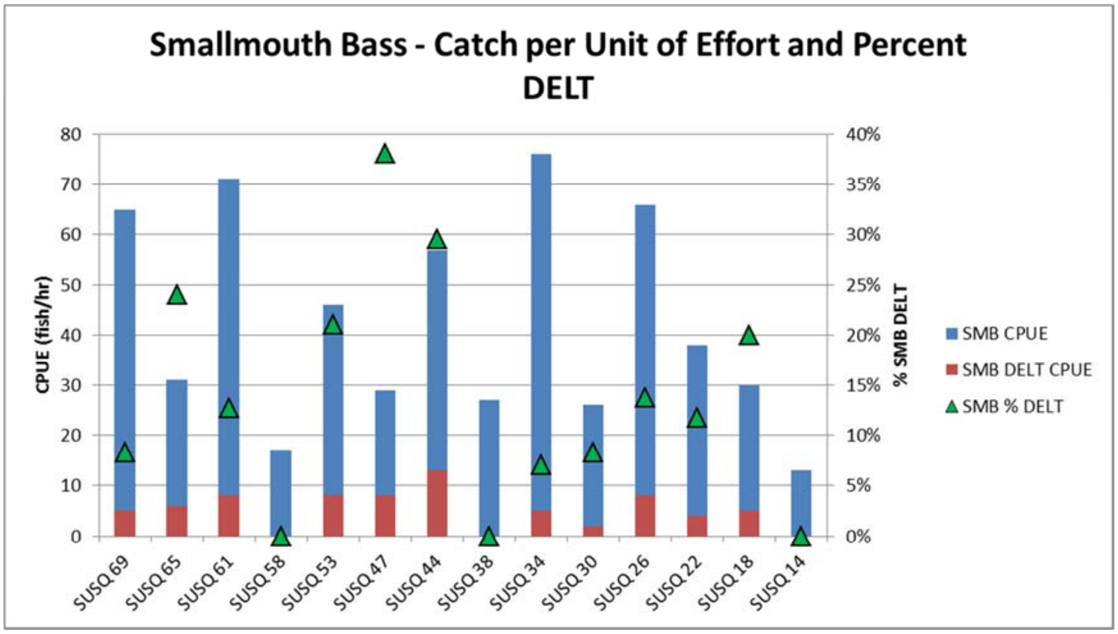

Figure 9. Smallmouth Bass Catch Per Unit of Effort (CPUE) and Percent of Smallmouth Bass Exhibiting One or More Deformities, Lesions, Erosions, or Tumors (DELT)

Macroinvertebrates

Macroinvertebrate samples were collected using two separate methods depending on the habitat conditions present at the sampling transect. Hester-Dendy artificial substrate samplers (HDs) were deployed where sites were determined to be impounded, while a D-frame kicknet was utilized at free-flowing transects. One HD sampler deployed at SUSQ 22 was unable to be recovered, and a D-frame sample was collected in substitute. To assess repeatability, a duplicate HD sampler was deployed at SUSQ 34 and a duplicate D-frame sample collected at SUSQ 53. The duplicate sample of the HD sample at SUSQ 34 showed more similarity to the paired sample (92.2 percent) than the duplicate D-frame sample at SUSQ 53 with the paired duplicate (74.5 percent).

Macroinvertebrate samples did show differentiation between impounded and free-flowing sites (Tables 5a and 5b). Samples collected using both methods were assessed using Pennsylvania's benthic macroinvertebrate index of biological integrity for large wadeable riffle/run freestone streams. The PA IBI (large) was developed and designed for use with composited D-frame samples taken in riffle/run streams up to 1,000 square miles and not large river systems such as the Susquehanna (PADEP, 2013b). Results are not directly comparable to other smaller systems that meet the drainage area criteria, but samples from within the river can be compared qualitatively. With scores of 51.2, 51.1, and 50.3, the highest PA IBI scores came from samples collected at free-flowing SUSQ 65, SUSQ 53, and SUSQ 69, respectively. The lowest scores were encountered at impounded SUSQ 30, SUSQ 22, and SUSQ 34.

