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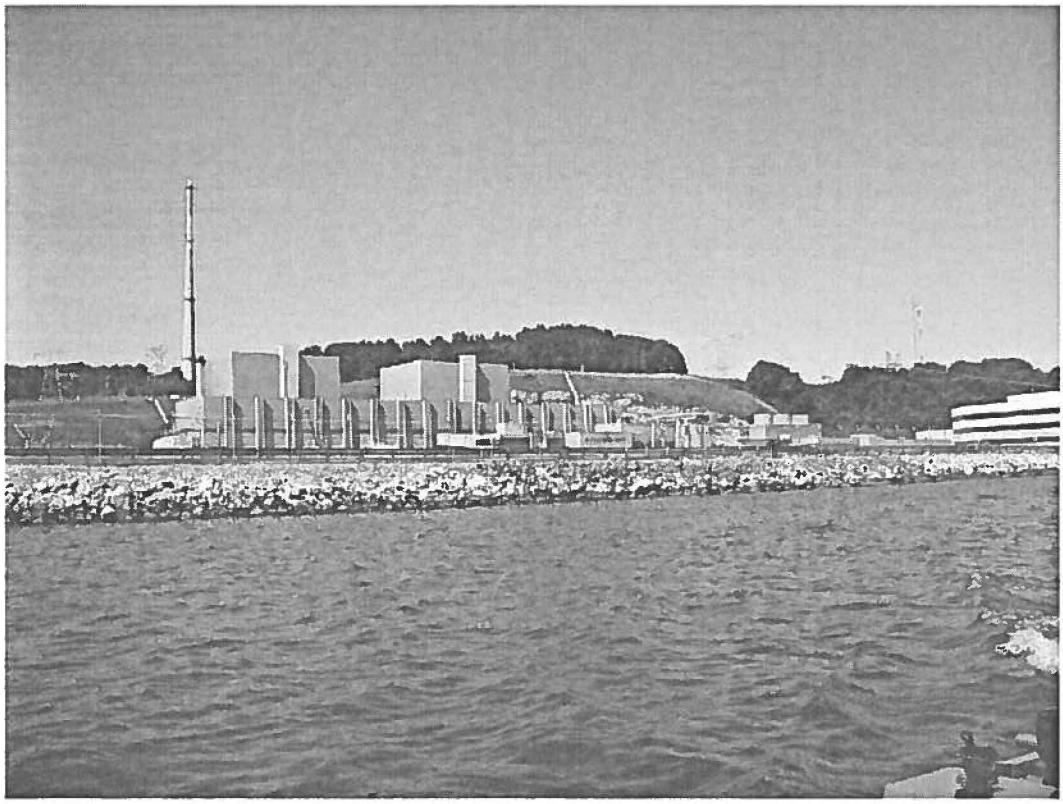
FINAL REPORT FOR POST-EPU THERMAL AND BIOLOGICAL MONITORING

PEACH BOTTOM ATOMIC POWER STATION



Exelon Generation

February 2017

FINAL REPORT FOR POST-EPU THERMAL AND BIOLOGICAL MONITORING

PEACH BOTTOM ATOMIC POWER STATION

Prepared for:

Exelon Generation

Prepared by: Normandeau Associates, Inc. and ERM, Inc.

February 2017

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Executive Summary

The Post-EPU Thermal and Biological Study (Post-EPU Study) supports the monitoring requirements set forth in the Station's NPDES Permit. The study evaluated increases in water temperature after implementation of the extended power uprate (EPU) and assessed the resulting effects on the biological community. Field studies included water temperature and dissolved oxygen monitoring, benthic macroinvertebrate sampling, and fish community surveys in thermally and non-thermally affected areas of Conowingo Pond. The study also included desktop evaluations of juvenile American Shad migration past the PBAPS thermal plume and the seasonal distribution of Gizzard Shad in Conowingo Pond relative to the PBAPS thermal discharge.

The Post-EPU Study is the follow-up to the four-year 316(a) Demonstration Study (Pre-EPU Demonstration Study) completed in 2013. The Pre-EPU Demonstration Study concluded that under pre-EPU operations, a balanced, indigenous community (BIC) existed in Conowingo Pond. Modeling and analysis performed during the Pre-EPU Demonstration Study concluded that after EPU implementation with cooling towers operating, a BIC would continue to be maintained. The Pre-EPU Demonstration Study also recommended that thermal and biological monitoring be continued to evaluate post-EPU conditions against predictions made during the Pre-EPU Demonstration Study.

Susquehanna River flows and temperatures during the 2016 study period were at extreme levels (i.e., low flows in combination with high ambient water temperatures) and were thus ideal for direct measurement of temperature increases. Comparisons showed that predicted temperature increases provided an upper bound to those observed in the field. Field observations also showed that the average post-EPU condenser temperature rise was less than the assumed value (i.e., 22.1°F actual compared with 22.4°F modeled). Observations also showed that each cooling tower performed better than expected (2.2°F temperature reduction per tower instead of the modeled value of 1.6°F). Overall, field observations show that cooling tower operation as specified in the current NPDES permit effectively mitigates the post-EPU increase in thermal load.

Water temperature observations at the biological monitoring locations were generally consistent with pre-EPU observations. Monitoring of dissolved oxygen (DO) concentrations indicated that DO was protective of the aquatic community and DO concentrations would not block fish migration past PBAPS.

Evaluation of the Pre-EPU Demonstration Study model output indicated that a BIC would be maintained after the implementation of the EPU. Post-EPU monitoring indicated that the measurable spatial and temporal impacts of the thermal plume to the biota of Conowingo Pond were similar to those observed during pre-EPU sampling, as expected. Similar to pre-EPU study results, the temporal patterns of fish avoidance and decline in benthos diversity were related to high water temperatures.

Both the fish and benthic macroinvertebrate community composition and relative abundance were similar to those observed during Pre-EPU monitoring. Indices used to describe the community structure of the biological community showed that thermally influenced and non-thermally influenced stations were similar biologically during pre- and post-EPU monitoring. Field observations showed that, as expected, a BIC has been maintained during post-EPU conditions with cooling tower mitigation.

The time-varying hydrothermal model used for the temperature predictions was subsequently used to predict the areas in Conowingo Pond with water temperatures that would impede juvenile American Shad emigration. The analysis indicated that virtually the entire Pond is available for juvenile American Shad emigration with no potential for thermal blockage. In Conowingo Pond, Gizzard Shad tolerate temperatures < 2.2 °C (< 36.0 °F) and do not appear to need a "thermal refuge" to sustain the population. The winter electrofishing catch supports a conclusion that the PBAPS thermal plume is not interfering with the fall outmigration of Gizzard Shad or attracting excessively large numbers of this species during the winter months.

1 Introduction

Exelon Generation, LLC's (Exelon) Peach Bottom Atomic Power Station (PBAPS) is a power generating facility located in York County, Pennsylvania. The Station operates under National Pollutant Discharge Elimination System (NPDES) Permit No. PA0009733 and a Federal Clean Water Act (CWA) §316(a) variance for its thermal discharge to Conowingo Pond.

This study supports the monitoring requirements set forth in the NPDES Permit under Part C, Alternate Thermal Limitations. The purpose of this study is to evaluate the increase in water temperature after implementation of the Extended Power Uprate (EPU) and to determine potential changes to the thermal plume and its effects on the biological community. After completion and acceptance of the pre-EPU 316(a) Demonstration Study (Normandeau and ERM 2014), Exelon developed a Post-EPU Study Plan that outlined the technical requirements necessary to confirm results of the Pre-EPU Demonstration Study. The Plan was subsequently reviewed and revised in coordination with the Pennsylvania Department of Environmental Protection (PADEP). The final, approved Study Plan was submitted to PADEP on April 25, 2016. The sampling program was initiated shortly thereafter.

The goal of the Post-EPU Study is to use physical and biological field data to confirm predicted biological outcomes and to validate model assumptions and results from the pre-EPU 316(a) Demonstration Study. The 2016 physical and biological field dataset are similar to the datasets used for the pre-EPU 316(a) Demonstration Study. The 2016 dataset is focused on critical areas and issues that were identified in the Pre-EPU Demonstration Study. In addition to the biological and temperature monitoring, the Post-EPU Study Plan included continuous dissolved oxygen monitoring, a desktop study to evaluate juvenile American Shad migration past the PBAPS thermal plume, and a desktop study to address concerns over Gizzard Shad seasonal distribution in Conowingo Pond relative to the PBAPS thermal discharge.

This Post-EPU Study is the follow-up to the four-year pre-EPU 316(a) Demonstration Study as described in the Post-EPU Study Plan (Normandeau and ERM 2016). In the pre-EPU 316(a) Demonstration Study, an extensive set of physical and biological field data were collected and analyzed to show the effects of PBAPS's thermal discharge. To estimate the impacts of increased heat loads to Conowingo Pond when each of the two generating units was equipped for EPU operations, a three-dimensional hydrothermal model was used to simulate the extent of the thermal plume for average and extreme ambient conditions with EPU operating conditions. The model also has the capability to simulate temperature in Conowingo Pond during the operation of one, two or three of the cooling towers located along the PBAPS discharge canal.

The approved NPDES permit for EPU operation required a summertime cooling tower operating schedule that balanced the additional heat load from the EPU against the heat reduction from the operation of the cooling towers. The cooling tower operating schedule also specified use of cooling towers during episodic, naturally-occurring high river temperature events.

The main components of the present study include water temperature monitoring, dissolved oxygen monitoring, and biological sampling of shore zone benthic macroinvertebrates and the

resident fish community in Conowingo Pond. Field data collection was completed for the months of May through September, the main period for fish reproduction and growth, as well as the period with the highest ambient and discharge water temperatures.

Section 2 of this report provides background information about previous thermal and biological studies conducted relative to PBAPS. Sections 3 through 6 discuss water temperature, biological, and dissolved oxygen monitoring results and analysis. Sections 7 and 8 provide information related to juvenile American Shad migration and seasonal distribution of Gizzard Shad in Conowingo Pond relative to PBAPS's thermal plume.

2 Background

This section summarizes important background information on the Station (including the EPU and cooling tower operations), Conowingo Pond's physical features and biota, and the main conclusions from the pre-EPU 316(a) Demonstration Study.

2.1 The Peach Bottom Atomic Power Station

Exelon operates two nuclear reactors at the Peach Bottom site. Unit 2 began commercial operation in June 1974; Unit 3 entered commercial service in December 1974[1]. PBAPS withdraws water for condenser cooling from Conowingo Pond (Pond) through an intake structure using six circulating water pumps (three per unit, 557 cubic feet per second (cfs) per pump) and for service water needs using six service water pumps (three per unit, 31.2 cfs per pump). After passing through the plant, water exits at the head of the 4,700-ft long discharge canal into Conowingo Pond. The discharge structure is designed for rapid mixing of the heated effluent into ambient Conowingo Pond water and an immediate reduction in temperature. Three cooling towers are located along the canal, each of which is capable of reducing the temperature by approximately 1.6 to 2.2°F, depending on meteorological conditions, especially humidity and wind speed.

The design temperature rise across the condensers is 22°F and across the service water system is 10.7°F. As noted in the Pre-EPU Demonstration Study, the actual temperature rise for the combined condenser and service water flow as observed in the study averaged 19.4°F at the head of the discharge canal during the two warmest months of the year, July and August.

Exelon began uprating Unit 2 in 2014 and Unit 3 in 2015, with the uprate for each Unit fully implemented about one year later (2015 and 2016, respectively). Variable cooling tower operation, discussed later in this report, began in the summer of 2015. The additional waste heat added when both uprated reactors are operating results in a 3°F increase in the temperature rise.

2.2 Conowingo Pond

Conowingo Pond, the lowermost of four hydroelectric impoundments on the lower Susquehanna River, was formed in 1928 by construction of Conowingo Hydroelectric Station at River Mile 10 (RM 10). Conowingo Hydroelectric Station is a modified run-of-river facility with limited storage for peaking hydropower generation. Conowingo Pond is bounded upstream by Holtwood Dam (RM 24) built in 1914. PBAPS at RM 17 is about equidistant between the two dams.

Conowingo Pond has a surface area of about 9,000 acres and is about 14 miles long and averages 1 mile wide. The elevation at normal full Pond is 108.5 ft and the elevation is normally

[1] Unit 1 was a small experimental reactor shut down in 1974.

maintained at 106.5 ft or higher for recreational use on weekends between Memorial Day and Labor Day and at levels no less than 104.5 ft at other times for operation of PBAPS.

Long-term monitoring that began around 1960 has shown that the Pond is not thermally stratified but that at summer water temperatures and low Susquehanna River (<12,000 cfs), dissolved oxygen stratification can occur in deeper areas of the Pond. Since monitoring pre-dates PBAPS operations, dissolved oxygen stratification is a natural phenomenon, common for this type of waterbody.

The circulation in the Pond is influenced by outflows and inflows that can occur on a daily or hourly basis from controlled inflows of up to 32,000 cfs from Holtwood Hydroelectric Dam and up to 32,000 cfs (during generation) from Muddy Run Pumped Storage Facility (MRPSF) at RM 22. Controlled outflows of up to 85,000 cfs occur at Conowingo Hydroelectric Station and of up to 28,000 cfs (during pumping) at Muddy Run.

2.3 Biota of Conowingo Pond

The biota of Conowingo Pond has been studied intensely for many years. Long-term thermal and biological monitoring studies have been completed in Conowingo Pond since 1966, both prior to operation of PBAPS in 1974 and in the subsequent operational period. Sampling has been performed upstream and downstream from PBAPS and in areas within the heated plume. The numerous long-term studies documented species composition, relative abundance and distribution of fishes within Conowingo Pond. The most recent thermal studies in the form of a pre-EPU 316(a) Demonstration Study were completed from 2010 to 2013. These studies included temperature monitoring and extensive fish community monitoring in Conowingo Pond. Since 1966, approximately 60 species have been captured in the Pond and the tributary streams.

2.4 Summary of 2014 316(a) Demonstration Study

The pre-EPU 316(a) Demonstration Study served multiple purposes:

- to study an alternative thermal effluent limitations under §316(a) of the CWA;
- to evaluate changes in the thermal plume created by operation of up to three helper cooling towers, and
- to predict changes to the thermal plume associated with planned uprates to Units 2 and 3 and to design the cooling tower protocol.

2.4.1 <u>316(a) Demonstration Study Description</u>

The Pre-EPU Demonstration Study was completed with extensive coordination with PADEP. The main components of the study were temperature monitoring, hydrothermal modeling, sampling of macroinvertebrates and of the resident fish community, and integrated analysis of the temperature and biological data. Each component was used to make an independent

assessment of the PBAPS thermal discharge and to evaluate the applicability of a thermal variance.

Monitoring and sampling were performed April through October, the main period of fish reproduction and growth as well as highest ambient and discharge water temperatures. Data collection began in 2010 and continued through 2013. No towers were operated during the summer of 2010, one tower was operated in 2011, two towers in 2012, and three towers in 2013. The resulting datasets provided all the information necessary to evaluate the temperature reduction effects of cooling tower operation.

2.4.2 316(a) Demonstration Study Results

Temperature Monitoring

- The towers performed as designed; each tower cooled the discharge by about an additional 1.6°F, measured from the head to the end of the discharge canal.
- Operation of the towers reduced water temperatures in Conowingo Pond by consistent and measurable amounts within 1.2 miles of the discharge and near the western shoreline and by smaller amounts beyond 1.2 miles.

Benthic Macroinvertebrate Community

- The composition and relative abundance of the benthic community was similar during all 4 years of the study.
- Temporary impact, in terms of lower IBI scores, was observed at Stations 214 and 215 in July and August after a sustained period of high water temperatures, but was followed by recovery.
- Benthic community changes resulting from the thermal plume are localized and temporary and limited to a small proportion of the available shallow shoreline habitat within Conowingo Pond.
- There was no observed impact to the benthic community at the three thermally-influenced Stations (189, 216 and 217) that are 1.3 miles or more downstream from the discharge canal.

Fish Community

- Inter-annual variation in relative abundance of the Representative Important Species (RIS) and other species did not appear to be related to differences in water temperature resulting from cooling tower operation.
- Metrics used to describe fish community structure show no clear differences in the fish community between thermally influenced and non-thermally influenced locations.
- Limited avoidance by selected species was observed at Stations 161, 214, and 215 which are closest to the end of the discharge canal, during the periods of highest water temperature in July and/or August.
- Little or no habitat avoidance occurs in May and early June, the peak spawning period for most fishes in Conowingo Pond.

- The observed fish avoidance for select species occurred mostly in July and August when either the species move out of the area or for most RIS, have completed spawning activity.
- Relative abundance of most RIS from 2010 through 2013 was within the range of values observed previously in Conowingo Pond.

Hydrothermal Model

- The model accurately reproduced the hydrodynamics and thermal structure of the Pond relative to the PBAPS thermal plume and other dynamic input parameters.
- The agreement of modeled and observed temperatures over the range of conditions that occurred in 2010, 2011 and 2012 allows the model to predict the thermal structure in the pond for other-than-observed conditions and to establish the cooling tower operating schedule shown in the NPDES Permit, Part C.
- EPU modeling results for the *typical summer condition* show that areas of potential fish avoidance would be small, localized, and temporary in nature.
- Most of the potential avoidance areas for the *typical summer condition* modeling scenario would occur at the water surface near to the west shoreline immediately downstream from the discharge canal.
- EPU modeling results for the *extreme summer condition* show that areas of potential fish avoidance would be sizable for several species with most of the elevated water temperatures and avoidance areas at the surface or in the immediate vicinity of the discharge canal.
- Cross-sections of the thermal plume for both modeling scenarios indicated that sufficient areas of the channel would be available at water temperatures less than the avoidance temperatures for the RIS and will allow for their movement within the Pond.

2.4.3 316(a) Demonstration Study Overall Conclusions

The Pre-EPU Demonstration Study concluded that under pre-EPU operations, a balanced, indigenous community (BIC) in Conowingo Pond existed. Modeling and analysis performed during the Pre-EPU Demonstration Study also concluded that after EPU implementation with cooling towers operating using the agreed schedule, a BIC would continue to be maintained. The Pre-EPU Demonstration Study also suggested that thermal and biological monitoring after EPU implementation should be continued to evaluate post-EPU conditions against predictions made during the Pre-EPU Demonstration Study.

3 Temperature Monitoring Program

This section of the report presents the results of the 2016 thermal plume monitoring organized by deliverables listed in the Post-EPU Study Plan. For the thermal plume monitoring, the deliverables are:

- Temperature data in electronic format
- Duration and frequency of high temperatures
- Temperature changes due to cooling tower operations
- Transition period temperatures
- Model verification

The Susquehanna River flows and temperatures that occurred in 2016 are important in understanding the temperature and biological data presented in this study. The 2016 flows and temperatures are discussed below relative to those observed during the four year Pre-EPU Demonstration Study, historical values, and values used to model post-EPU conditions.

3.1 Characteristics of the 2016 Post-EPU Study Year

Table 3-1 shows monthly average 2016 Susquehanna River flows compared to the long-term mean and the four years of the Pre-EPU Demonstration Study. Shaded cells are those flows below the long-term mean. The table shows that the years 2010, 2012 and 2016 stand out as low flow years. July and September are important because those flows are very near or below the 7000 cfs flow chosen for the "extreme" scenario modeled for the Pre-EPU Demonstration Study.

Table 3-1 Monthly average Susquehanna River flows: Historical, Demonstration Study, and Post-EPU Study years.

Month	Average Susquehanna River flow, cfs					
	1932-2011	2010	2011	2012	2013	2016
April	78,600	46,385	149,867	23,704	53,462	33,210
May	48,500	34,392	110,399	52,547	29,717	34,010
June	28,900	17,508	35,079	29,693	31,949	15,640
July	16,200	10,060	13,202	8,730	37,117	6,947
August	12,700	8,808	17,797	10,275	15,692	9,857
September	15,800	6,142	141,479	11,222	12,266	5,506
October	18,800	40,228	80,023	18,378	18,853	13,821

Table 3-2 is shows monthly average temperatures in a similar format, but in this table the shaded months identify temperatures greater than the long-term mean. Like many of the months in the Demonstration Study, 2016 is also characterized by warm temperatures. September 2016 is unusual – not only are temperatures more than 5°F higher than all Septembers shown in the table, September 2016 most resembles temperatures typically seen in August.

Overall, 2016 resembles 2010; both are warmer and dryer than most years. September 2016 is unique, characterized by very low flows and unusually high temperatures.

Table 3-2 Monthly average Susquehanna River temperatures: Historical, Demonstration Study, and Post-EPU Study years.