The substitute D-frame sample collected from impounded SUSQ 22 more closely resembled the D-frame sample collected at SUSQ 44 and other free-flowing sites than HD samples from other impounded locations. Direct comparisons between samples collected using different gear types could not be made due to selection bias encountered in their respective methodologies. Comparisons between data collected in the 2012 study and the 2014 study were applicable however.

NMDS methodology was also utilized to examine annual variation between macroinvertebrate samples collected using identical methodology (six-week HD sampler deployments) at repeat impounded sites SUSQ 14, SUSQ 18, SUSQ 26, SUSQ 30, SUSQ 34, and SUSQ 38. Samples possessed greater similarity across sites within the same year than between years at the same site (Figures 10 and 11).

Table 5a. Macroinvertebrate Assemblage Metrics at Free-flowing Sites

	SUSQ 69	SUSQ 65	SUSQ 61	SUSQ 58	SUSQ 53	SUSQ 53*	SUSQ 47	SUSQ 44
Method	Kick	Kick	Kick	HD	Kick	Kick	Kick	Kick
PA IBI Score	50.3	51.2	44.9	27.4	51.1	44.2	37.4	33.1
Taxa Richness	25	23	24	15	25	20	20	22
Hilsenhoff Biotic Index	5.09	4.81	5.07	6.67	4.86	5.00	4.55	7.68
Percent Ephemeroptera Individuals	12.3%	22.2%	7.7%	8.3%	20.4%	18.1%	10.1%	5.9%
Percent Dominant Taxon individuals	30.5%	25.2%	46.0%	64.8%	29.4%	27.0%	39.7%	28.6%
Number of EPT taxa	9	8	8	2	12	6	9	5
Percent Chironomids	21.8%	12.8%	2.1%	0.9%	9.0%	8.3%	3.0%	8.6%
Shannon Diversity	2.13	2.22	1.96	1.41	2.21	2.07	1.39	2.33

*denotes duplicate sample

Table 5b. Macroinvertebrate Assemblage Metrics at Impounded Sites

	SUSQ 38	SUSQ 34	SUSQ 34*	SUSQ 30	SUSQ 26	SUSQ 22	SUSQ 18	SUSQ 14
Method	HD	HD	HD	HD	HD	Kick	HD	HD
PA IBI Score	28.3	22.3	22.6	18.4	24.8	20.7	28.3	28.0
Taxa Richness	10	10	11	10	14	13	11	16
Hilsenhoff Biotic Index	4.68	5.86	5.82	6.07	6.03	8.22	5.83	6.23
Percent Ephemeroptera Individuals	53.4%	2.7%	4.4%	0.4%	0.4%	0.4%	17.8%	9.3%
Percent Dominant Taxon individuals	52.5%	83.9%	81.5%	91.5%	71.5%	43.9%	61.7%	61.1%
Number of EPT taxa	5	6	4	2	2	1	5	7
Percent Chironomids	24.6%	83.9%	81.5%	91.5%	71.5%	17.2%	61.7%	61.1%
Shannon Diversity	1.20	0.66	0.78	0.44	1.00	1.62	1.30	1.42