Month	Average Susquehanna River temperatures, °F					
	1999-2013	2010	2011	2012	2013	2016
June	74.8	78.8	76.2	75.0	75.1	77.3
July	81.1	84.0	83.3	83.8	81.2	83.6
August	80.1	82.3	80.1	81.8	77.2	84.4
September	73.1	75.1	68.1	74.2	73.8	80.1

In the Pre-EPU Demonstration Study, the flows and temperatures for the typical and extreme modeling scenarios were based on the 10% and 1% frequency of occurrence of combinations of low Susquehanna River flows and high Susquehanna River temperatures. Table 3-3 characterizes July, August and September 2016 in the same fashion. The table shows, of all historical combinations of Susquehanna River flows and temperatures (1956-2012, all months), 97% of the months had either higher flows or lower temperatures than occurred in September 2016, making its combination of flows and temperatures unusual, but less so than the extreme scenario modeled for the Pre-EPU Demonstration Study.

Table 3-3 Frequency of occurrence of combinations of low Susquehanna River flows and high Susquehanna River temperatures.

Case	Monthly mean intake temperature, °F	Monthly mean Susquehanna River flow, cfs	Fraction of months this combination is exceeded
Extreme Modeling Scenario	86	7000	99%
Typical Modeling Scenario	80	13000	90%
July 2016	84	7051	98%
August 2016	84	9954	97%
September 2016	80	5587	97%

The fact that 2016 was both a low flow and a high temperature year makes it a unique year in which to collect both temperature and biological data and to measure cooling tower performance and the response of the aquatic communities to near-extreme conditions.

3.2 Thermal Plume Monitoring

The 316(a) Demonstration Study measured temperatures with 0, 1, 2, and 3 towers in operation to determine the rate of cooling in the canal and downstream, modeled 1% and 10% combinations of flow and ambient temperature to estimate post-EPU downstream temperatures for extreme conditions, and used the model to help design the cooling tower operating schedule published in Part C of the NPDES permit.

The Post-EPU Study used observations to show that the expected downstream cooling occurs and compared modeled and observed temperatures to demonstrate the model correctly predicted temperatures for extreme events ("verification").

The use of cooling towers after implementation of the EPU is based on the concept that a healthy fishery existed in Conowingo Pond prior to EPU implementation and that the same healthy fishery post-EPU will be maintained if the additional heat from the EPU is offset by operation of the cooling towers. This offset can be demonstrated by comparing the temperature increase at the head of canal due to the EPU (3°F) with the temperature decrease from operating two cooling towers, each reducing the temperature by 1.6°F for a total of 3.2°F.

3.2.1 Data Program

Monitoring Station Descriptions

Temperature monitoring for the Post-EPU Study used a subset of the stations used in the Pre-EPU Demonstration Study, as approved by PA DEP in consultation with the US Fish and Wildlife Service. Figure 3-1 shows the location of these monitoring stations. The location, data, and analysis of the biological monitoring stations are discussed in "Biological Station Temperature Monitoring."

Figure 3-2 shows the monitoring stations in the discharge canal.

Water Temperature Data

All water temperature data have been provided to PA DEP, as required, in a separate spreadsheet and transmittal. The period of record is May 1 through September 30, 2016; data are measured hourly and retrieved monthly.

Loss of Data

There were 30 monitoring stations taking data hourly for a total of 110,160 (= 30 stations x 153 days x 24 hours) possible data points over the five month monitoring period. Nearly all temperature data were recovered and available for analysis as 99% data recovery was achieved.

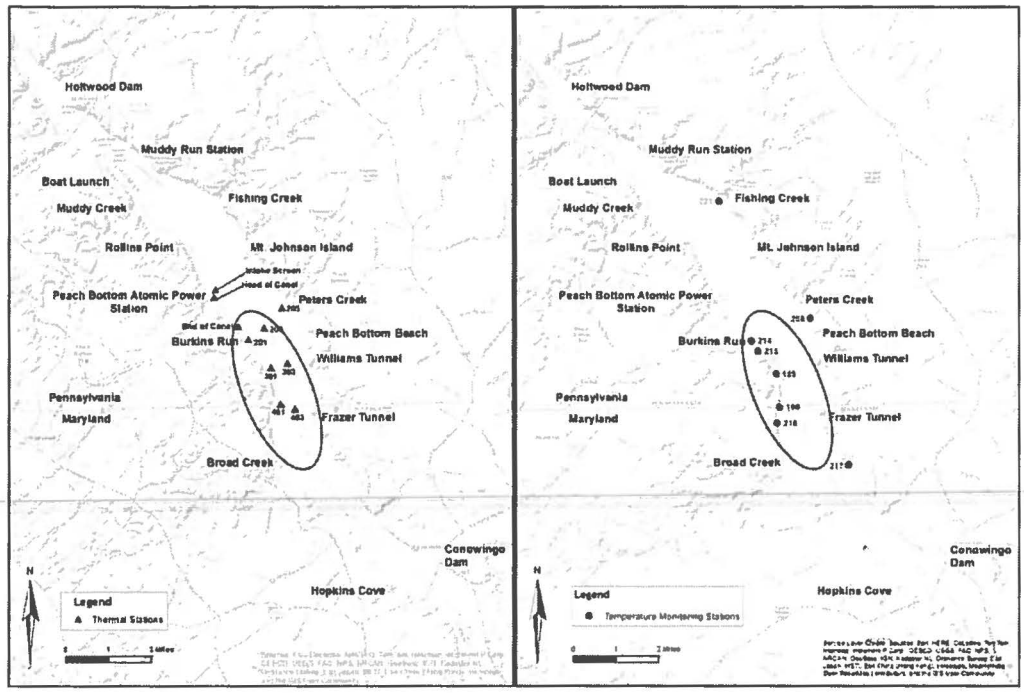


Figure 3-1 Location of 2016 temperature monitoring stations.

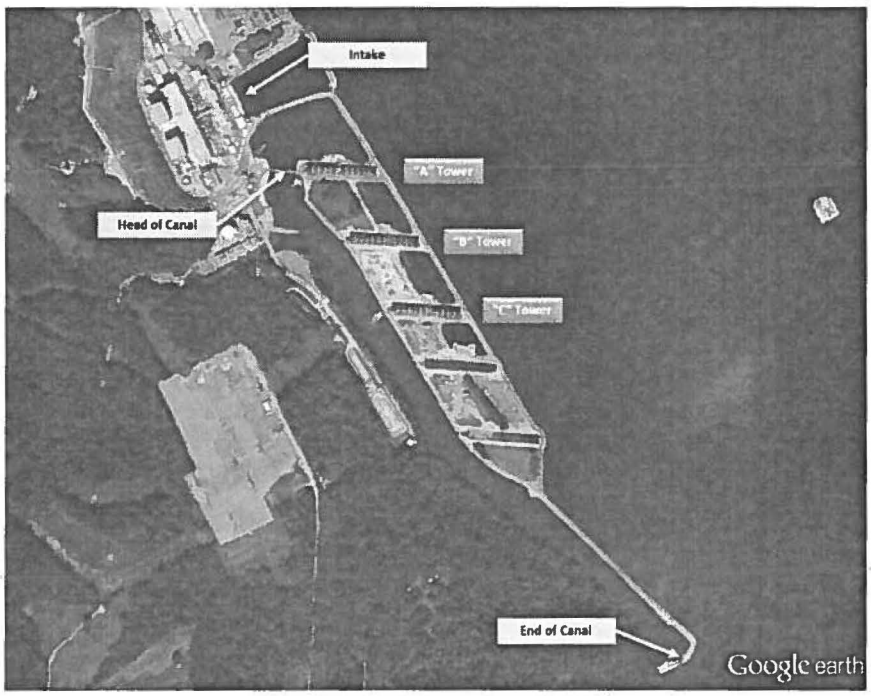


Figure 3-2 Location of 2016 intake and discharge canal temperature monitoring stations.

3.2.2 *Temperature Data Analysis*

There are four analytical deliverables, each of which is discussed below.

Duration and Frequency of High Temperatures

Because the Pre-EPU Demonstration Study presents the duration and frequency of high temperatures as part of the analysis of the biological data, the corresponding Post-EPU Study data are reported in Section 6.

Temperature Changes Due to Cooling Tower Operations

This section of the report quantifies temperature changes during cooling tower operations, first from the head of the discharge canal to the end, then at monitoring stations immediately downstream of the canal. During the post-EPU 2016 study period PBAPS operated at full load with the EPU and the cooling towers operated as set forth in Part C of the NPDES Permit (Figure 3-3).

> Cooling towers shall be operated for the combined operation of Units 2 and 3 during the period of June 15 through August 31 of each year, according to the sequential order. Average intake temperatures listed below are based on the prior two day rolling average using Unit 2 or Unit 3 circulating water intake temperature instrumentation:
>
> (1) One tower shall commence operation on June 15 and shall operate continuously through August 31. Should environmental conditions warrant, the Permitee may request that DEP authorize a delay in commencement of such tower operation.
>
> (2) A second cooling tower shall commence operation within 48 hours of average intake temperatures being equal to or greater than 83°F. Once operation has commenced, the second tower shall operate continuously through August 31. Should environmental conditions warrant, the Permitee may request that DEP authorize the termination of the second tower operation prior to August 31.
>
> (3) A third cooling tower shall commence operation within 48 hours of average intake temperatures being equal to or greater than 86°F. The tower shall operate continuously for seven days, and shall cease operation on the first day, following the seven days, when the average intake temperature is less than 86°F. Thereafter, the third tower shall commence and cease operations when the conditions set forth herein reoccur.

Figure 3-3 Excerpt from the NPDES Permit, Part C describing the cooling tower operating schedule.

In the following discussion, temperatures will generally be presented as temperature differences, e.g., increases over ambient[2] or reductions from the temperature measured at the head of the canal. This approach facilitates year-to-year and model-to-observations comparisons.

[2] Ambient is assumed to be equivalent to the temperature measured at the PBAPS intake.

Cooling tower performance, measured by temperature reductions in the canal, is discussed next, followed by a discussion of temperature reductions in Conowingo Pond downstream of the discharge with respect to the number of cooling towers operating.

Figure 3-4 shows the number of towers in operation through the summer of 2016, with start-up and shutdown times highlighted in Table 3-4. This table shows dates beginning five days before start-up of the first tower and ending five days after shutdown of the last tower.

Figure 3-5 shows observed temperatures at the intake, head of canal, and end of canal[3] for May through September 2016. Temperatures at Monitoring Station 214 are also shown for reference. Figure 3-5 shows that there is only a small temperature reduction from the head to the end of canal through June 15th (orange and black lines), but that the temperature reduction increases as each tower starts up (note the separation of orange and black lines).

Figure 3-6 shows the same locations but the temperatures in this figure are shown as <u>increases</u> above intake temperature.

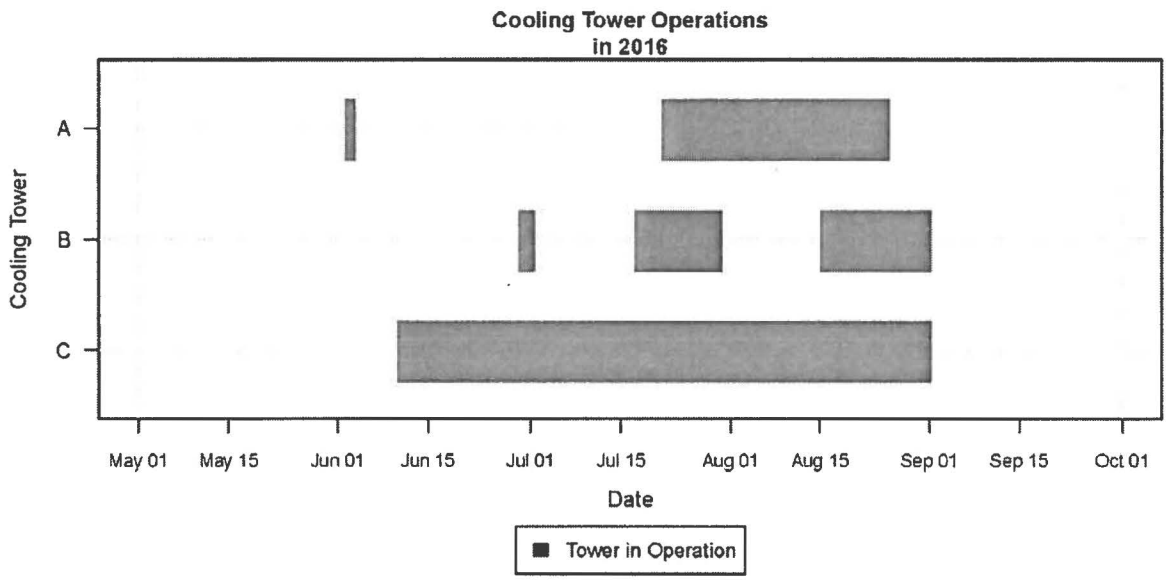


Figure 3-4 Summer 2016 cooling tower operations.

Table 3-4 Cooling tower start-up and shutdown dates.

Date	Cooling Tower A Status	Cooling Tower B Status	Cooling Tower C Status
6/6/2016	Off	Off	Off
6/7/2016	Off	Off	Off
6/8/2016	Off	Off	Off
6/9/2016	Off	Off	Off

[3] The end of canal monitoring station is called Outfall 001 in the NPDES Permit.

Date	Cooling Tower A Status	Cooling Tower B Status	Cooling Tower C Status
6/10/2016	Off	Off	Off
6/11/2016	Off	Off	**On**
6/12/2016	Off	Off	Off
6/13/2016	Off	Off	Off
6/14/2016	Off	Off	**On**
6/15/2016	Off	Off	**On**
6/16/2016	Off	Off	**On**
6/17/2016	Off	Off	**On**
6/18/2016	Off	Off	**On**
6/19/2016	Off	Off	**On**
6/20/2016	Off	Off	**On**
6/21/2016	Off	Off	**On**
6/22/2016	Off	Off	**On**
6/23/2016	Off	Off	**On**
6/24/2016	Off	Off	**On**
6/25/2016	Off	Off	**On**
6/26/2016	Off	Off	**On**
6/27/2016	Off	Off	**On**
6/28/2016	Off	Off	**On**
6/29/2016	Off	Off	**On**
6/30/2016	Off	**On**	**On**
7/1/2016	Off	**On**	**On**
7/2/2016	Off	Off	**On**
7/3/2016	Off	Off	**On**
7/4/2016	Off	Off	**On**
7/5/2016	Off	Off	**On**
7/6/2016	Off	Off	**On**
7/7/2016	Off	Off	**On**
7/8/2016	Off	Off	**On**
7/9/2016	Off	Off	**On**
7/10/2016	Off	Off	**On**
7/11/2016	Off	Off	**On**
7/12/2016	Off	Off	**On**
7/13/2016	Off	Off	**On**
7/14/2016	Off	Off	**On**
7/15/2016	Off	Off	**On**
7/16/2016	Off	Off	**On**
7/17/2016	Off	**On**	**On**
7/18/2016	Off	**On**	**On**
7/19/2016	Off	**On**	**On**
7/20/2016	Off	**On**	**On**
7/21/2016	Off	**On**	**On**

Date	Cooling Tower A Status	Cooling Tower B Status	Cooling Tower C Status
7/22/2016	**On**	**On**	**On**
7/23/2016	**On**	**On**	**On**
7/24/2016	**On**	**On**	**On**
7/25/2016	**On**	**On**	**On**
7/26/2016	**On**	**On**	**On**
7/27/2016	**On**	**On**	**On**
7/28/2016	**On**	**On**	**On**
7/29/2016	**On**	**On**	**On**
7/30/2016	**On**	**On**	**On**
7/31/2016	**On**	Off	**On**
8/1/2016	**On**	Off	**On**
8/2/2016	**On**	Off	**On**
8/3/2016	**On**	Off	**On**
8/4/2016	**On**	Off	**On**
8/5/2016	**On**	Off	**On**
8/6/2016	**On**	Off	**On**
8/7/2016	**On**	Off	**On**
8/8/2016	**On**	Off	**On**
8/9/2016	**On**	Off	**On**
8/10/2016	**On**	Off	**On**
8/11/2016	**On**	Off	**On**
8/12/2016	**On**	Off	**On**
8/13/2016	**On**	Off	**On**
8/14/2016	**On**	Off	**On**
8/15/2016	**On**	Off	**On**
8/16/2016	**On**	**On**	**On**
8/17/2016	**On**	**On**	**On**
8/18/2016	**On**	**On**	**On**
8/19/2016	**On**	**On**	**On**
8/20/2016	**On**	**On**	**On**
8/21/2016	**On**	**On**	**On**
8/22/2016	**On**	**On**	**On**
8/23/2016	**On**	**On**	**On**
8/24/2016	**On**	**On**	**On**
8/25/2016	**On**	**On**	**On**
8/26/2016	Off	**On**	**On**
8/27/2016	Off	**On**	**On**
8/28/2016	Off	**On**	**On**
8/29/2016	Off	**On**	**On**
8/30/2016	Off	**On**	**On**
8/31/2016	Off	**On**	**On**
9/1/2016	Off	Off	Off

Date	Cooling Tower A Status	Cooling Tower B Status	Cooling Tower C Status
9/2/2016	Off	Off	Off
9/3/2016	Off	Off	Off
9/4/2016	Off	Off	Off
9/5/2016	Off	Off	Off

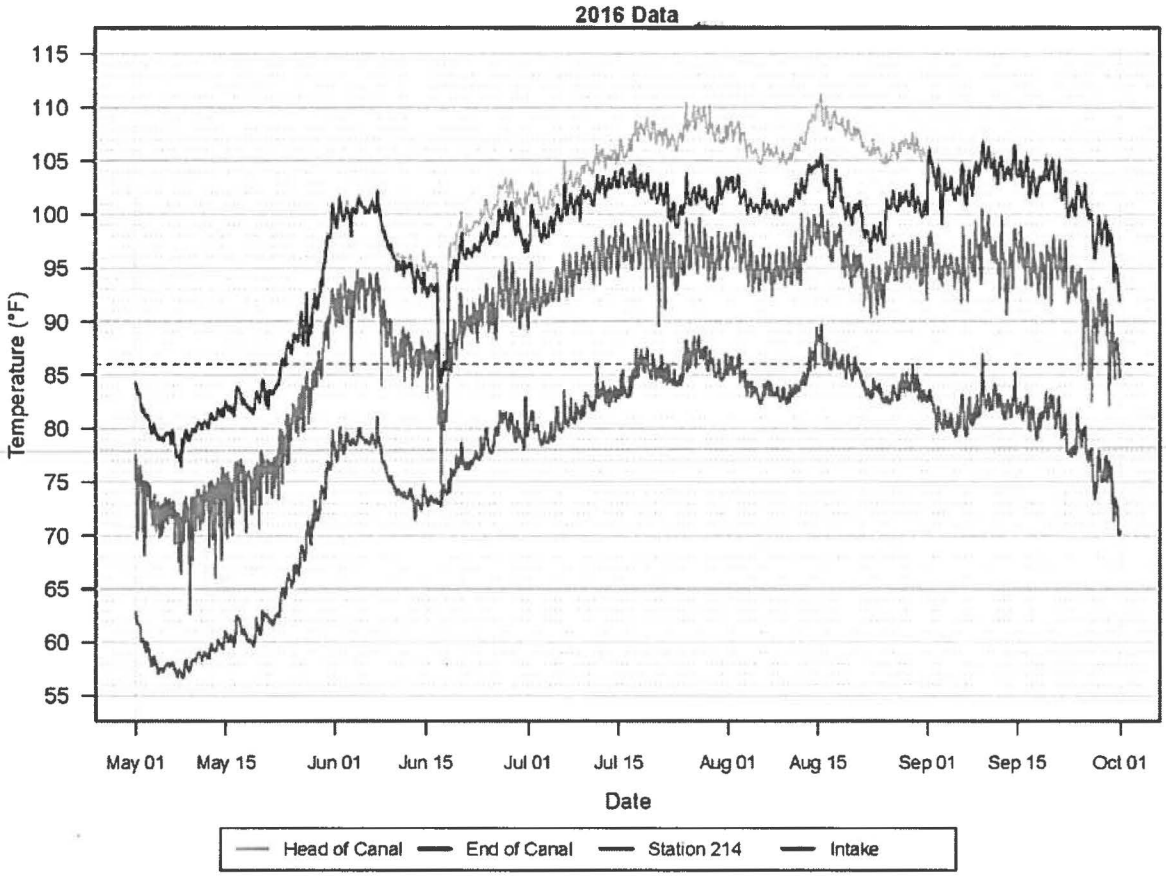


Figure 3-5 Temperatures in the discharge canal and at Monitoring Station 214.