*denotes duplicate sample

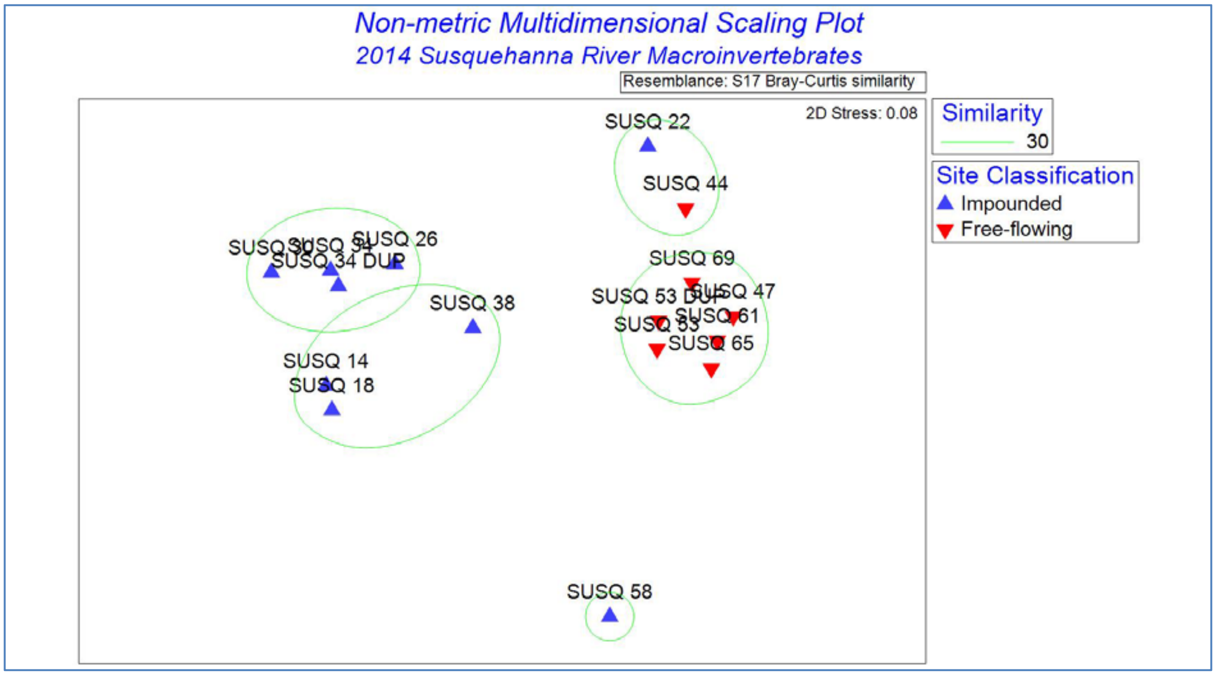

Figure 10. NMDS Plot of 2014 Macroinvertebrate Samples (Hester-Dendy and D-frame Samples)

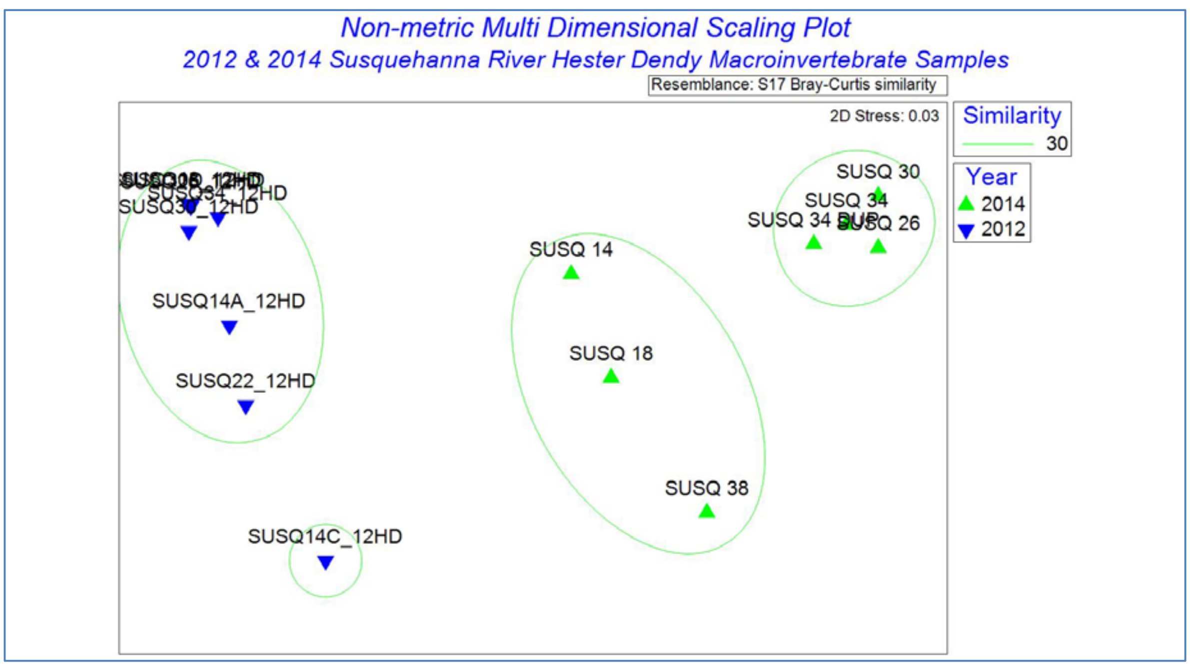

Figure 11. NMDS Plot of 2012 and 2014 Hester-Dendy Macroinvertebrate Samples at Repeated Sites