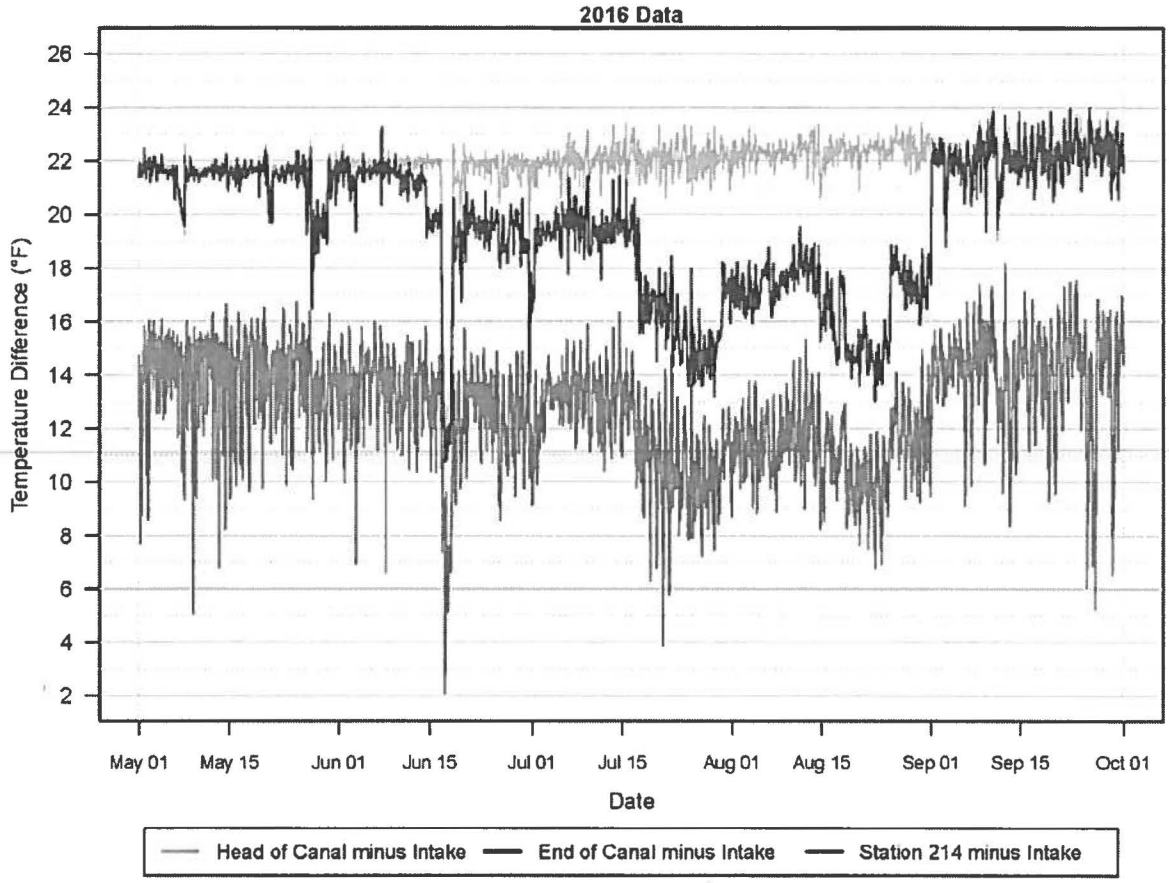


Figure 3-6 Summer 2016 temperatures presented as increases above intake temperature.

The mean temperature increase from intake to head of canal was 22.1°F which is to be compared to the post-EPU condenser temperature rise of 22.4°F used in the Pre-EPU Demonstration Study. The condenser temperature rise is an important parameter because it, along with the condenser flow rate, represents the heat released by PBAPS to Conowingo Pond. As was the case for the data taken during the Pre-EPU Demonstration Study, there was some variation in this number in 2016, as shown in Table 3-5, with occasional, short duration exceedances of 22.4°F.

Table 3-5 Temperature increases from the intake to the head of canal for 2016

Period	Temperature increase (°F) from the intake to head of canal		
	Min	Mean	Max
All Months	18.7	22.1	24.0
April	19.2	21.6	22.7
May	19.3	21.7	22.6
June	18.7	21.9	22.7
July	20.3	22.0	23.4
August	20.6	22.4	23.4

Period	Temperature increase (°F) from the intake to head of canal		
	Min	Mean	Max
September	19.0	22.5	24.0

In 2016 there was one period with one tower in operation, two periods with two cooling towers in operation, and two periods with three cooling towers in operation. By analyzing each period separately, cooling tower temperature reductions on a per tower basis can be calculated. This calculation shows that the value of the per tower temperature decrease in the canal was 2.2°F, which exceeds the 1.6°F found for the 2010 through 2013 Pre-EPU Demonstration Study dataset. The reason for the improvement is believed to be maintenance upgrades performed on the cooling towers. The decrease in temperature in the canal absent cooling towers was 0.2°F, identical to the value found in the Pre-EPU Demonstration Study.

As noted in Section 3.4 of the Pre-EPU Demonstration Study (Table 3-5) observed temperature reductions in Conowingo Pond downstream of the discharge canal ranged from 2.1°F to 0.0°F and were highly variable (Section 3.4 "Effectiveness of Cooling Towers in Reducing Downstream Temperatures" in that same report). Similar values and variability were found in the 2016 data period, summarized in Table 3-6 below.

Temperature changes at downstream stations due to cooling tower operation are further discussed in "Model Verification," below.

Table 3-6 Temperature reduction as a function of number of cooling towers in operation at downstream stations.

Monitoring Station	Temperature reduction per cooling tower (°F)			
	1 tower	2 towers	3 towers	Average
214	1.2	1.2	1.3	1.2
215	1.2	1.1	1.0	1.1
301S	0.9	0.8	0.8	0.8
189	0.5	0.6	0.6	0.6

Transition Period Temperatures

This section of the Post-EPU Study report presents observed temperatures changes in the discharge canal and downstream in Conowingo Pond during cooling tower start-ups and shutdowns.

In general there are six common transitions (three start-ups and three shutdowns) built into the cooling tower operating schedule (Figure 3-3):

- Start-up of the first cooling tower operation on June 15 and shutdown on August 31st
- Start-up of the second cooling tower when intake temperatures reach 83°F; shutdown on August 31st
- Start-up of the third cooling tower when intake temperatures reach 86°F; operation for at least seven days; shutdown when temperatures are below 86°F (multiple start-ups and shutdowns of the third tower in a single summer are possible).

Examples of all six common transitions occurred in 2016. Figure 3-6 and Table 3-4 show the start-up and shutdown dates for each cooling tower in the summer of 2016. From the table, three periods in 2016 which capture all six common transitions were selected for further analysis:

- Start-up of the first tower in mid-June 2016
- Start-up of the second and third towers, shutdown of the third tower in the second half of July 2016
- Shutdown of all three towers in the second half of August.

Temperature reductions and increases associated with these transitions are shown in Figure 3-7, Figure 3-8, and Figure 3-9. The figures show temperature reductions (or increases when a tower shuts down) relative to intake temperatures at the end of the canal, at Monitoring Station 214, and the number of towers in operation (right hand vertical scale). Taken together these figures span a period that begins five days prior to the first transition and ends five days after the last transition. Each figure focuses on a particular type of transition (e.g., from one to two towers). The noticeable decrease in temperature on June 17th (Figure 3-7) is not related to cooling tower operations, but instead to a sudden reduction in generation that results in the discharge of less waste heat.

Although temperature changes at the end of the canal are reasonably clear in all three figures, the changes are less obvious at Monitoring Station 214. Operation of the cooling towers reduce temperatures at Monitoring Station 214 when viewed over a multi-day period, but these changes are obscured when viewed on an hourly basis by fluctuations due the daily cycle of pumpback and generation operations at MRPSF, by heat loss to the atmosphere, and variable entrainment of cooler ambient water.

Numerical values of temperature reductions and increases corresponding to the figures are tabulated in Table 3-7, Figure 3-8 and Table 3-9.

The simulations conducted for the Pre-EPU Demonstration Study were stationery-state, i.e., all input parameters were held constant except for pumpback and generation at MRPSF. Stationery-state means that a repeating cycle of flows and temperatures in Conowingo Pond was calculated. The length of the repeating cycle is dictated by the frequency of operations at MRPSF. Cooling tower operations in the model were held constant throughout the simulation periods and for this reason transition period temperatures were not explicitly modeled.

The model does compute velocities from which estimates of the travel time to downstream stations can be obtained. These times are shown in Table 3-10 which shows that travel times are short – less than half an hour to Monitoring Station 214 and less than four hours to Monitoring Station 189. That the hourly observations cannot distinguish the arrival time of cooler water is a consequence of the short travel time.

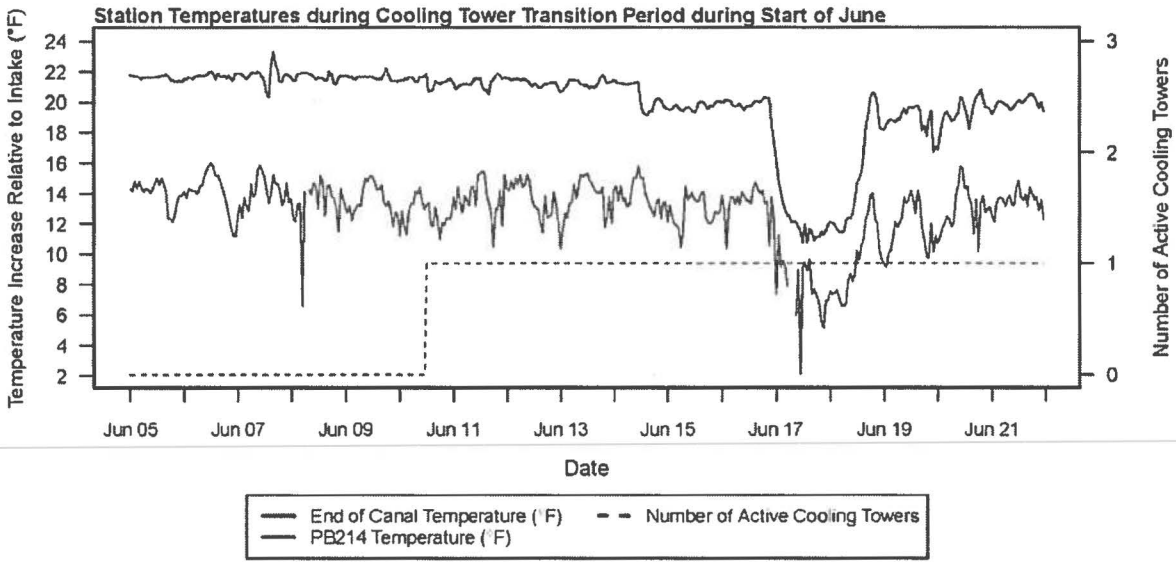


Figure 3-7 End of canal and 214 temperatures during startup of the first cooling tower.

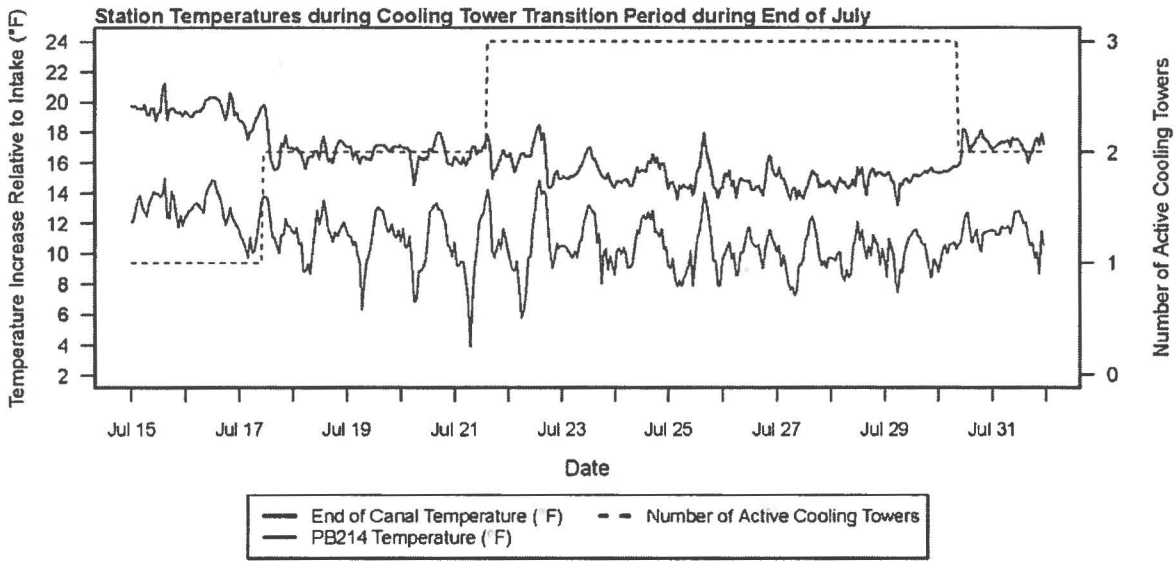


Figure 3-8 End of canal and 214 temperatures during the transitions from two to three to two cooling towers.

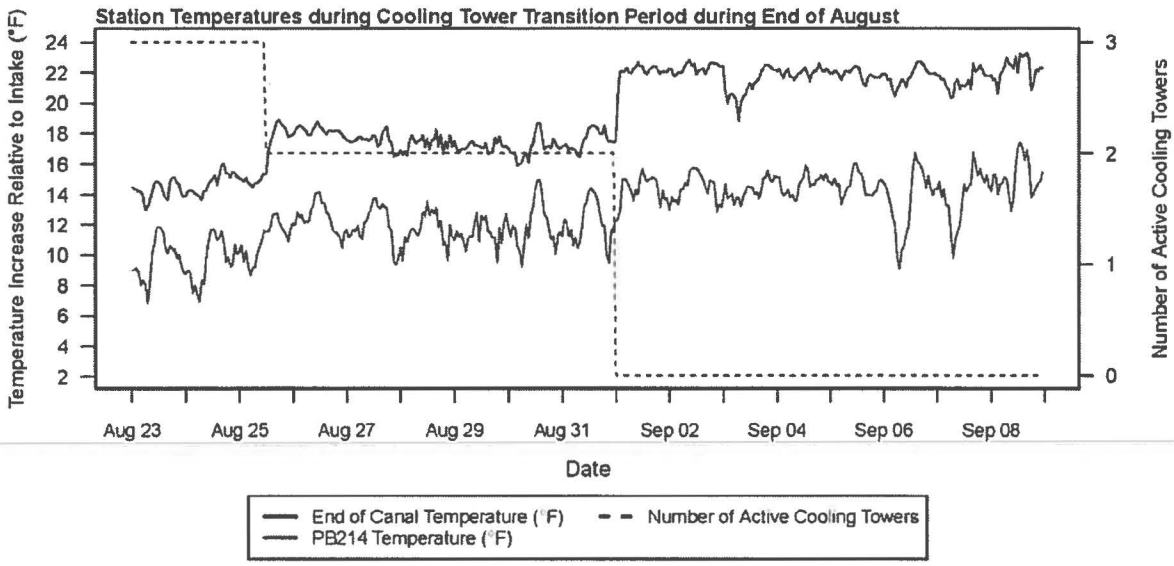


Figure 3-9 End of canal and 214 temperatures during shutdown of all three towers.

Table 3-7 End of canal and 214 daily average, minimum, and maximum temperatures relative to intake temperatures during startup of the first cooling tower.

Date	End of Canal Difference Relative to Intake (°F)			PB214 Difference Relative to Intake (°F)		
	Min	Mean	Max	Min	Mean	Max
6/5/2016	21.3	21.6	21.8	12.1	14.0	15.0
6/6/2016	21.4	21.7	22.0	11.2	14.1	16.0
6/7/2016	20.3	21.8	23.3	12.4	14.1	15.8
6/8/2016	21.1	21.7	22.0	6.6	13.4	15.2
6/9/2016	21.4	21.6	22.3	11.8	13.6	15.2
6/10/2016	20.7	21.4	21.8	11.0	12.6	14.4
One cooling tower starts up, one now running						
6/11/2016	20.5	21.3	21.9	10.5	13.7	15.5
6/12/2016	20.9	21.3	21.6	11.4	13.7	15.2
6/13/2016	20.6	21.2	21.8	10.4	13.7	15.3
6/14/2016	19.1	20.5	21.5	12.4	13.9	15.8
6/15/2016	19.3	19.7	20.0	10.4	12.8	14.5
6/16/2016	17.4	19.8	20.3	10.3	13.4	14.7
6/17/2016	10.8	12.2	16.2	2.1	7.7	11.3
6/18/2016	11.4	15.1	20.6	6.6	9.6	14.0
6/19/2016	16.7	18.8	19.8	9.1	11.8	14.2
6/20/2016	16.9	19.3	20.8	10.1	13.0	15.8
6/21/2016	19.2	19.9	20.5	12.1	13.5	14.8

Table 3-8 End of canal and 214 daily average, minimum, and maximum temperatures during transitions from two to three then back to two cooling towers in operation.

Date	End of Canal Difference Relative to Intake (°F)			PB214 Difference Relative to Intake (°F)		
	Min	Mean	Max	Min	Mean	Max
7/15/2016	18.8	19.5	21.2	11.7	13.2	15.0
7/16/2016	18.8	19.7	20.6	11.9	13.2	14.9
One cooling tower starts up, two now running						
7/17/2016	15.5	17.8	19.8	9.8	11.5	13.8
7/18/2016	15.6	16.7	17.7	8.7	11.2	13.5
7/19/2016	15.9	16.8	17.2	6.3	11.0	13.1
7/20/2016	14.5	16.6	18.0	6.8	10.7	13.3
7/21/2016	15.0	16.4	17.8	3.9	10.2	14.2
One cooling tower starts up, three now running						
7/22/2016	14.3	16.3	18.5	5.8	10.4	14.9
7/23/2016	14.5	15.5	17.0	8.0	10.7	13.2
7/24/2016	14.4	15.3	16.6	8.6	10.9	12.8
7/25/2016	13.6	14.9	18.0	7.8	9.8	14.0
7/26/2016	13.7	14.8	16.5	8.5	10.3	11.8
7/27/2016	13.6	14.5	15.6	7.2	9.7	12.5
7/28/2016	13.8	14.9	15.7	8.2	10.0	12.1
7/29/2016	13.2	15.0	15.7	7.5	9.9	11.6
One cooling tower shuts down, two now running						
7/30/2016	15.3	16.6	18.2	8.8	10.9	12.7
7/31/2016	15.9	17.2	17.9	8.7	11.4	12.8

Table 3-9 End of canal and 214 daily average, minimum, and maximum temperatures during shutdown of all three towers.

Date	End of Canal Difference Relative to Intake (°F)			PB214 Difference Relative to Intake (°F)		
	Min	Mean	Max	Min	Mean	Max
8/23/2016	13.0	14.3	15.1	6.8	9.7	11.9
8/24/2016	13.6	14.8	16.1	6.9	9.6	11.7
One cooling tower shuts down, two now running						
8/25/2016	14.5	16.4	18.9	8.7	10.9	12.8
8/26/2016	17.8	18.2	18.8	10.5	12.5	14.1
8/27/2016	16.5	17.5	18.5	9.3	12.0	13.7
8/28/2016	16.5	17.4	18.3	9.6	11.7	13.5
8/29/2016	16.7	17.2	17.8	9.5	11.5	12.8
8/30/2016	15.9	17.1	18.7	9.2	11.9	14.9
8/31/2016	16.4	17.6	18.5	9.5	12.1	14.4
Two cooling towers shut down, none now running						
9/1/2016	17.5	21.9	22.7	12.2	14.3	15.7
9/2/2016	21.8	22.3	22.9	12.8	14.4	15.7
9/3/2016	18.8	21.2	22.5	13.2	14.2	15.6
9/4/2016	21.4	22.0	22.6	13.6	14.7	15.9
9/5/2016	21.1	21.9	22.4	13.3	14.6	16.1
9/6/2016	20.4	21.8	22.8	9.1	13.6	16.7
9/7/2016	20.3	21.5	22.6	9.8	13.9	16.8
9/8/2016	20.6	22.2	23.3	12.9	15.1	17.4

Table 3-10 Travel time to reach the monitoring stations

Station	Incremental distance from the next upstream station (mi)	Average velocity from the next upstream station (ft/s)	Total travel time to reach the monitoring station (hours)
End of canal	0.37	-	-
214	0.28	1.39	0.4
215	0.67	0.78	0.9
189	0.37	0.33	3.9

Model Verification

Model verification was performed in two steps: (1) validation of model assumptions and (2) comparison of modeled and observed temperatures. There were two model assumptions that in combination quantify the amount of heat released to Conowingo Pond: (1) the post-EPU temperature rise from the intake to the head of canal and (2) the performance of the cooling towers.

For the post-EPU temperature rise, the model assumed a temperatures rise of 22.4°F from the PBAPS intake to the head of canal. The value of 22.4°F is the sum of the pre-EPU rise of 19.4°F and the post-EPU temperature increase of 3.0°F. The assumed pre-EPU rise of 19.4°F was based on the observed rise for all July's and August's from 2010 to 2013 (typically the warmest months). As shown in Table 3-5, the 2016 values of 22.1°F (entire summer) and 22.2°F (July and August) were measured. The mean post-EPU temperature rise from the intake to the head of the canal for July and August of 22.2°F is less than the 22.4°F assumed value, thus validating this model assumption.

The second model assumption is the extent to which temperatures in the discharge canal are reduced, both from natural cooling and from operation of the cooling towers. The model assumed natural cooling in the discharge canal (i.e., with no cooling towers operating) to be 0.2°F based on the 2010 – 2013 dataset. This same value was measured in 2016. For temperature reduction in the discharge canal, the model assumed 1.6°F for each cooling tower, a value also based on the 2010 – 2013 dataset. The observations showed that in 2016, the per tower discharge canal cooling was 2.2°F, greater than that assumed for the typical and extreme modeling scenarios and showing that the value assumed in the modeling was conservative.

For the comparisons of modeled and observed temperature increases at downstream stations, data for the four monitoring stations shown in Figure 3-10 were examined. These stations were identified in the Pre-EPU Demonstration Study as those which experienced the warmest temperatures, the clearest effects of cooling tower operations and the largest biological impacts. That the warmest temperatures occur at these monitoring stations is a consequence of the fact that the thermal plume generally follows along the western shore.

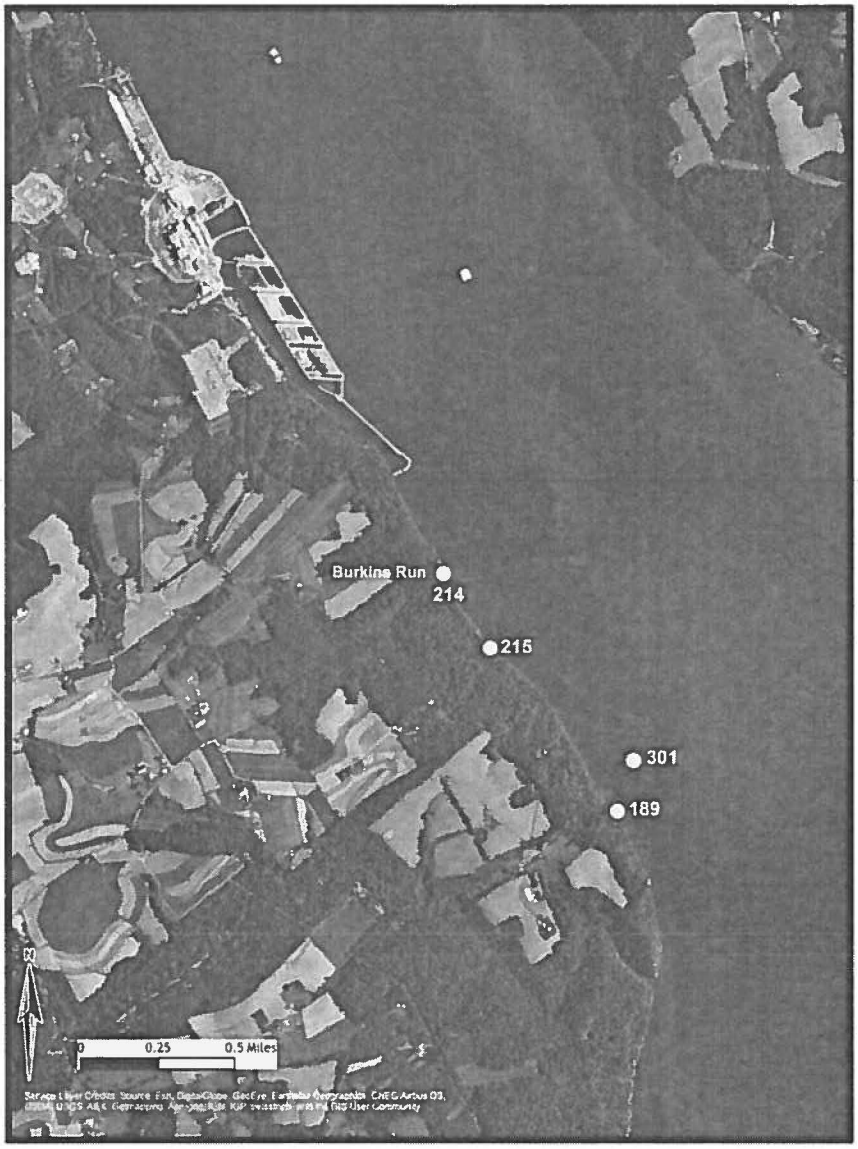


Figure 3-10 Monitoring stations used for the model verification.

There are hourly observations at each monitoring station for five months in the 2016 dataset available for comparison with the modeled results published in the Pre-EPU Demonstration Study. However the Pre-EPU Demonstration Study only predicts post-EPU temperatures for typical (10%) and extreme (1%) flow and temperature conditions (see Section 3.1 for definitions). Among the observations are relatively few instances where the combination of Susquehanna River flows and temperatures approach those used for the typical and extreme condition scenarios. To verify the model, therefore, it is sufficient to show that all observed temperature increases are no larger than the modeled results.

The 2016 observations are shown as the cumulative frequency of exceedance of temperature increases above ambient, expressed as a percentage of all observations in Figure 3-11, Figure

3-12, Figure 3-13, and Figure 3-14. Model results are shown as the blue band that is bounded at the top by modeled extreme temperature increases and at the bottom by modeled average temperature increases.

These figures show that nearly all of the observed temperature increases are below the modeled values (extreme conditions; right side of each panel). The exceptions are

- for Monitoring Station 214, 3 cooling towers in operation: 1 exceedence out of 456 observations (0.2%)
- for 215, no cooling towers: 5 exceedences out of 1696 observations (0.3%)
- for 215, 1 cooling tower: 1 exceedence out of 816 observations (0.1%)
- for 215, 3 cooling towers, 2 exceedences out of 448 observations (0.4%).

These exceedances do no impair the overall functionality of the model in bounding the modeled upper temperatures.

The figures show all the 2016 data, including observations at higher flows and lower temperatures than the flows and temperatures used in the model. These observations are shown on the left side of each panel and typically represent about 10% of the observations.

In the figures, the comparisons are shown by the number of cooling towers operating for each monitoring station. Temperatures decrease as more cooling towers are in operation, as expected, and decrease in the downstream direction, also as expected. The fact that observed temperature increases fall into or below the modeled values can be taken as evidence that the model results agree well with observed values.

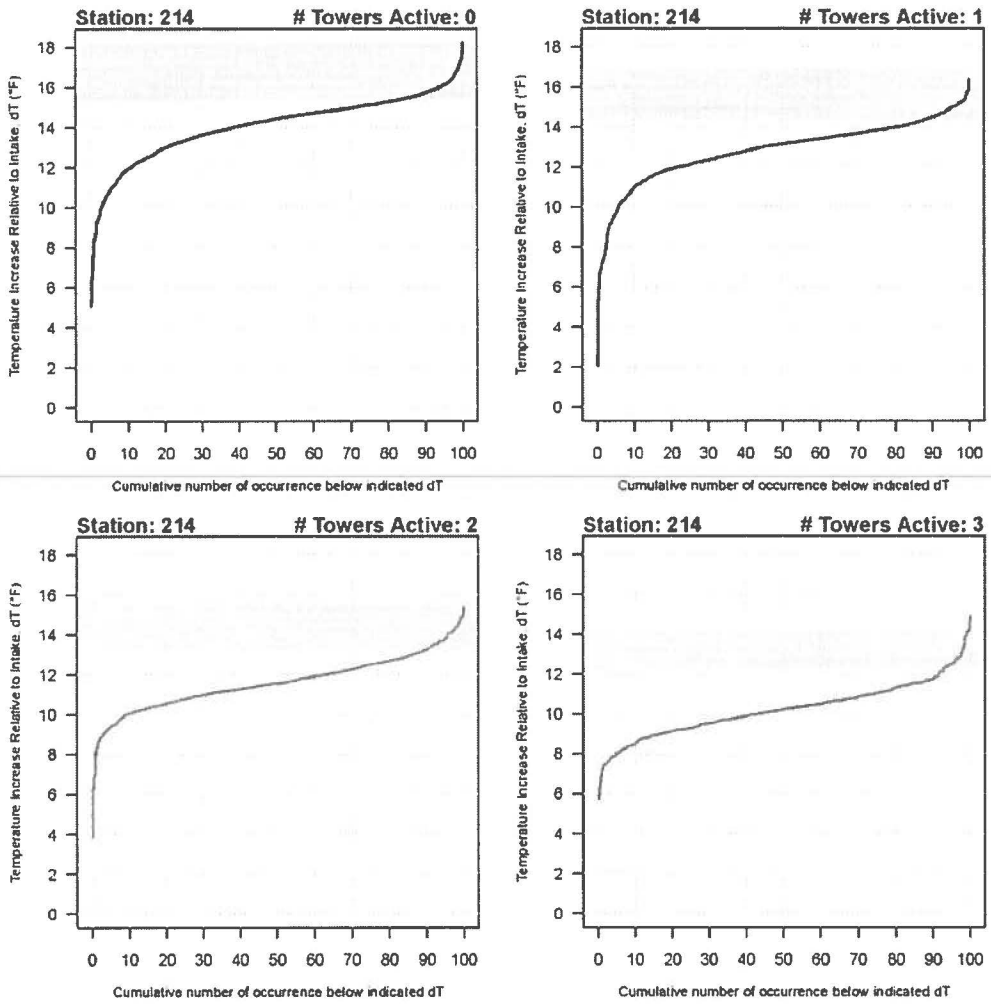


Figure 3-11 Comparisons of modeled and observed temperature increases at 214.

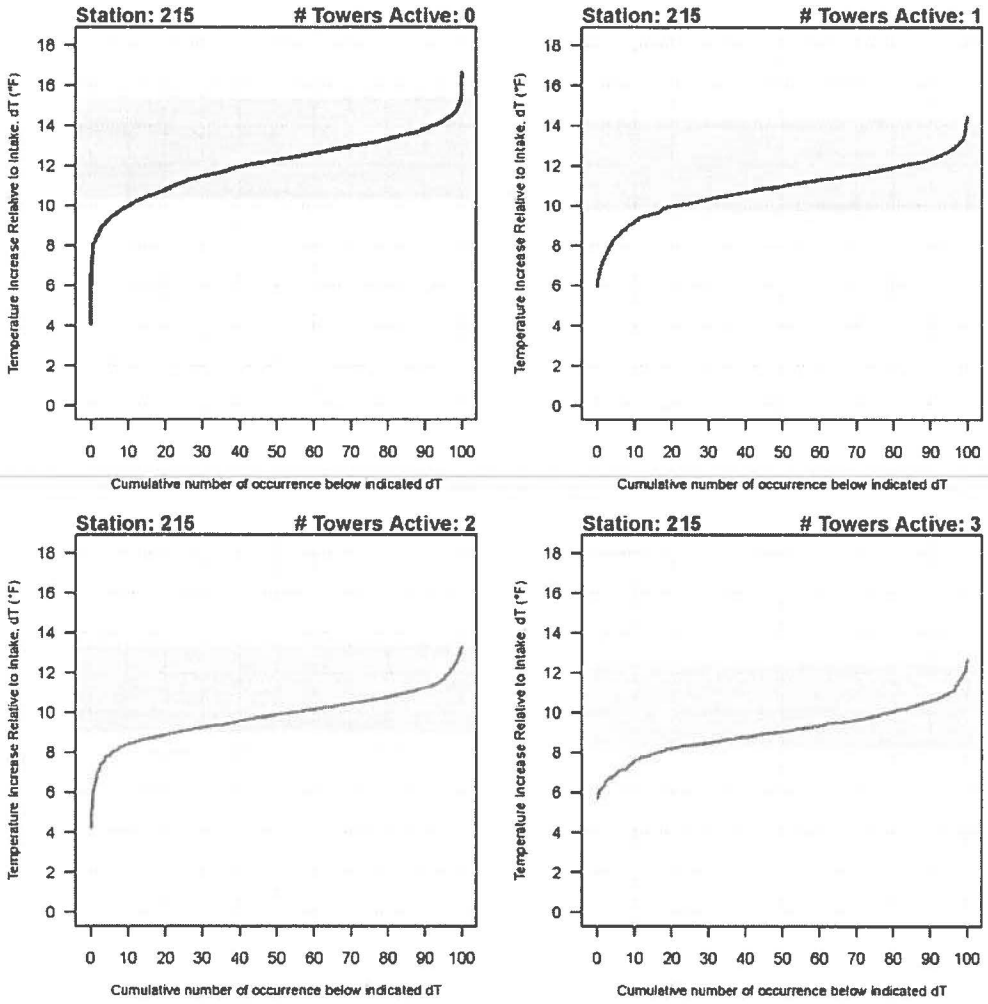


Figure 3-12 Comparisons of modeled and observed temperature increases at 215.

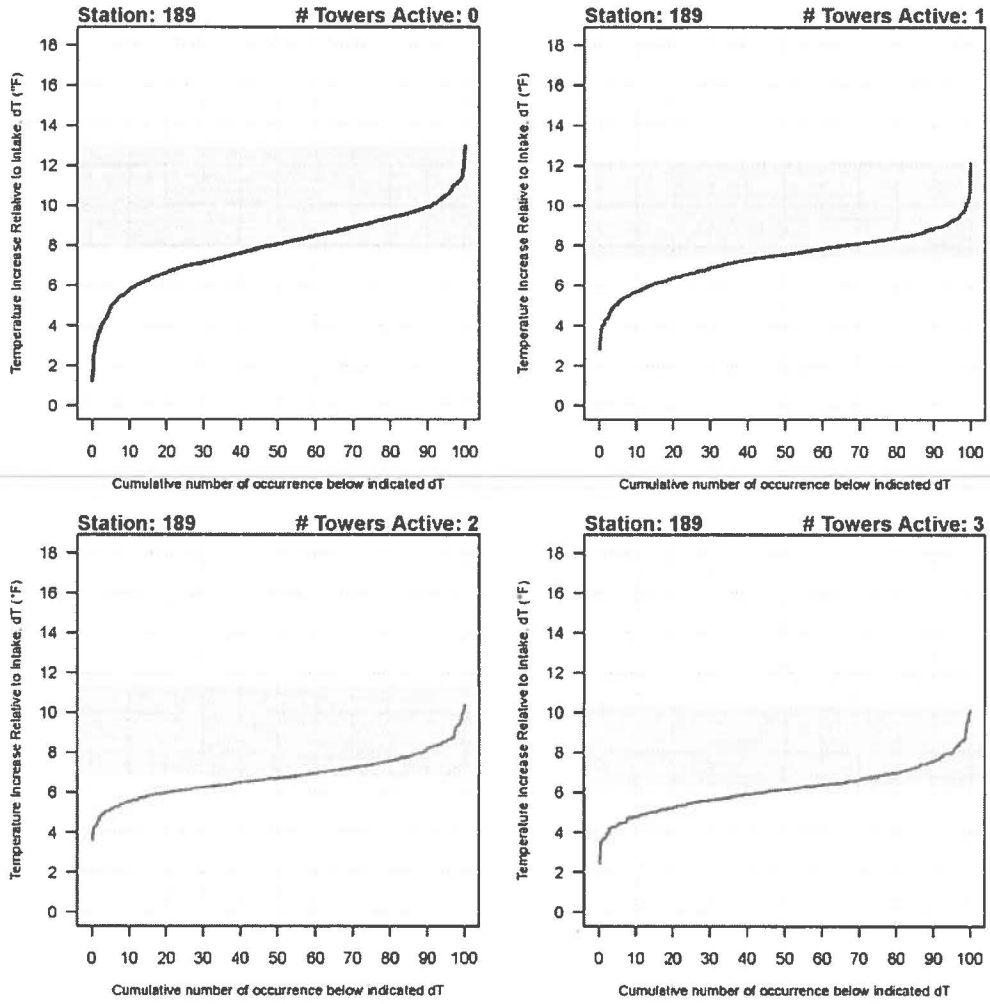


Figure 3-13 Comparisons of modeled and observed temperature increases at 189.

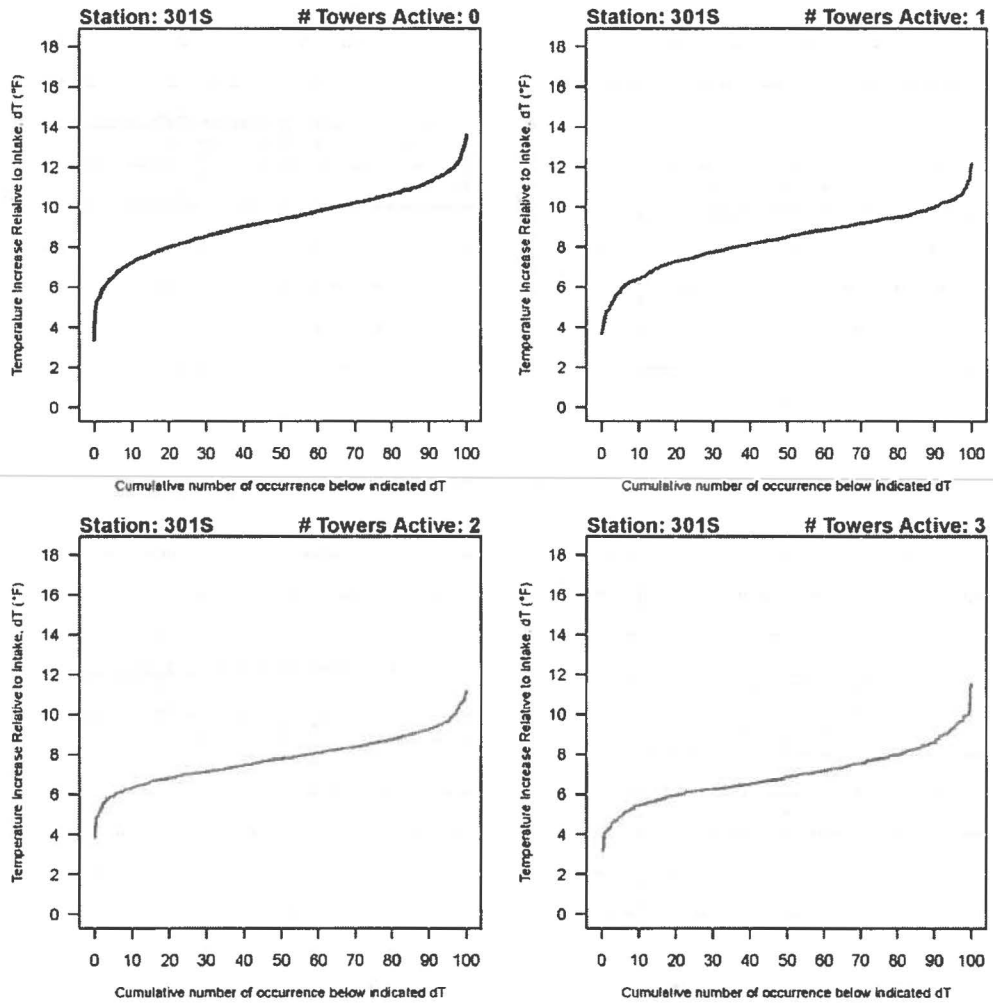


Figure 3-14 Comparisons of modeled and observed temperature increases at 301S.

3.2.3 Thermal Plume Monitoring Conclusions

The year 2016 featured Susquehanna River flows and temperatures that were at extreme values. For that reason, 2016 was ideally suited as the follow-on study year to the Pre-EPU Demonstration Study because extreme temperatures occurred and temperatures increases due to the EPU, temperature reductions when cooling towers operate, and resulting net temperature increases in Conowingo Pond could be directly measured.