CONCLUSION/FUTURE DIRECTION

A pilot study was conducted by SRBC on the lower 45 miles of the river in 2012. The study conducted in 2014 sought to resample the original 2012 sites and better understand and document the water quality and biological conditions of the 25 miles upstream of the entirely impounded lower 45 miles. This entire portion of the river is unique with complex interactions between natural and anthropogenic factors influencing biology and water chemistry. Distinguishable differences in water quality across the stream channel were detected throughout the northern half of the study area, both above and below York Haven Dam. These differences persisted to a degree, under the observed flow conditions, until the vicinity of Columbia, Pa. (RM 44), where the river becomes truly impounded. Downstream of RM 44, water quality conditions are nearly identical across sampled transects with little variation shown in measured constituents. Conversely, the sample sites located upstream of RM 44 exhibited distinct lateral variation in the form of three separate influences, presumably from the contributions of the major tributaries: the Juniata River, the West Branch Susquehanna River, and the North Branch of the Susquehanna River.

In general, biological, water quality, and habitat conditions degrade and homogenize as the river proceeds towards the mouth. Sites in the lower impounded sections possessed less biological diversity and habitat complexity than the sites in the upper free-flowing portion of the river examined in this study. Sites in the free-flowing areas typically possessed more varied and complex habitats relative to the impounded sites. Impounded sites were characterized by steep banks with few in-river features. Conversely, free-flowing sites were generally shallower but with more varied depths and possessed functionally important features such as backwaters, riffles, and emergent aquatic vegetation. Results confirmed correct pre-assigned classifications of sites into two groups, free-flowing or impounded, was performed prior to sampling. Sites SUSQ 14 – SUSQ 38 were accurately grouped as impounded and generally possess similar biology and nearly identical water quality signatures.

Free-flowing sites SUSQ 61 – SUSQ 69 exhibited similar patterns in water quality with three distinct signals being detected at positions A, B, and C. Within this area, sites sharing the same relative transect position (A, B, or C), regardless of river mile, possessed greater similarity to upstream and downstream counterparts than to different positions along the transect at the same site (i.e., 65A more similar to 61A than 65B). Biological factors examined across these three free-flowing sites were generally similar.

The study sites adjacent to York Haven Dam and the impoundment it creates (SUSQ 47 – SUSQ 58) represent a transitional area where flow conditions through and around the dam are highly variable. The physical design and the run-of-river operation of the York Haven Dam allow for differentiation from the three other dams farther downstream in the impounded part of the river. Future studies would benefit from the use of a macroinvertebrate collection method that allows direct comparison of the communities. Both the D-frame and Hester-Dendy methods were effective at sampling macroinvertebrates within ideal habitats appropriate for either, but the lack of direct comparability throughout the entire study area was a shortcoming of this study. An examination of macroinvertebrate communities along the span of individual transects may reveal biological differences that may correspond with differences in water quality from SUSQ 44 – SUSQ 69. PADEP reported variation in IBI scores from samples collected along transects at Columbia, Pa. RM 44 (53.8 – 64.7) and Sunbury, Pa. RM 124 (52.4 – 77.6) (PADEP, 2014).

Due to observed homogeneity of both water quality and biological conditions, future efforts to study the impounded portion of the lower Susquehanna River can be condensed. The lack of variability in water quality across the river in this area suggests a single composited water sample from each dam's impoundment is representative of actual conditions. Additionally, future studies of the free-flowing portions of the river would benefit from retaining a sampling approach which accounts for monitoring influences of the major tributaries.