The Pre-EPU Demonstration Study model assumptions were validated as each cooling tower provided more cooling than expected (2.2°F instead of 1.6°F) and the temperature increase from the intake to the head of canal was 22.1°F, less than the assumed post-EPU condenser temperature rise of 22.4°F. The observed temperatures at the warmest, most biologically sensitive monitoring stations were less than modeled temperatures for extreme conditions presented in the 316(a) Demonstration Study. The modeled temperatures had been used in the

Pre-EPU Demonstration Study as the basis for the biological assessment of post-EPU conditions and therefore, were sufficiently conservative.

The field observations show that operation of the cooling towers effectively mitigates the additional heat generated by the EPU during the summer period.

4 Biological Station Temperature Monitoring

The temperature record observed at the biological stations is critical to understanding the influence of the PBAPS thermal plume on the biological community. Continuous temperature monitoring was completed at all of the benthic macroinvertebrate and fish seining collection stations, and four of the six electrofishing stations (no monitoring at Stations 165 and 187) (Figure 4-1). Monitoring was performed *in situ* using Onset HOBO® Pro v2 Water Temperature Data Loggers. These instruments are accurate to 0.36°F in the range 32°F to 122°F and have a five-minute response time in water. The loggers recorded water temperature every hour and were located on the river bottom in shallow shoreline locations (<5 ft water depth) where complete mixing of the water column occurs.

This analysis characterizes the biological water temperature monitoring stations. Monitoring locations are divided into those stations that are not influenced by the thermal plume (208, 221, PBAPS Intake) and those stations that are thermally influenced (214, 215, 189, 190, 216, and 217). The PBAPS Intake monitor was installed specifically for this study and is used as an ambient temperature reference. Note that although Station 208 is located along the east shoreline of the Pond and upstream from the end of the discharge canal, it does experience an increase in water temperature resulting from the PBAPS thermal discharge at low river flows during the summer months. This phenomenon is coincident with River flows less than 12,000 cfs and MRPSF pumpback operations (Normandeau and Gomez and Sullivan Engineers 2012). Thermally affected electrofishing Station 161 is characterized by the monitoring at Station 214 (a seine and benthos station). Thus, a separate water temperature monitor was not installed at Station 161.

The analysis provided herein includes post-EPU biological water temperature monitoring in 2016 and pre-EPU biological water temperature monitoring from 2010 through 2013. Comparison of water temperature observations at these locations is completed to identify differences in the duration and frequency of elevated water temperatures during each year of monitoring.

Ambient water temperatures measured in Conowingo Pond over the course of the 2016 study period (May 1 to September 30) followed a typical seasonal pattern for the Susquehanna River for most of the monitoring period with warmest temperatures observed during July and August (Figure 4-2) Water temperature during mid-August through September was elevated from the typical seasonal pattern with extraordinarily warm and dry and conditions during September.

Figure 4-2 through Figure 4-19 provide daily mean and daily instantaneous maximum water temperatures for each monitoring location during each year. The highest water temperatures at the biological monitoring stations were observed in July and August at Station 214, which is located along the west shoreline and is the monitoring station closest to the end of the PBAPS discharge canal (Figures 4-4 and 4-13). Water temperatures decreased in a downstream direction at monitoring locations farther downstream from the end of the discharge canal. The lowest ambient water temperatures were observed at Station 221, which is located upstream from the PBAPS intake along the east shoreline (Figure 4-3). Station 221 is located at the

confluence of Fishing Creek with Conowingo Pond. This monitoring location is strongly influenced by Fishing Creek. During periods of low pond elevation (MRPST pumpback or Conowingo Hydroelectric Station generation), this monitor essentially measured Fishing Creek water temperature.

Ambient water temperatures in 2016 were much warmer than previous years from mid-August through the end of September (Figure 4-3). The mean water temperature measured in September 2016 at the PBAPS intake was 5 °F warmer than the highest average termperature measured previously in September at the intake (Table 4-1).

Table 4-2 through Table 4-6 provide a summary of the of the number of exceedances (days) of both 80 and 90 °F threshholds for instantaneous maximum and mean daily water temperatures for the monitoring locations during each year of the study. The basis for these two water temperature values is that 80°F corresponds to a normal summer condition and 90°F corresponds to a temperature that does not typically occur under natural conditions in the Pond. The purpose is to provide a comparison of these two temperature points among the monitoring stations.

In 2016, water temperatures were warmer than previous years, with a greater number of days that the ambient water temperatures exceeded 80°F as instantaneous maximum or daily mean (Table 4-2). Similarly, the thermally influenced stations in 2016 had a greater number of days exceeding 90°F as instantaneous or daily mean compared to previous years. Overall, the monitoring data indicate that the warmest water temperatures were observed during a greater number of days in 2016 for all locations, compared to the other years. However, the water temperatures observed in 2010 were also high but the monitoring period was abbreviated (not initiated until July 28) and not directly comparable to other years in terms of absolute number of days exceeding 80 or 90°F.

As noted above, the highest water temperatures were observed to occur in July and August in 2010 through 2013 and July through September in 2016. Therefore, analyses of potential thermal effects on benthic macroinvertebrates and fish will focus on these months. However, the cumulative effects of elevated temperatures during the course of the year will also be considered. These types of cumulative effects, as opposed to just the highest temperatures in July, August, and September may potentially alter the aquatic assemblage, in particular, at the near-field stations (Stations 161, 214 and 215). Cumulative effects of elevated water temperatures will be evaluated for fish by documenting body condition, disease occurrence, length/age structure, and retrospective analysis of relative abundance. In addition, cumulative effects will be evaluated in comparisons of fish and benthic macroinvertebrate community composition (e.g. species richness, and diversity) between thermally influenced and non-thermally influenced collection locations.

The final data set was compiled into an Excel spreadsheet and the raw water temperature data and a list of collected daily average, minimum and maximum water temperatures was provided to PADEP in electronic format.

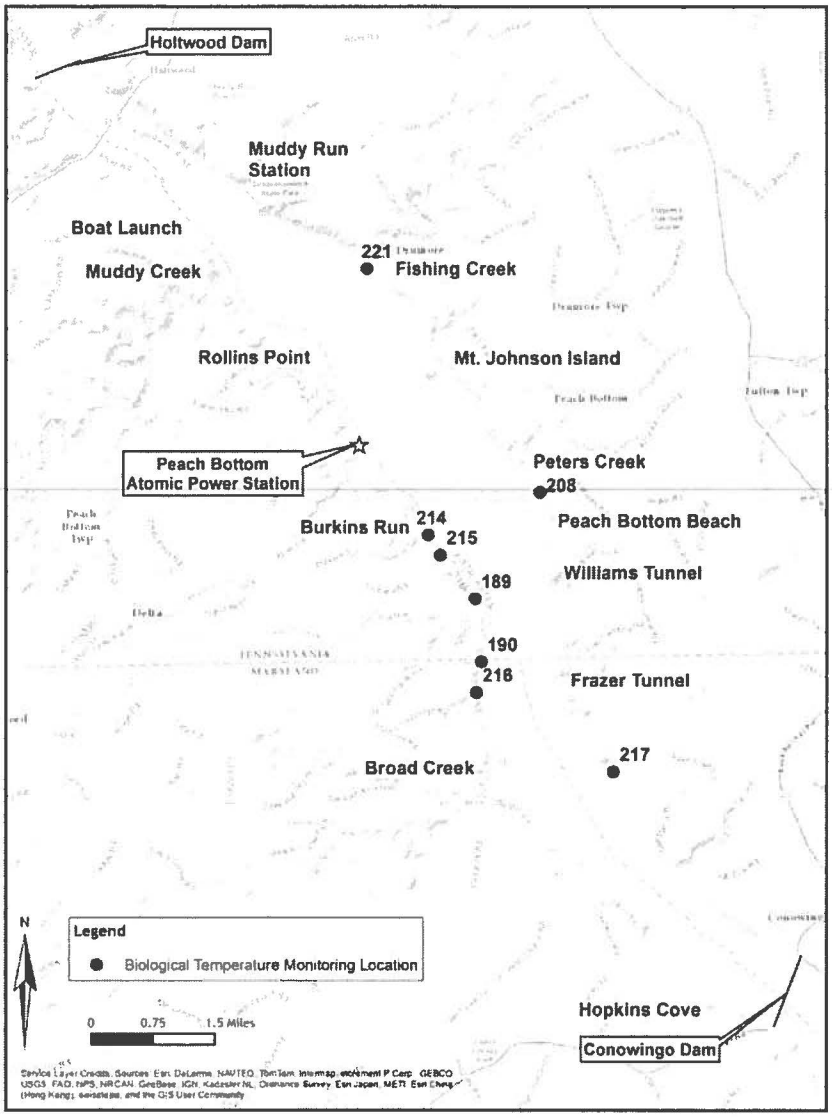


Figure 4-1. Location of biological water temperature collection stations.

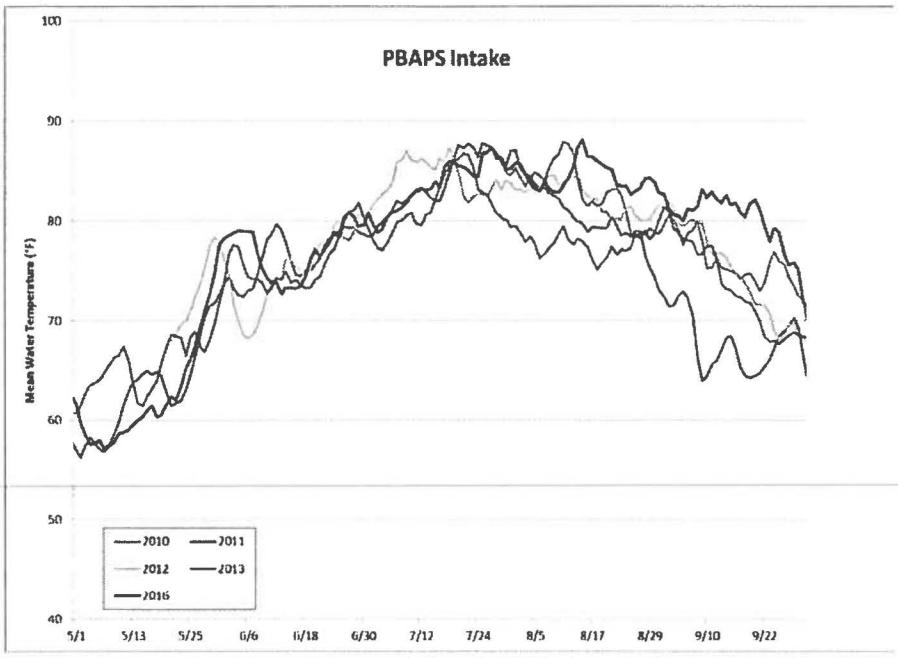


Figure 4-2. Daily mean water temperature measured at PBAPS Intake, 2010-2016.

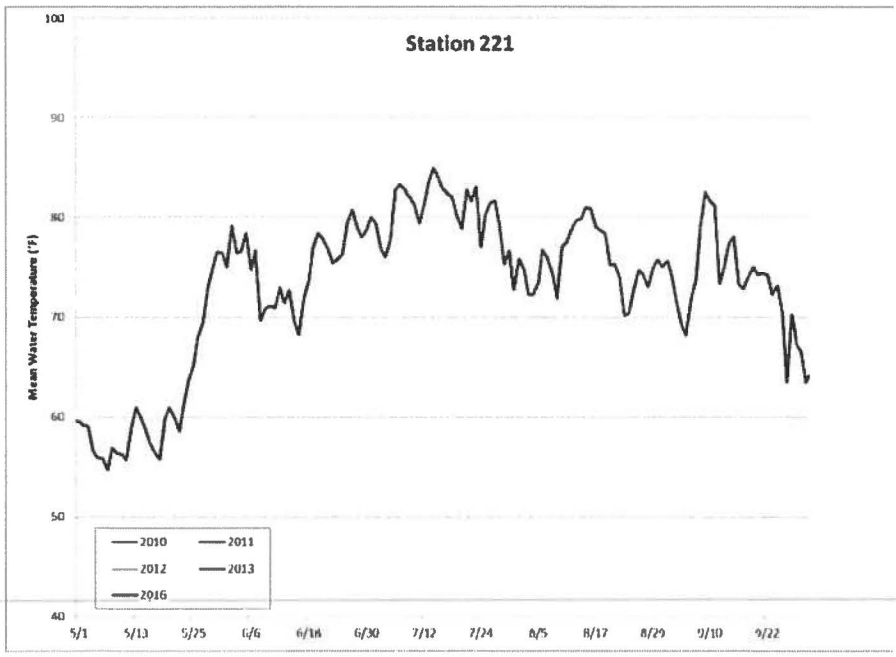


Figure 4-3. Daily mean water temperature measured at Station 221 in 2016.

Note: no monitoring occurred during 2010-2013 at this location; location added for 2016 monitoring

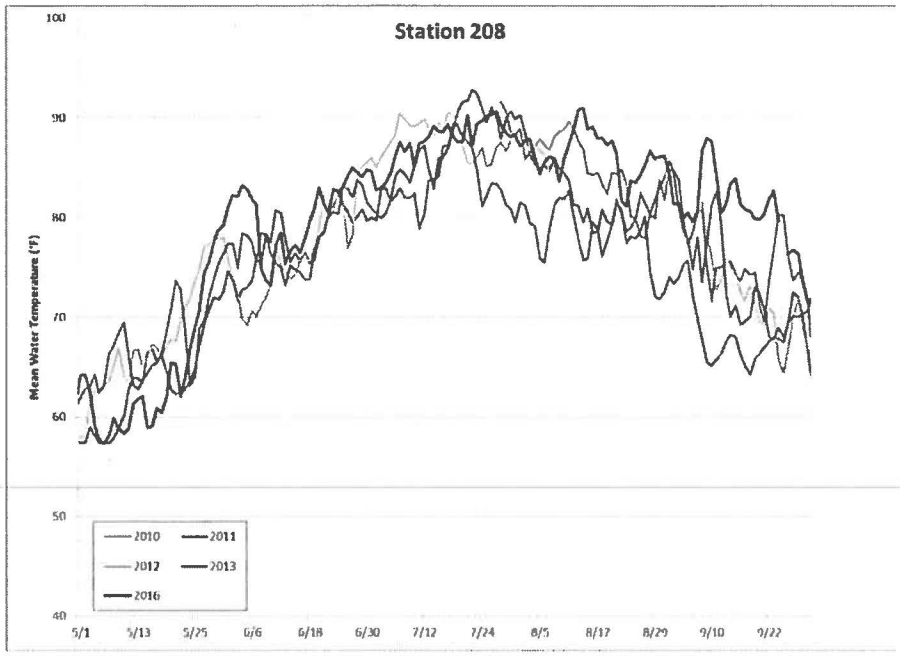


Figure 4-4. Daily mean water temperature measured at Station 208, 2010-2016.

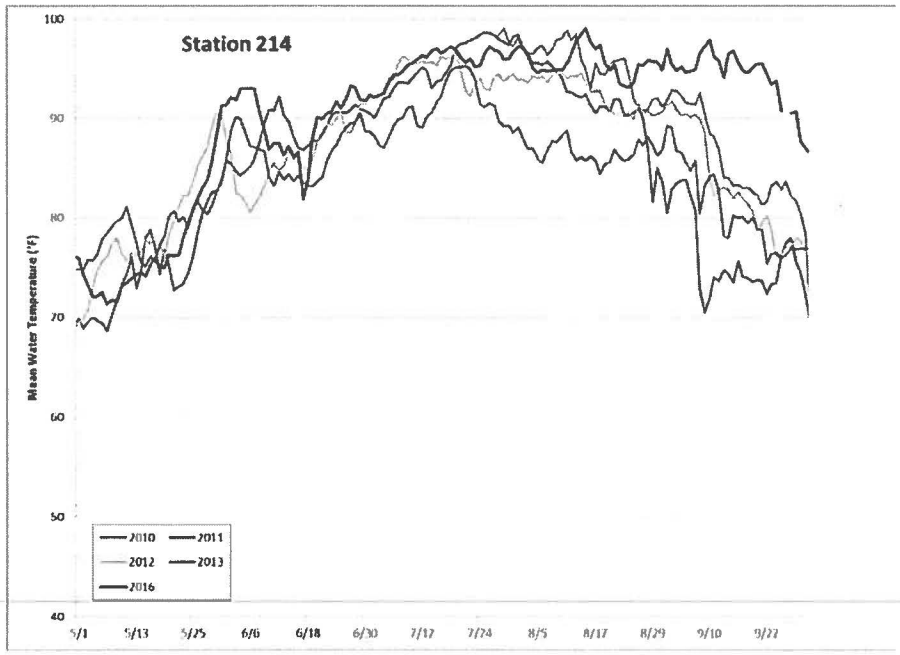


Figure 4-5. Daily mean water temperature measured at Station 214, 2010-2016.

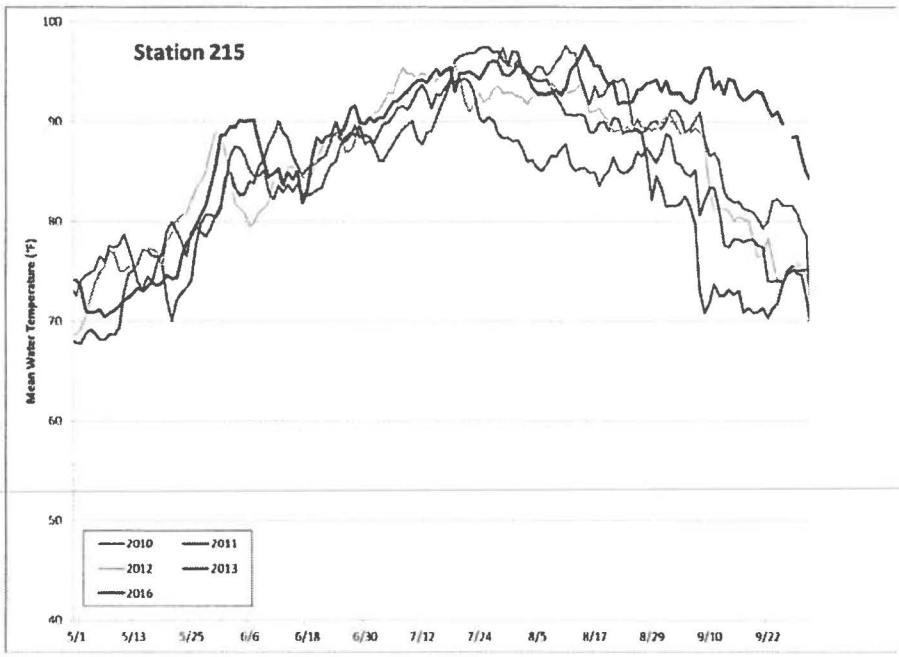


Figure 4-6. Daily mean water temperature measured at Station 215, 2010-2016.

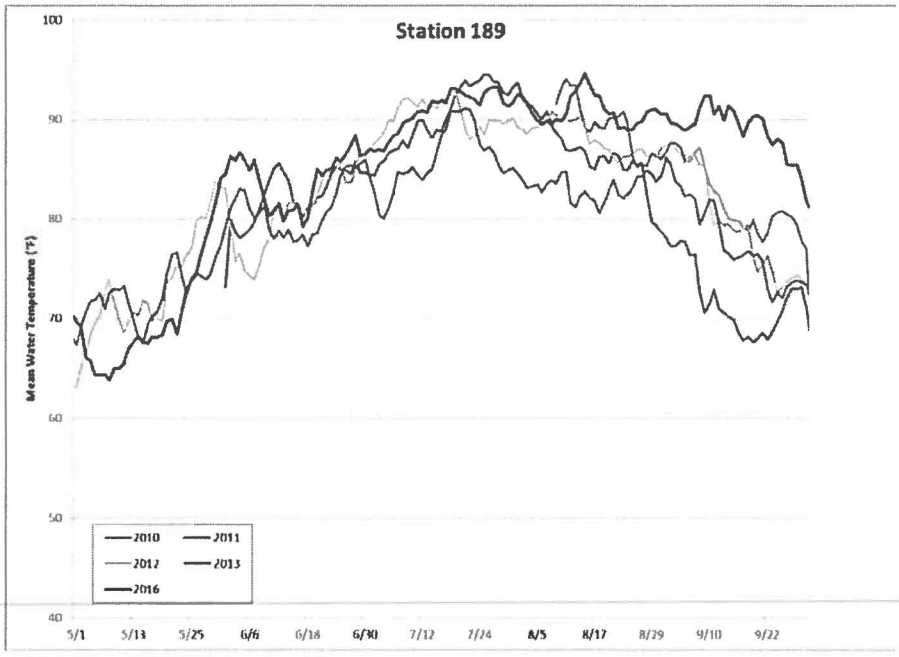


Figure 4-7. Daily mean water temperature measured at Station 189, 2010-2016.

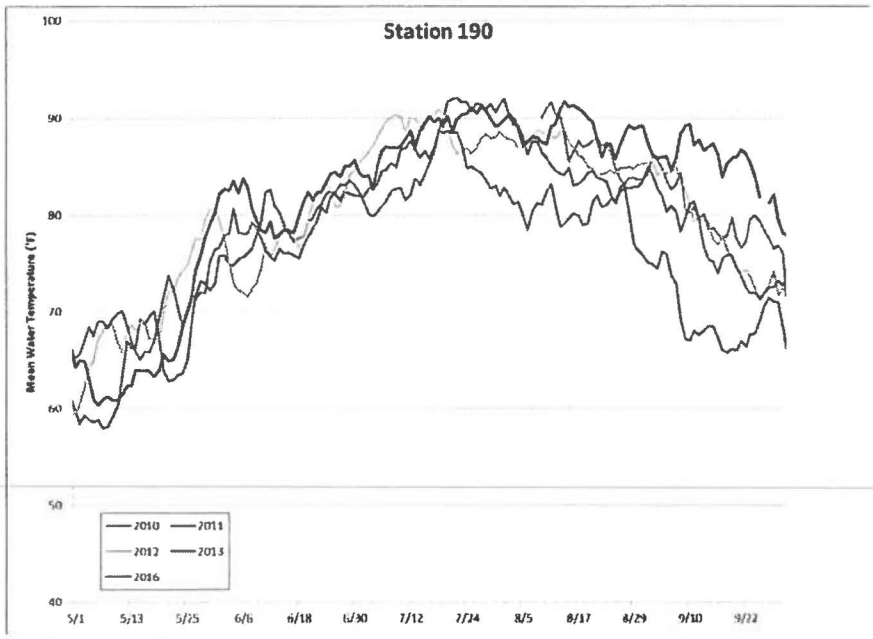


Figure 4-8. Daily mean water temperature measured at Station 190, 2010-2016.

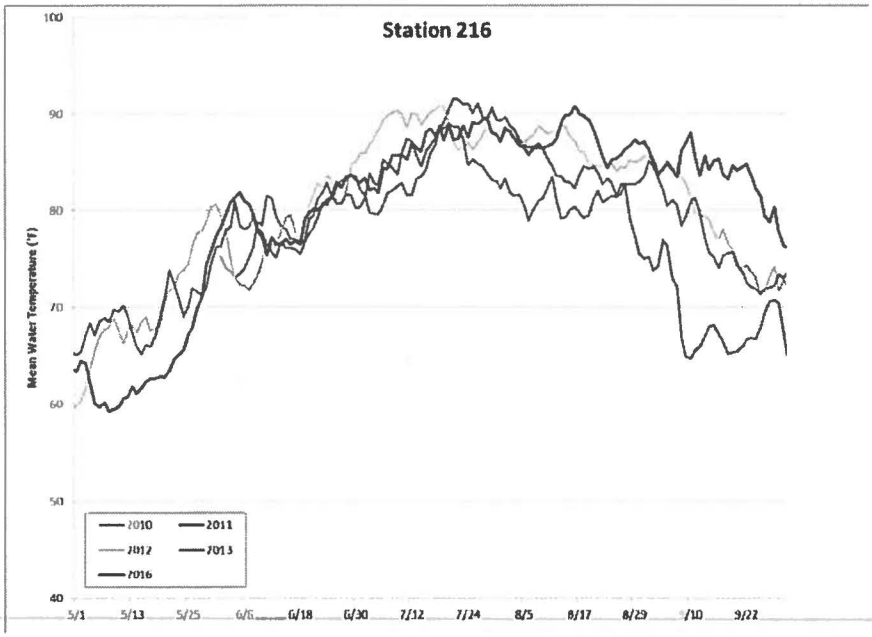


Figure 4-9. Daily mean water temperature measured at Station 216, 2010-2016.

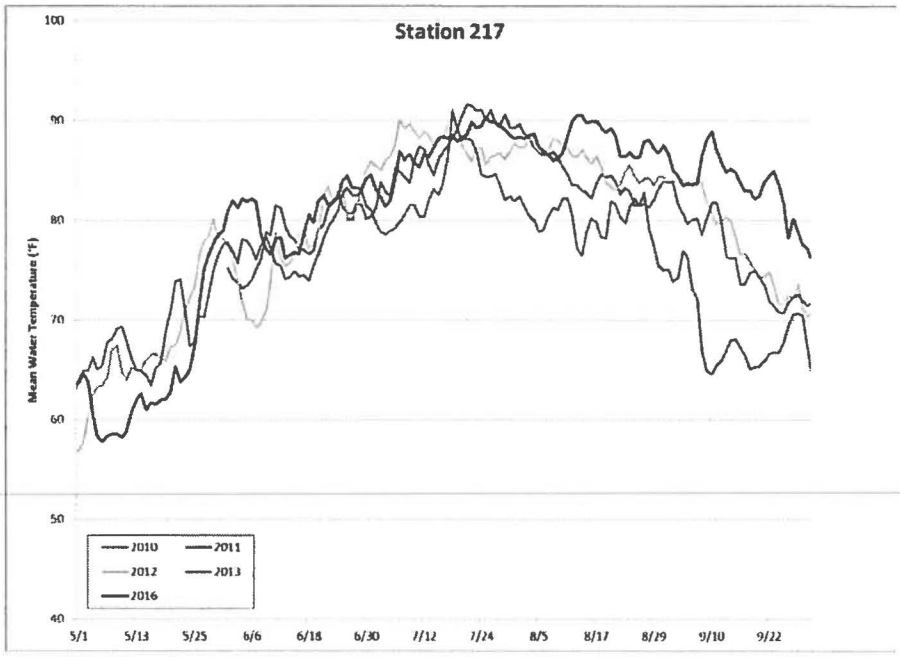


Figure 4-10. Daily mean water temperature measured at Station 217, 2010-2016.

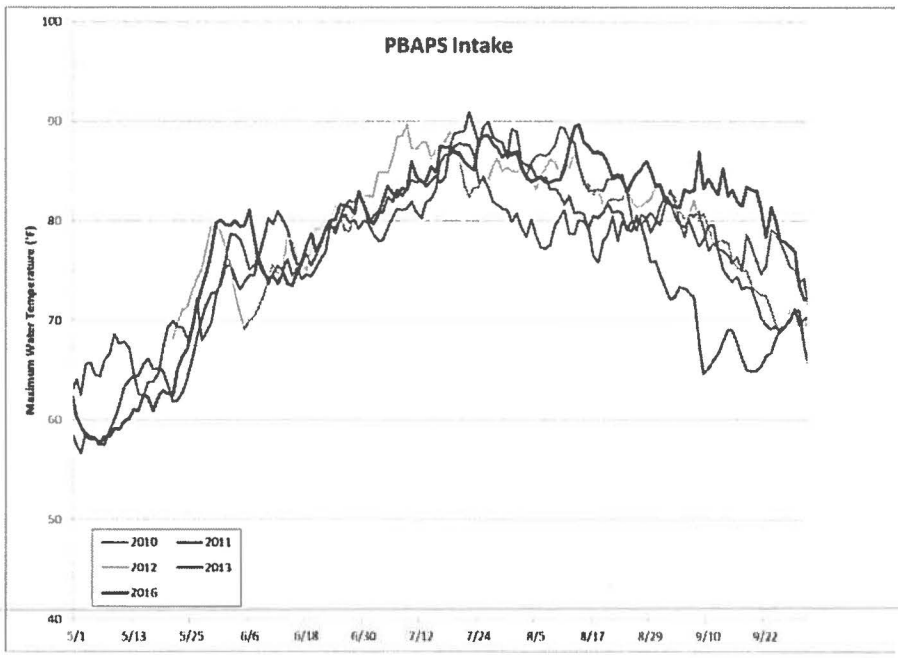


Figure 4-11. Daily maximum instantaneous water temperature measured at PBAPS Intake, 2010-2016.

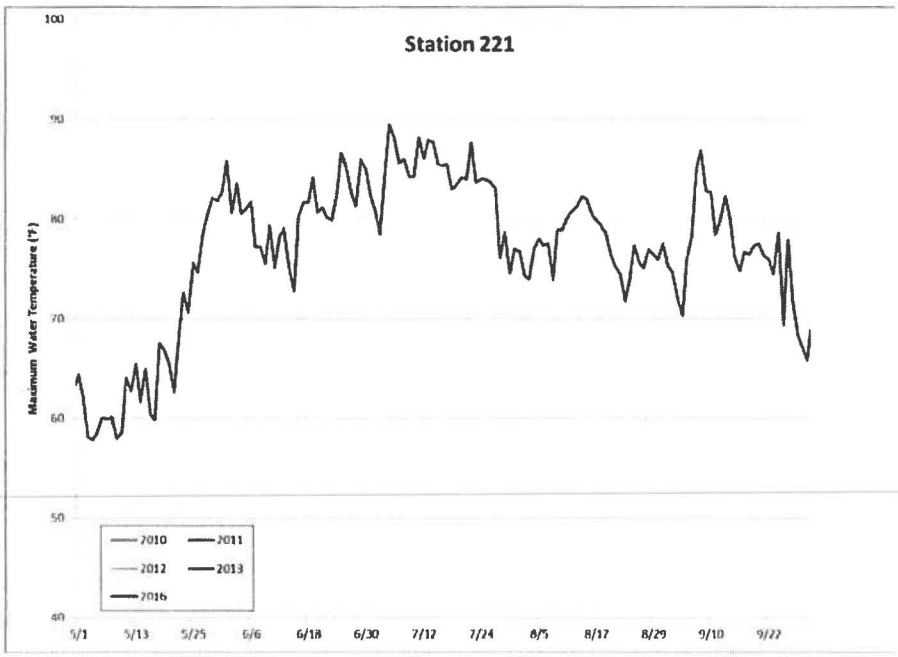


Figure 4-12. Daily maximum instantaneous water temperature measured at Station 221 in 2016.

No monitoring occurred during 2010-2013 at this location; location added for 2016 monitoring

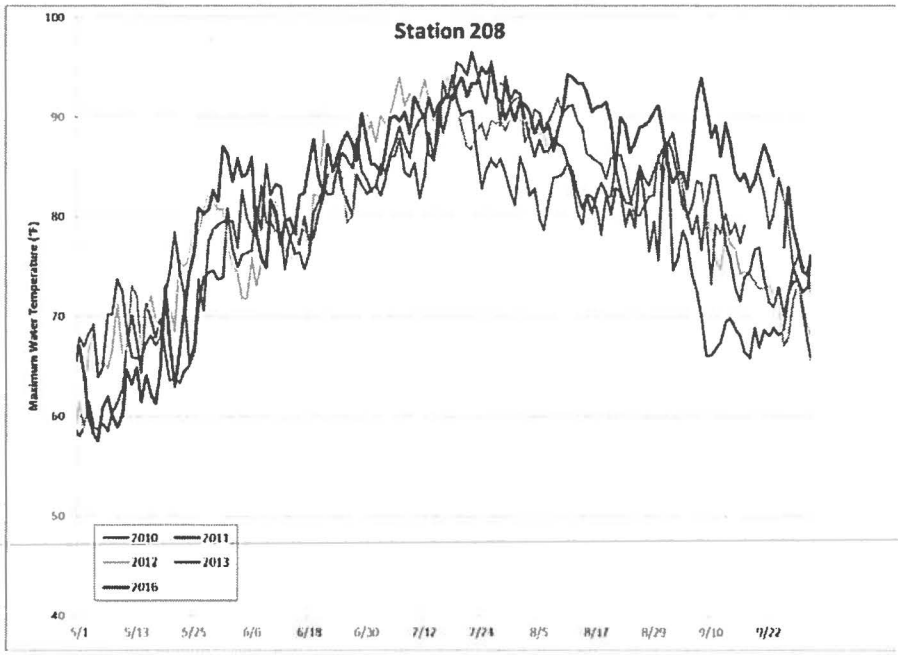


Figure 4-13. Daily maximum instantaneous water temperature measured at Station 208, 2010-2016.

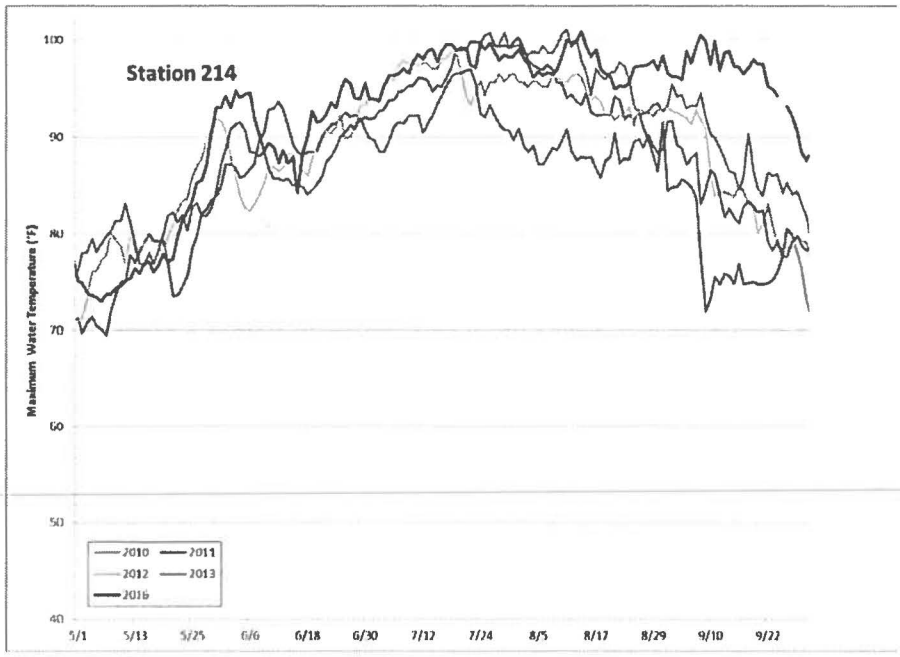


Figure 4-14. Daily maximum instantaneous water temperature measured at Station 214, 2010-2016.

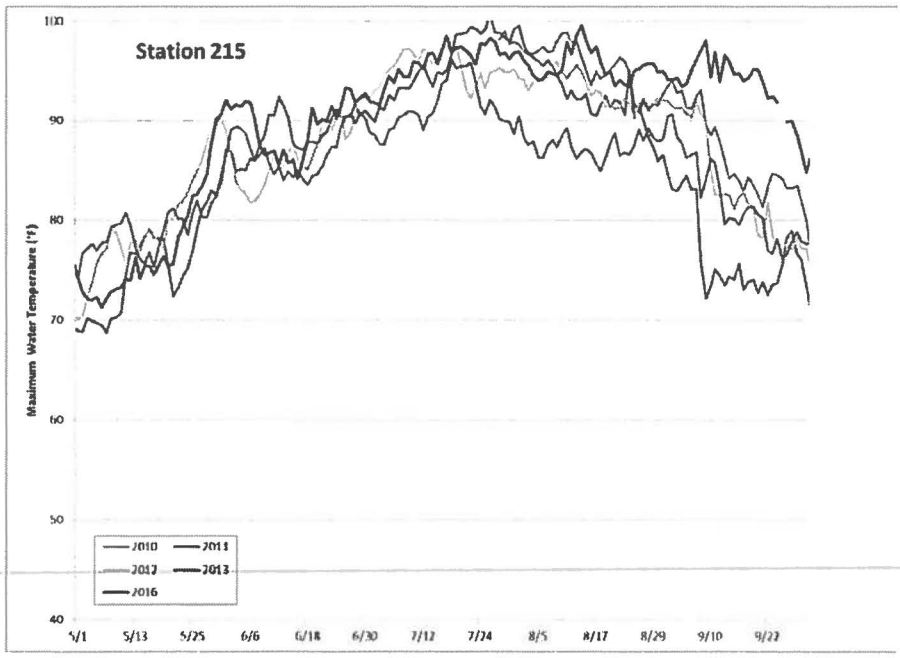


Figure 4-15. Daily maximum instantaneous water temperature measured at Station 215, 2010-2016.

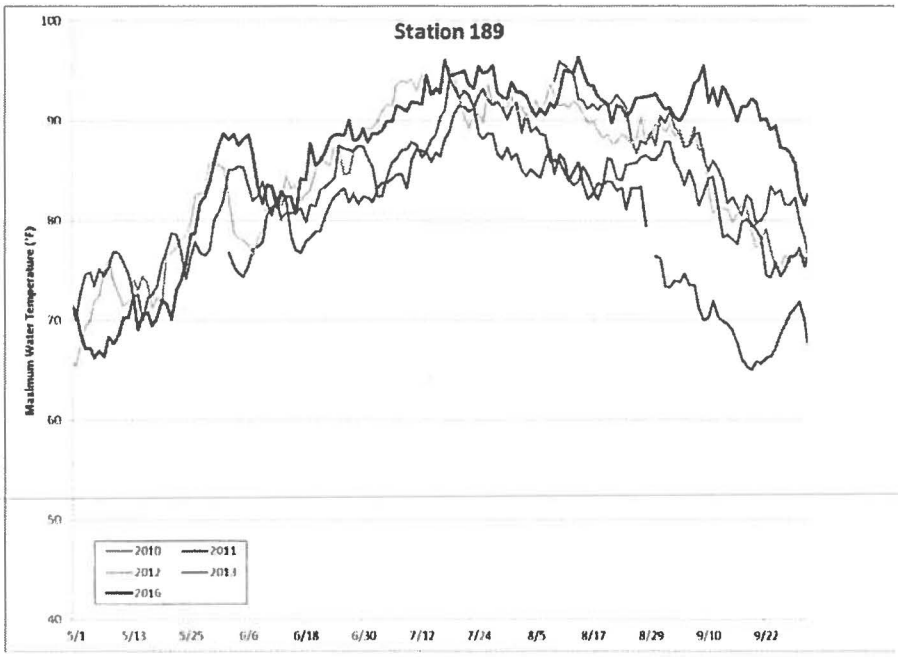


Figure 4-16. Daily maximum instantaneous water temperature measured at Station 189, 2010-2016.

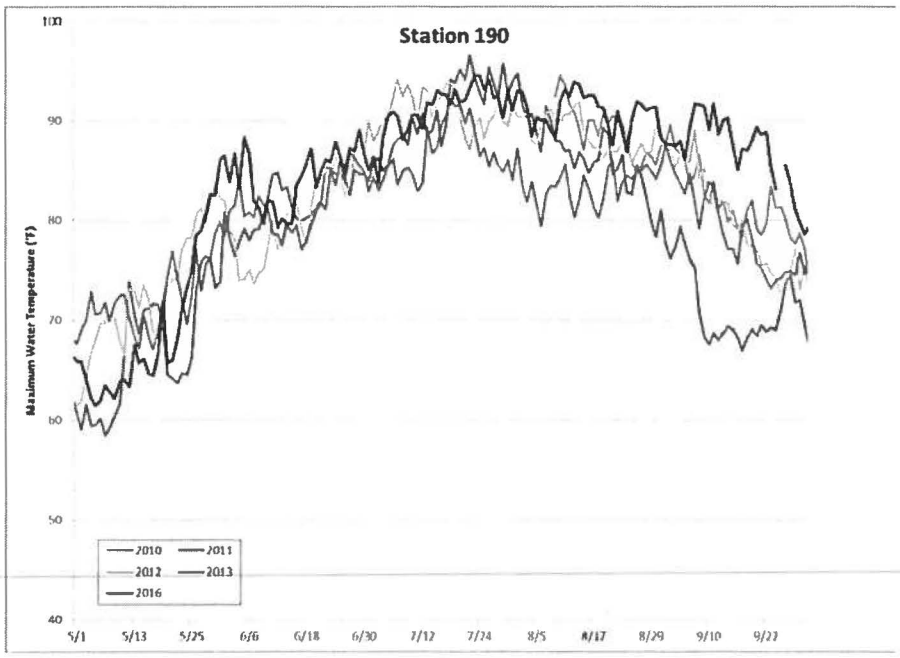


Figure 4-17. Daily maximum instantaneous water temperature measured at Station 190, 2010-2016.