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APPENDIX

Macroinvertebrate Community Resemblance Matrix

	SUSQ 14	SUSQ 18	SUSQ 26	SUSQ 30	SUSQ 34	SUSQ 34 DUP	SUSQ 38	SUSQ 58	SUSQ 22	SUSQ 44	SUSQ 47	SUSQ 53	SUSQ 53 DUP	SUSQ 61	SUSQ 65	SUSQ 69
SUSQ 14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUSQ 18	46.19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUSQ 26	24.83	25.81	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUSQ 30	23.95	25.81	69.79	-	-	-	-	-	-	-	-	-	-	-	-	-
SUSQ 34	32.73	30.40	78.87	81.48	-	-	-	-	-	-	-	-	-	-	-	-
SUSQ 34 DUP	35.67	33.26	80.09	76.19	92.24	-	-	-	-	-	-	-	-	-	-	-
SUSQ 38	32.74	34.76	29.30	19.53	32.17	33.69	-	-	-	-	-	-	-	-	-	-
SUSQ 58	8.97	7.83	9.46	2.15	4.41	6.13	4.72	-	-	-	-	-	-	-	-	-
SUSQ 22	9.67	11.09	17.30	2.11	11.66	12.88	16.84	8.10	-	-	-	-	-	-	-	-
SUSQ 44	8.26	9.33	16.70	3.08	10.81	12.98	17.11	9.78	41.83	-	-	-	-	-	-	-
SUSQ 47	5.75	3.86	14.86	2.12	10.43	10.80	19.49	7.30	17.68	23.25	-	-	-	-	-	-
SUSQ 53	13.43	15.78	17.89	2.75	12.24	14.49	25.63	16.24	22.27	34.20	52.63	-	-	-	-	-
SUSQ 53 DUP	11.43	13.36	18.22	2.73	11.68	13.92	24.09	17.51	27.09	34.91	58.64	74.57	-	-	-	-
SUSQ 61	5.32	6.02	16.17	2.98	9.15	9.96	18.68	13.33	18.57	33.85	50.53	57.80	52.85	-	-	-
SUSQ 65	4.44	7.76	15.35	2.13	9.17	9.54	18.72	19.40	22.41	33.04	48.94	59.77	63.01	54.58	-	-
SUSQ 69	8.72	9.78	16.26	2.20	11.26	12.98	22.37	11.11	29.63	37.27	52.19	64.61	60.38	56.26	59.91	-

Fish Community Resemblance Matrix (Excluding Gizzard Shad)

	SUSQ 69	SUSQ 65	SUSQ 61	SUSQ 58	SUSQ 53	SUSQ 47	SUSQ 44	SUSQ 38	SUSQ 34	SUSQ 30	SUSQ 26	SUSQ 22	SUSQ 18	SUSQ 14
SUSQ 69	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUSQ 65	45.02	-	-	-	-	-	-	-	-	-	-	-	-	-
SUSQ 61	39.05	73.82	-	-	-	-	-	-	-	-	-	-	-	-
SUSQ 58	39.93	65.82	51.16	-	-	-	-	-	-	-	-	-	-	-
SUSQ 53	26.52	56.23	60.52	55.64	-	-	-	-	-	-	-	-	-	-
SUSQ 47	24.14	24.40	17.90	34.54	30.56	-	-	-	-	-	-	-	-	-
SUSQ 44	27.22	27.74	23.68	36.17	32.93	43.97	-	-	-	-	-	-	-	-
SUSQ 38	15.42	17.72	14.17	26.82	26.83	59.85	42.86	-	-	-	-	-	-	-
SUSQ 34	13.07	8.57	8.06	11.11	15.41	41.06	35.17	29.41	-	-	-	-	-	-
SUSQ 30	20.39	22.98	17.77	28.26	25.11	47.54	35.59	52.98	52.41	-	-	-	-	-
SUSQ 26	54.39	26.99	30.07	24.65	22.10	25.80	20.45	28.09	35.85	54.86	-	-	-	-
SUSQ 22	29.88	41.67	54.02	30.79	47.07	31.58	32.20	31.16	35.91	54.08	59.31	-	-	-
SUSQ 18	15.69	17.86	12.24	24.23	20.71	47.62	20.57	47.73	23.84	39.34	35.03	22.33	-	-
SUSQ 14	10.59	10.17	6.46	12.97	17.94	50.81	31.86	41.16	67.30	53.83	31.83	35.00	39.74	-