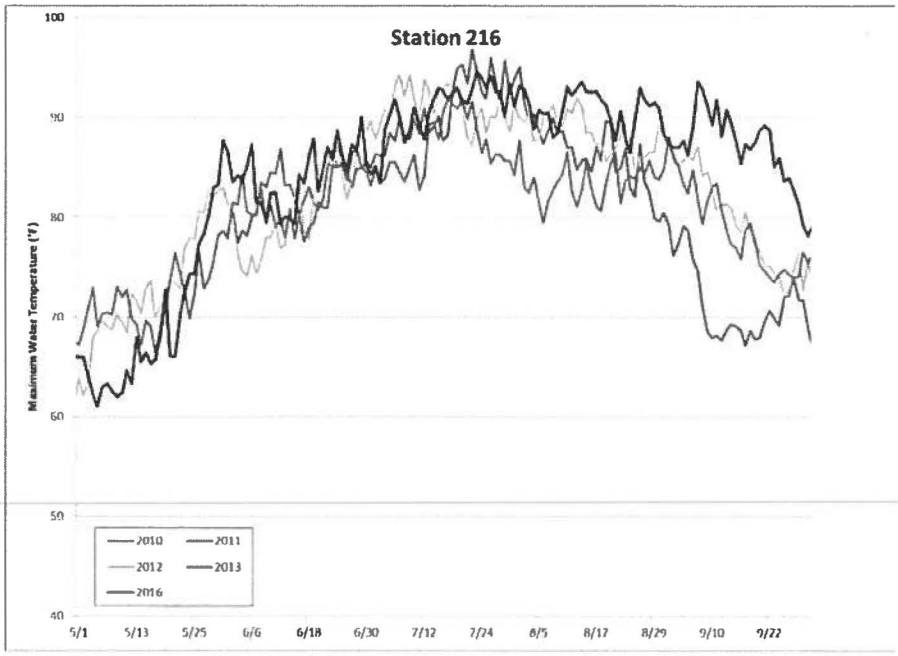


Figure 4-18. Daily maximum instantaneous water temperature measured at Station 216, 2010-2016.

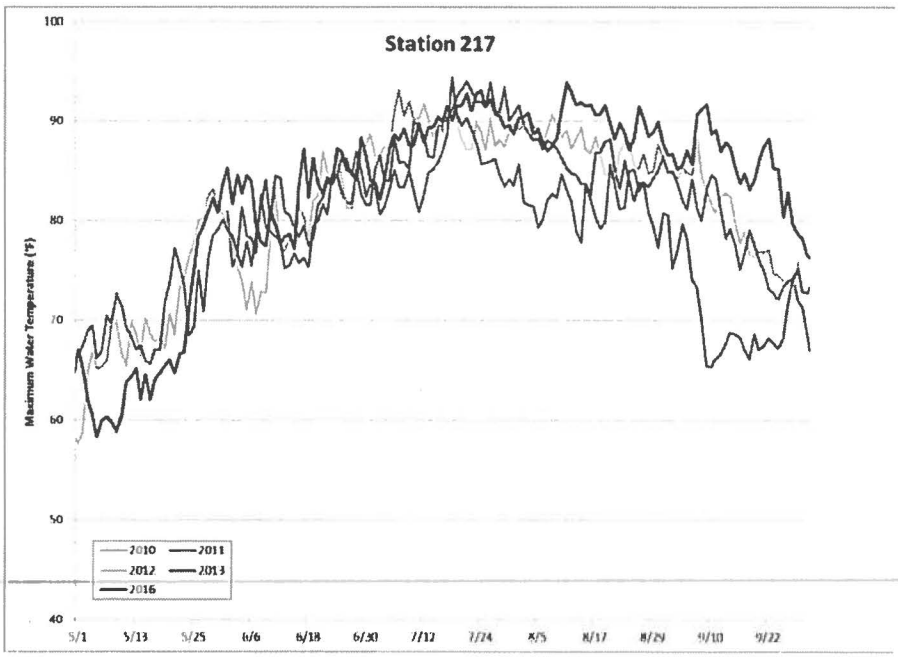


Figure 4-19. Daily maximum instantaneous water temperature measured at Station 217, 2010-2016.

Table 4-1. Monthly mean water temperature measured at the biological monitoring locations and PBAPS intake, May through September, 2010-2013, and 2016.

2010	214	215	189	190	216	217	221	Intake	208
May	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Jun	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Jul	98.0	96.2	N/A	N/A	N/A	N/A	N/A	85.4	89.2
Aug	95.3	93.5	89.3	86.9	N/A	N/A	N/A	82.8	84.8
Sep	85.9	84.3	82.0	80.1	N/A	N/A	N/A	75.2	76.4
2011	214	215	189	190	216	217	221	Intake	208
May	74.8	73.6	N/A	64.9	N/A	N/A	N/A	63.0	63.5
Jun	88.5	86.6	82.2	79.1	79.4	78.3	N/A	76.6	77.4
Jul	95.2	93.7	90.2	87.8	88.0	87.2	N/A	83.9	87.0
Aug	91.9	90.5	86.8	84.3	84.5	83.7	N/A	80.5	81.0
Sep	76.0	74.6	72.0	69.6	69.7	68.8	N/A	68.2	68.8
2012	214	215	189	190	216	217	221	Intake	208
May	79.0	78.0	73.0	70.0	70.0	68.0	N/A	72.9	67.9
Jun	86.3	85.0	80.9	78.0	78.3	77.4	N/A	75.1	76.6
Jul	94.5	93.4	90.3	88.4	88.5	87.6	N/A	84.0	87.8
Aug	92.5	91.3	88.2	86.4	86.5	85.8	N/A	82.4	86.6
Sep	83.1	81.4	79.5	78.2	78.3	77.9	N/A	75.1	72.1
2013	214	215	189	190	216	217	221	Intake	208
May	78.4	76.8	72.1	69.0	69.0	68.1	N/A	65.2	66.7
Jun	86.3	85.0	80.7	78.5	78.5	77.8	N/A	75.5	77.8
Jul	91.0	89.9	86.0	83.9	84.0	83.2	N/A	81.5	83.3
Aug	86.8	86.0	83.2	81.1	81.2	80.6	N/A	77.6	79.6
Sep	81.1	80.0	78.1	77.1	77.2	76.8	N/A	73.9	74.3
2016	214	215	189	190	216	217	221	Intake	208
May	76.8	75.2	69.9	66.2	66.2	64.6	61.3	62.5	64.3
Jun	89.8	87.7	84.0	81.6	81.6	80.6	75.1	76.9	80.4
Jul	95.6	93.8	90.8	88.3	88.3	87.1	80.4	83.6	87.6
Aug	95.7	94.0	91.0	88.9	89.0	88.0	75.6	84.4	86.4
Sep	94.4	92.1	89.0	85.4	85.4	83.6	73.3	80.1	80.9

Table 4-2. Summary of instantaneous maximum and daily mean water temperature data for multiple locations within Conowingo Pond in 2016.

	Number of Days Exceeding			
	Instantaneous Maximum Temperature		Mean Temperature	
Station	>80°F	>90°F	>80°F	>90°F
221 [a]	62	0	25	0
PBAPS Intake	95	0	83	0
208	115	40	101	6
214	132	113	131	108
215	131	105	129	92
189	129	77	125	53
190	119	53	110	17
216	120	51	111	17
217	114	31	107	3

[a] station was not monitored previously

Table 4-3. Summary of instantaneous maximum and daily mean water temperature data for multiple locations within Conowingo Pond in 2010.

	Number of Days Exceeding			
	Instantaneous Maximum Temperature		Mean Temperature	
Station	>80°F	>90°F	>80°F	>90°F
220	34	0	28	0
PBAPS Intake	38	0	29	0
208	50	14	38	2
214	65	46	64	44
215	65	43	62	34
189	51	18	42	10
190	43	10	35	5
216	*	*	*	*
217	*	*	*	*

*stations not monitored in 2010

Table 4-4. Summary of instantaneous maximum and daily mean water temperature data for multiple locations within Conowingo Pond in 2011.

	Number of Days Exceeding			
	Instantaneous Maximum Temperature		Mean Temperature	
Station	>80°F	>90°F	>80°F	>90°F
220	55	3	38	0
PBAPS Intake	60	1	41	0
208	75	17	56	10
214	105	74	104	70
215	104	70	102	45
189	96	32	82	21
190	82	22	72	14
216	87	20	72	15
217	80	16	69	8

Table 4-5. Summary of instantaneous maximum and mean water temperature data for multiple locations within Conowingo Pond in 2012.

	Number of Days Exceeding			
	Instantaneous Maximum Temperature		Mean Temperature	
Station	>80°F	>90°F	>80°F	>90°F
220	76	0	55	0
PBAPS Intake	77	0	69	0
208	58	18	48	3
214	127	84	122	73
215	124	78	117	54
189	108	43	97	19
190	99	30	84	8
216	99	30	85	7
217	96	14	84	1

No data recovered for Station 208 from 8/8/12 to 9/6/12

Table 4-6. Summary of instantaneous maximum and mean water temperature data for multiple locations within Conowingo Pond in 2013.

	Number of Days Exceeding			
	Instantaneous Maximum Temperature		Mean Temperature	
Station	>80°F	>90°F	>80°F	>90°F
220	43	0	25	0
PBAPS Intake	45	0	29	0
208	82	7	57	0
214	133	40	117	20
215	124	28	106	13
189	106	8	89	5
190	93	5	71	0
216	93	6	71	0
217	82	3	63	1

5 Dissolved Oxygen Monitoring

Introduction

Aquatic life in Pennsylvania freshwater waterbodies is protected by dissolved oxygen (DO) criteria, which are found in PA Code Chapter 93.7. The criteria were established to protect aquatic organism from adverse impacts associated with low DO. For warmwater fisheries (WWF) the PA Code criteria for concentration of DO are a minimum 7-day average of 5.5 mg/L and instantaneous minimum of 5.0 mg/L. These criteria were developed to be protective of the entire aquatic community, in particular, all life stages of warmwater fish. The criteria specifically are protective of early life stages of fish, such as embryonic and larval stages, which are generally more sensitive to low DO concentrations than adult life stages (PADEP 2016).

Methods

Dissolved oxygen monitoring was conducted in shallow shoreline areas along the west shoreline downstream of the PBAPS discharge canal at Stations 215 and 189 and upstream of the PBAPS discharge canal on the east shoreline at Station 208 (Figure 5-1). Monitoring was completed June 1 through September 30, 2016. A HACH HL4 Sonde with luminescent dissolved oxygen (LDO) sensor was used to record hourly DO concentrations. The accuracy of this instrument is ±0.1 mg/L for DO between 0 and 8 mg/L and ±0.2 mg/L for DO more than 8 mg/L. This monitoring period was selected to focus on the typical seasonal periods of low-flow and high water temperature that occur in Conowingo Pond which could result in low DO concentrations. Monitoring at Station 208 was completed to determine whether sufficient DO concentrations were present in waters typically outside of the thermal plume. The objective of this monitoring was to determine if there are periods when there is a low DO barrier spanning the width of the pond during low flows, high water temperatures, and upstream migration of the thermal plume due to MRPSF pumping. These areas are thought to be important to provide a refuge or zone of passage for resident and migratory fish migrating upstream or downstream past the PBAPS.

A single monitoring device was installed toward the bottom of the water column at each monitoring location. Monitors were installed in water with depth less than 10 ft with the intent of monitoring to be near the bottom of the water column. Each monitor was attached to a buoy which was attached by cable to an anchor. Challenges associated with fluctuations in Conowingo Pond water elevation (range between 105 and 109 ft during monitoring period at the Conowingo Dam forebay) occurred during the monitoring period. During several different occasions at low Pond elevation the LDO sensor contacted the bottom which resulted in the sensor being covered in sediment or touching the bottom substrate, and provided erroneous DO data. The hourly DO data sets were reviewed for the entire monitoring period in relation to hourly Conowingo Pond elevation in order to determine whether DO data was representative of actual DO at each monitoring location and obvious erroneous data were removed from the final data set before analysis was completed. In addition, the Sonde deployed at Station 208 malfunctioned and was removed for repair from August 23 to 29.

The final data set was compiled into an Excel spreadsheet and the raw DO data and the revised data set along with a list of collected daily mean, minimum, and maximum dissolved oxygen concentrations was provided to PADEP in electronic format. This data set also included hourly Conowingo Pond water surface elevation data measured at the Conowingo Dam forebay.

Results

The number of valid hourly DO measurements varied among the three stations: Station 208: 2,338; Station 215: 2,500, and Station 189: 2,537 (Table 5-1). The total number of days that the daily mean DO was less than 5.5 mg/L varied from 3 days at Station 208 to 11 days at Station 215. The 7-day mean DO criterion of 5.5 mg/L was not exceeded at any of the three monitoring locations. However, at Station 215 there were 26 occurrences of the 7-day mean DO equal to the minimum of 5.5 mg/L. The lowest minimum daily average DO (5.0 mg/L) recorded among the stations was at Stations 208 and 215. The total number of hourly DO measurements less than 5.0 mg/L varied from 18 at Station 189 to 98 at Station 215 with a majority of these measurements occurring during September. The total number of days that at least one hourly DO measurement was less than 5.0 mg/L (the instantaneous minimum criterion) varied from 9 days at Station 189 to 35 days at Station 215.

Figure 5-2 through Figure 5-4 provide a time series of the hourly DO measurements for each monitoring location. The lowest instantaneous minimum DO measurement was 4.4 mg/L and occurred at all three stations.

Discussion

Dissolved oxygen (DO) concentrations in the subsurface waters of Conowingo Pond are important in assessing the potential suitability of fish habitat. Low DO can result in stressful conditions that fish may avoid or could potentially result in higher rates of disease. Dissolved oxygen concentrations were measured in the shallow shoreline areas directly downstream from the PBAPS discharge and at an upstream location and evaluated to determine whether sufficient DO was present within these areas to be protective of aquatic life. This monitoring occurred during the typical seasonal periods of low-flow and high water temperature that occur in Conowingo Pond which could result in low DO concentrations. DO concentrations were similar among the three stations over the course of the monitoring period. Nearly all measurements were above the instantaneous DO criterion of 5.0 mg/L. Similarly, DO concentrations were always equal to or above the 7-day mean criterion of 5.5 mg/L. The monitoring did not indicate that DO concentrations were low and restrictive to aquatic organism movement or use of shallow shoreline areas within the Pond. In addition, the monitoring at Station 208 indicated that DO concentrations do not cause a low DO barrier that would prevent fish from migrating past PBAPS.

Most of the lowest instantaneous DO measurements were recorded in August and September. This was an extremely low flow period in Conowingo Pond. Although DO concentrations were occasionally below the water quality instantaneous minimum criterion of 5.0 mg/L it is unlikely that the lowest observed concentration (4.4 mg/L) were injurious or caused stress to fish. Low DO concentration is an environmental stressor that may predispose fish to viral or bacterial

infections. Section 6.3 of this report discusses disease occurrence in Conowingo Pond fish. The instantaneous criterion for DO is protective of the most sensitive life stages of fish (eggs and larvae); these life stages of fish are not present in August and September. Thus DO during this time period needs to be protective of only juvenile/adult life stages of fish which can tolerate DO less than 5.0 mg/L for short periods of time without measurable negative effects.

Nutrient enrichment of the lower Susquehanna River and Chesapeake Bay from upstream sources is a long-term concern for the health of the aquatic ecosystem. Increases in nutrients have been linked to increased biomass of aquatic macrophytes, which can lead to wide swings and depressions of DO during the growing season. Aquatic macrophytes produce DO during daytime hours when photosynthesis is occurring, but then use the DO for respiration during the nighttime hours. A large amount of aquatic macrophyte biomass in a water body can lead to DO depression or sag during early morning hours particularly during summer time. This pattern was observed in the current study and occurs throughout the Susquehanna River particularly in portions of the river where macrophytes are abundant (SRBC 2013). Low DO concentrations occur in many portions of the Susquehanna River well upstream of PBAPS and are a result of multiple factors including river flow, nutrient enrichment, and aquatic macrophyte growth and decomposition (PADEP 2012).

Conclusions

Monitoring during 2016 under the prevailing high water temperature and low flow conditions indicated that sufficient DO concentrations existed in Conowingo Pond with the EPU to protect the aquatic community. No exceedances of the 7-day average criterion were observed and few exceedances of the instantaneous minimum criterion (1.9% of total measurements) were observed. The exceedances of the instantaneous minimum criterion were few and did not occur over consecutive hours and were not of extended duration. The DO concentrations observed during actual EPU conditions in an extreme high temperature and low flow year were protective of the aquatic community. The monitoring also indicated that DO was sufficiently high as to not block fish migration past PBAPS. DO concentrations were sufficient to maintain fish habitat and did not indicate the monitored locations would be unavailable for use by fish or other aquatic organisms.

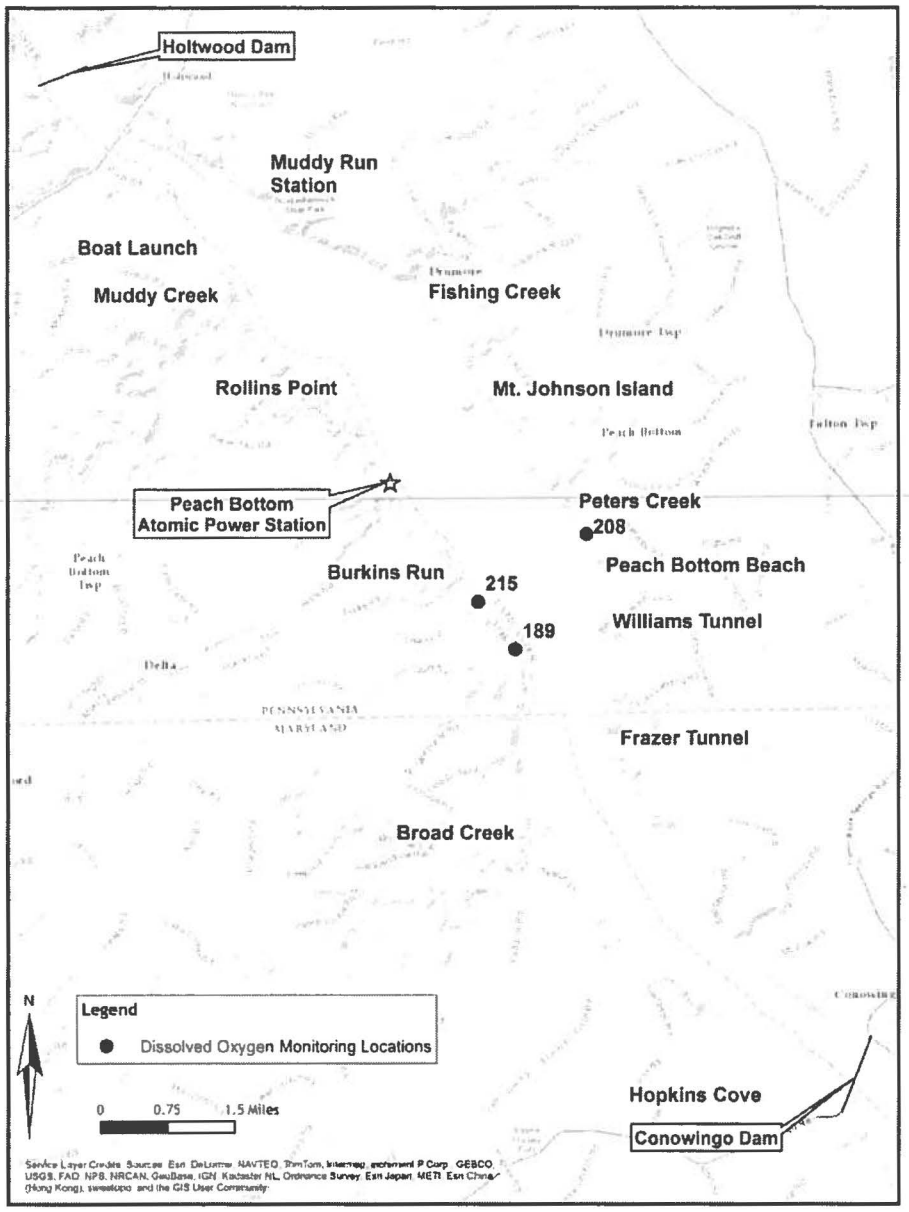


Figure 5-1. Dissolved Oxygen monitoring locations in Conowingo Pond during 2016.

Table 5-1. Descriptive statistics for dissolved oxygen monitoring in Conowingo Pond, June through September 2016.