Fish Community Resemblance Matrix, 2012 and 2014 Repeated Sites

	SUSQ 34 - 2014	SUSQ 30 - 2014	SUSQ 22 - 2014	SUSQ 14 - 2014	SUSQ 14 - 2012	SUSQ 22 - 2012	SUSQ 30 - 2012	SUSQ 34 - 2012
SUSQ 34 - 2014	-	-	-	-	-	-	-	-
SUSQ 30 - 2014	52.41	-	-	-	-	-	-	-
SUSQ 22 - 2014	35.91	54.08	-	-	-	-	-	-
SUSQ 14 - 2014	67.30	53.83	35.00	-	-	-	-	-
SUSQ 14 - 2012	52.44	44.29	22.91	53.91	-	-	-	-
SUSQ 22 - 2012	44.44	47.65	26.48	46.03	60.40	-	-	-
SUSQ 30 - 2012	55.81	43.01	22.22	53.64	78.46	50.36	-	-
SUSQ 34 - 2012	39.23	66.25	62.06	44.50	37.20	36.20	37.74	-

Fish Species Encountered by Site

common name	scientific name	SUSQ 69	SUSQ 65	SUSQ 61	SUSQ 58	SUSQ 53	SUSQ 47	SUSQ 44	SUSQ 38	SUSQ 34	SUSQ 30	SUSQ 26	SUSQ 22	SUSQ 18	SUSQ 14
quillback	*Carpiodes cyprinus*				X		X	X	X	X			X		
white sucker	*Catostomus commersoni*		X		X	X	X					X		X	
northern hog sucker	*Hypentelium nigricans*	X	X	X	X			X			X		X		
shorthead redhorse	*Moxostoma macrolepidotum*					X		X		X	X	X	X	X	X
rock bass	*Ambloplites rupestris*	X	X	X	X	X	X	X		X			X		
redbreast sunfish	*Lepomis auritus*	X	X	X	X	X									
green sunfish	*Lepomis cyanellus*				X	X	X	X	X	X	X	X	X	X	X
pumpkinseed	*Lepomis gibbosus*						X	X							
bluegill	*Lepomis macrochirus*				X	X	X		X	X	X		X	X	X
smallmouth bass	*Micropterus dolomieu*	X	X	X	X	X	X	X	X	X	X	X	X	X	X
largemouth bass	*Micropterus salmoides*		X		X	X	X		X		X	X	X		
black crappie	*Pomoxis nigromaculatus*	X													
gizzard shad	*Dorosoma cepedianum*		X	X			X				X	X	X	X	X
central stoneroller	*Campostoma anomalum*				X										
satinfin shiner	*Cyprinella analostana*	X										X	X		X
spotfin shiner	*Cyprinella spiloptera*	X	X	X	X	X	X	X	X	X	X	X	X	X	X
common carp	*Cyprinus carpio*		X		X	X	X		X	X	X		X	X	X
grass carp	*Ctenopharyngodon idella*										X				
river chub	*Nocomis micropogon*	X	X	X		X									
golden shiner	*Notemigonus chrysoleucas*														X
comely shiner	*Notropis amoenus*					X	X	X	X	X	X	X	X	X	X
spottail shiner	*Notropis hudsonius*	X	X	X	X	X	X		X		X	X	X		
roseyface shiner	*Notropis rubellus*	X	X	X	X				X				X		X
mimic shiner	*Notropis volucellus*	X	X	X	X	X	X	X	X		X		X		
bluntnose minnow	*Pimephales notatus*	X	X	X	X	X	X		X		X	X	X	X	
fallfish	*Semotilus corporalis*	X	X	X	X	X	X	X	X	X	X	X	X		
tiger musky	*Esox masquinongy X Esox lucius*					X									
banded killifish	*Fundulus diaphanus*	X	X	X	X	X					X				
yellow bullhead	*Ameiurus natalis*				X										
channel catfish	*Ictalurus punctatus*	X	X			X	X	X	X	X	X	X	X	X	X
flathead catfish	*Pylodictis olivaris*	X						X		X	X	X	X		
greenside darter	*Etheostoma blennioides*	X	X				X			X			X	X	X
tessellated darter	*Etheostoma olmstedi*	X	X	X	X	X					X	X			
banded darter	*Etheostoma zonale*												X		
yellow perch	*Perca flavescens*	X				X					X		X		
chesapeake logperch	*Percina bimaculata*												X	X	X
shield darter	*Percina peltata*	X		X	X								X		
walleye	*Sander vitreus*	X	X	X	X	X	X	X							