	Station		
Dissolved Oxygen (mg/L) [1]	208	215	189
Total Number of Hourly Measurements	2,338	2,500	2,537
Total Number Hourly Measurements < 5.0 mg/L	26	98	18
Total Days with Hourly Measurements <5.0 mg/L	13	35	9
Minimum Daily Average	5	5.0	5.2
Total Days Daily Average < 5.5 mg/L	3	11	5
Number of Occurences 7-day Average < 5.5 mg/L	0	0 [2]	0
Instantaneous Maximum	11.4	8.5	9.3
Instantaneous Minimum	4.4	4.4	4.4

[1] *§ 93.7. Specific water quality criteria for Warm Water Fishery (WWF): 7-day average 5.5 mg/L; instantaneous minimum 5.0 mg/L.*

[2] *A total of 26 occurrences of 7-day average of 5.5 mg/L*

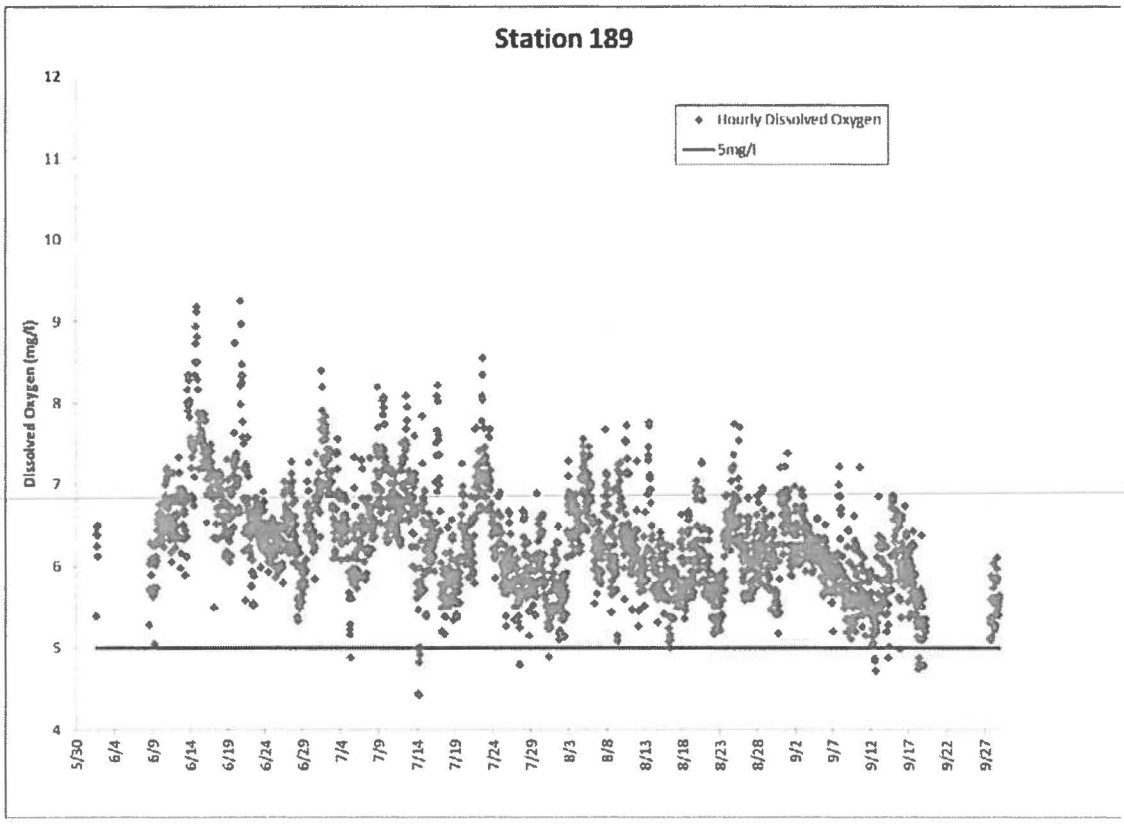


Figure 5-2. Hourly dissolved oxygen measurements at Station 189, June through September 2016.

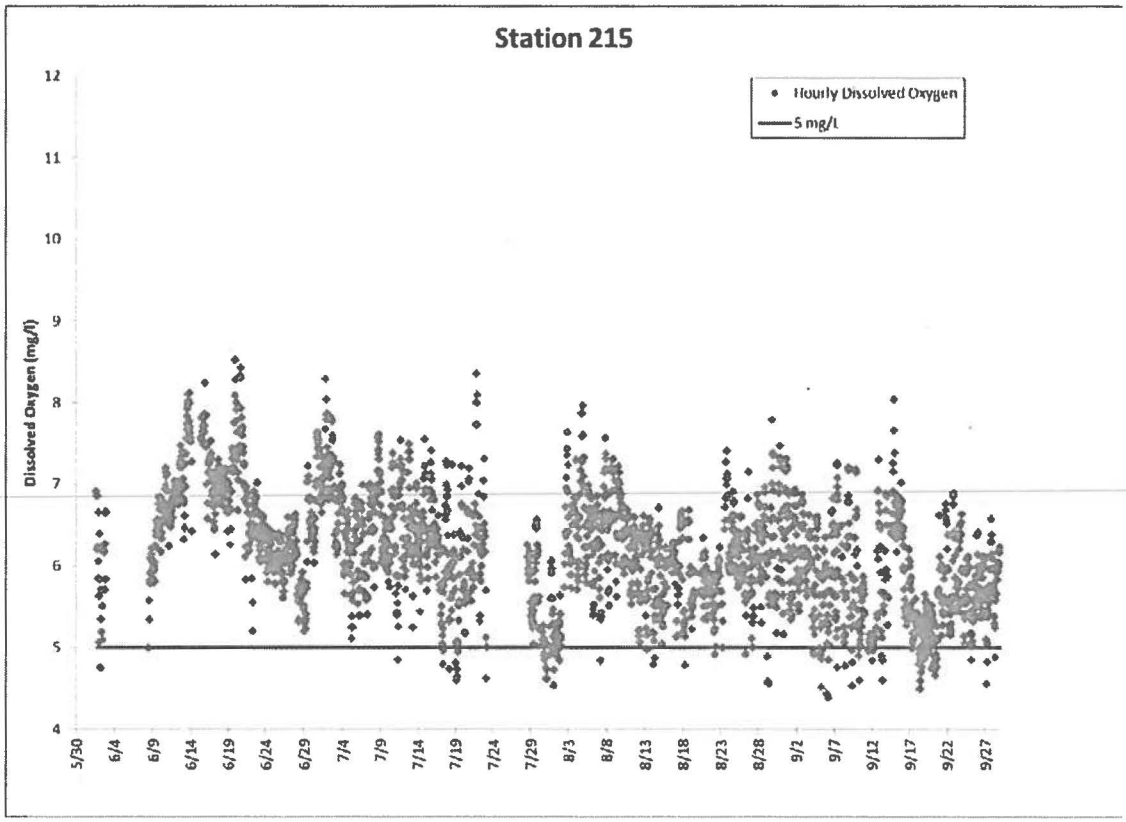


Figure 5-3. Hourly dissolved oxygen measurements at Station 215, June through September 2016.

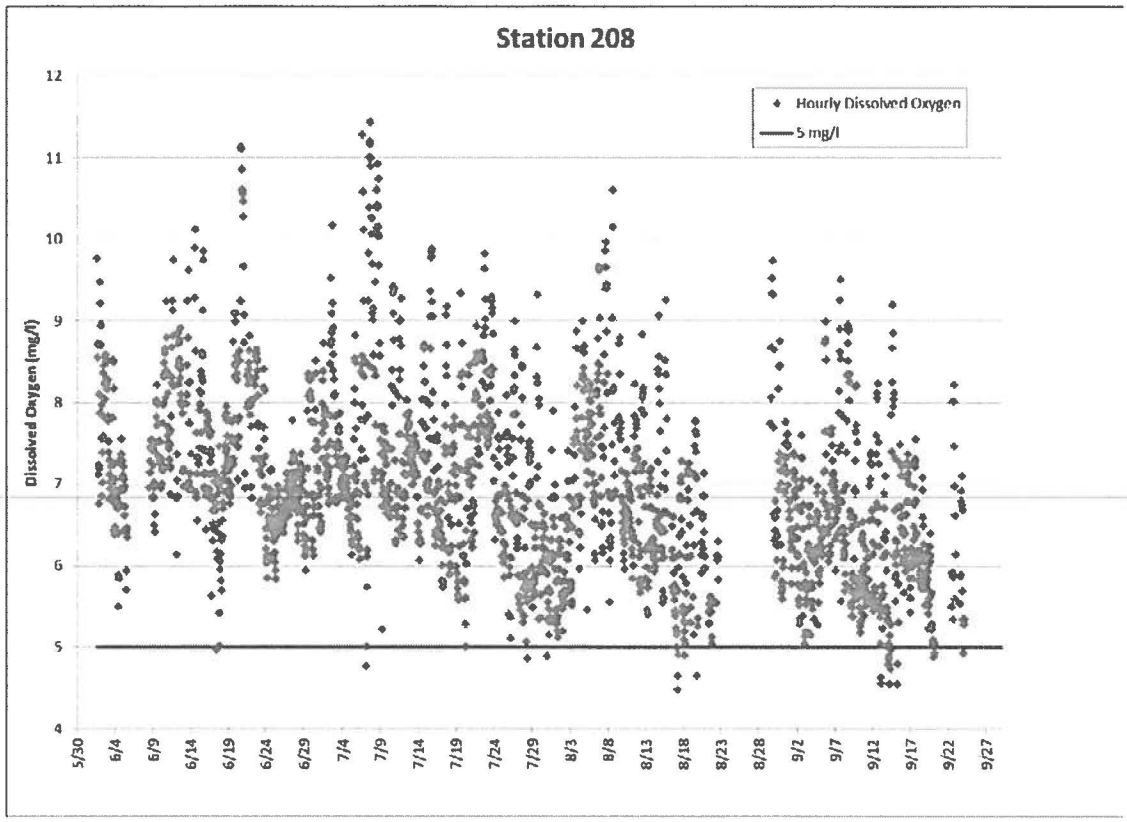


Figure 5-4. Hourly dissolved oxygen measurements at Station 208, June through September 2016.

6 Biological Monitoring and Assessment

6.1 Introduction

This section describes the benthic macroinvertebrate and fisheries components of the Post-EPU Study. As described in the Post-EPU Study Plan, the primary objective of the biological monitoring component of the study was to determine the characteristics of the fish and benthic macroinvertebrate communities after implementation of the EPU. The characteristics of the communities observed in 2016 Post-EPU Study will be compared to Pre-EPU Demonstration Study observations completed from 2010-2013 during the 316a Demonstration Study (Normandeau and ERM 2014). These comparisons will focus on whether any discernable changes have occurred to the aquatic communities that resulted from the increase in water temperature associated with the EPU.

Sampling and data collection for the 2016 monitoring program was performed from May 1 through September 30. A total of 35 benthic macroinvertebrate samples were collected at seven stations (Figure 6-1) Fish community surveys were completed to determine distribution and relative abundance within and outside of the thermal plume. A total of 25 collections were completed using a seine at five stations (Figure 6-2) and 30 collections were completed using a boat electrofisher at six stations (Figure 6-3). Table 6-1 provides a description of seine, benthos, electrofishing, and water temperature stations and the distance each station is from the PBAPS discharge canal.

Methodologies and analyses for the benthic macroinvertebrate community sampling, and fish community surveys are summarized below.

6.2 Benthic Macroinvertebrate Community

A study of the benthic macroinvertebrate community was conducted to determine the influence of the thermal plume post-EPU on the composition and relative abundance of the benthic macroinvertebrate, or benthos, community inhabiting shallow-water shoreline habitat in Conowingo Pond. Previous benthos surveys were conducted at the same monitoring locations using identical methodology during 2010-2013. Comparison between the pre-EPU and post-EPU communities was completed to evaluate the potential effect of the temperature rise associated with the EPU. The benthic macroinvertebrate sampling included an assessment of habitat quality each month at each of the collection locations.

Methods

Habitat Assessment

The quality, quantity, and variety of physical habitat are well-known determinants of macroinvertebrate community composition. When comparing sample stations, habitat assessments are used to infer whether observed differences in macroinvertebrate communities are the result of water quality degradation (in this case, increases in temperature) or due to

variations in habitat. The PADEP methodology used for this study is for low gradient streams and is referenced in the Post-EPU Study Plan. The methodology involves visual inspection and quantification of nine habitat parameters listed below.

Habitat Parameters	
Epifaunal Substrate/Available Cover	Bank Vegetative Protection
Channel Alteration	Sediment Deposition
Pool Substrate Characterization	Riparian Vegetative Zone Width
Bank Stability	Channel Flow Status
Pool Variability	

Each habitat parameter is awarded a score between 0 and 20 for a possible maximum total of 180. The resulting values can be used to rate habitat quality into four categories: Optimal (166-180), Sub-optimal (113-153), Marginal (60-100), and Poor (<47). Scores falling between these ranges are given a dual rating.

Macroinvertebrate Collection and Analysis

Macroinvertebrates were collected monthly from May through September 2016 with a D-frame kick net according to a PA DEP (2007) multi-habitat protocol. Benthic macroinvertebrates were collected from seven locations throughout Conowingo Pond, spatially covering a large portion of the Pond (Figure 6-1). Two locations were well upstream from PBAPS and not influenced by the thermal plume. Station 208 was located across from PBAPS and is exposed to thermal plume during low-flow conditions during MRPSF pumpback operations. The other four stations (214, 215, 189, and 216) are located downstream from PBAPS along the west shoreline and are within the thermal plume during the entire year.

Each multi-habitat sample was a composite of 10 "kicks," collected from five habitat types including cobble/gravel, snag, coarse particulate organic matter, submerged aquatic vegetation, and sand/fine sediment. Where all five habitat types were present, two "kicks" were taken from each to produce the composite. If one or more habitat types were absent, the "kicks" that would have been assigned to them were proportioned according to the predominant habitat types remaining.

Samples were sorted and identified following the methods described in PADEP (2007) multi-habitat protocol. The resulting data were condensed to six ecological metrics developed by PADEP (2007). The metrics are Total Richness, EPT Richness, Beck's 4 Index, Shannon Diversity, Mayfly Taxa Richness, and Caddisfly Taxa Richness. Table 6-2 provides a brief summary of the metrics and whether their values increase or decrease in response to water or habitat quality degradation. Standardized scores for each metric were used to produce an Index

of Biotic Integrity (IBI) value for each station. The IBI is a means to integrate information from the metrics into a station score ranging between 0 and 100.

Habitat Assessment

Results and Discussion

The results of the habitat assessment are provided in Table 6-3. Average station scores ranged from 95 to 133 producing similar descriptors of sub-optimal/marginal or marginal at each location. Placed into context, the habitat constraints observed in the Conowingo Pond are essentially due to channel alteration inherent to impoundment; i.e., a free-flowing section of the Susquehanna River has been transformed into a reservoir where shoreline habitat is much less varied and the current is much slower than it would be in a natural state. This habitat alteration would be expected to produce a negative response in what was initially a riverine benthic community; one which should be, and is, characterized by low IBI scores. Because the station scores show habitat quality to be relatively similar at each sample location, differences in the benthic community resident in the thermally influenced versus the non-thermally influenced locations may be considered, in part, attributable to temperature increase. However, other habitat features such as the amount of submerged aquatic vegetation (SAV), water velocity, and spatial location in reference to tributaries or other Pond features are not accounted for in the habitat assessment.

Macroinvertebrates

2016 Results

Benthic macroinvertebrate collections made at seven stations in 2016 yielded a total of 7,097 organisms that were processed and identified. A total of 59 taxa were collected. The identity of common macroinvertebrate taxa (>1% of total organisms) was similar among collection locations and six to 12 common taxa were collected at individual stations (Table 6-4). The samples contained taxa expected to be found in a lentic environment, including representatives of most of the orders of aquatic insects as well as worms (Oligochaeta), snails (*Elimia*, *Ferrissia*, and *Gyraulus*, etc.), clams (*Corbicula*), and crustaceans (*Caecidotea* and *Gammarus*) (Table 6-5).

A few benthic macroinvertebrate taxa comprised a large proportion of all organisms collected at each of the stations. With few exceptions, Chironomidae, *Gammarus*, and Oligochaeta were among the most abundant organisms at all stations (Table 6-5).

Other common taxa included *Corbicula*, *Physella,* Hydrachnidea, and *Caenis*. No Plecoptera (stoneflies) and few Trichoptera (caddisflies) were collected. The mayfly *Caenis* was the only mayfly commonly collected among stations. Other Ephemeroptera and Trichoptera that comprised >1% of total organisms included *Stenonema, Stenacron, Oecetis, Hexagenia, Orthotrichia*, and *Maccaffertium*. Differences were observed in composition of common taxa among stations. Fewer common taxa were collected at Station 214, compared to the other locations. Chironomidae, Oligochaeta and *Corbicula* comprised a greater proportion (88%) of

the benthic community at Station 214 compared to the other stations (Table 6-5). In contrast, Chironomidae, Oligochaeta and *Corbicula* comprised the lowest proportion (34.5 %) of the benthic community at Station 220.

2016 IBI and Metrics

IBI scores were generally low for all stations within and outside of the thermal plume and ranged between 11.5 and 49.4 (Figure 6-4). The lowest IBI scores were observed at Stations 214 (IBI score 11.5) in September and 221 (IBI Score 14.9) in June. However, IBI scores at the other thermal and non-thermal stations were similar with IBI scores generally higher from July through September for all stations. Other slight spatial differences were observed both between and within non-thermal and thermal station groups. The highest scores at the non-thermal stations were observed at Station 220 and for the thermally influenced stations the highest scores varied from month to month.

Individual metrics that comprised the IBI scores were also evaluated for each monthly collection. Table 6-7 through Table 6-12 provide the monthly metric values for each station. Total richness values were higher during July, August, and September for most stations with the most taxa observed at Station 220 (n= 17) during July and September. However, the fewest taxa (n = 5) were observed at Station 214 during September. EPT Richness values followed the general pattern of Total Richness with the highest values observed from July through September for all stations. The EPT Richness values ranged between zero to seven taxa among stations. Similar to EPT Richness, Ephemeroptera Richness values were low and variable, ranging zero to five taxa among stations. Few Trichoptera were collected, as indicated by low richness values for all stations with the highest richness (5 taxa) observed at Station 220 in July (Figure 6-7). Modified Beck's Index values were similar among stations with the highest value observed at Station 220 in August. Shannon Diversity ranged between 0.63 for Station 214 in September to 2.33 for Station 220 in September. Shannon Diversity values were generally lower for Station 214 during most months.

Water Temperature vs IBI scores all years

The observed IBI scores in relation to mean water temperature for the month of collection were similar between post-EPU and pre-EPU monitoring. Figure 6-10 provides a scatter plot which illustrates the relation between mean water temperature and IBI score for each month during pre-EPU and post-EPU monitoring. Generally, similar patterns were observed for IBI scores across the range of measured water temperatures. Except for the low post-EPU September IBI score, the IBI scores tended to be higher during post-EPU period for temperatures >90 °F. The post-EPU scores clustered between 25 and 40, whereas; the pre-EPU scores were between 10 and 25. A consistent trend between water temperatures and IBI score was not observed. However, a seasonal pattern was observed with lowest scores occurring during May at most Stations and during August at the thermally influenced stations (Stations 214 and 215) with the highest water temperatures. The lowest scores (<10) recorded during pre-EPU monitoring occurred in May and August. Generally for both pre- and post-EPU monitoring IBI Scores were highest during July through September at water temperatures between 80 and 90 °F. The lowest September IBI score occurred post-EPU (Station 214) at temperature >90 °F.

Post-EPU IBI Score Comparison to Pre-EPU

Comparison of post-EPU IBI scores during 2016 to the pre-EPU IBI scores (2010-2013) allows for inspection of potential differences that may have been a result of the increase in temperature from the EPU. Figure 6-5 through Figure 6-9 provide box plots of IBI scores by month and by station from May through September. The May post-EPU IBI scores were within the range of IBI scores observed pre-EPU for all stations except 189 which was lower than pre-EPU. June post-EPU IBI scores were within the range of IBI scores observed pre-EPU for all stations except 189 (thermally influenced) and 221 (non-thermal) which were lower than pre-EPU and just outside of the interquartile (IQ) range. July post-EPU IBI scores were within the range of IBI scores and most were higher than pre-EPU observations with the exception of Station 208 which was lower than pre-EPU scores and outside of the IQ range. For August generally higher IBI scores were observed during the Post-EPU Study as compared to the pre-EPU study. The Station 216 (thermal) post-EPU score in August was lower than all pre-EPU observations and just outside of the IQ range. In September similar IBI scores were observed during pre- and post-EPU except for Stations 214 and 215 which were both outside the IQ range. The lowest IBI Score observed during September occurred at Station 214 during post-EPU monitoring. For most months and stations the IBI scores were generally higher during the post-EPU monitoring except for Stations 214 and 215 in September.

Post-EPU Metric Comparison to Pre-EPU

Similar to IBI scores, a comparison of pre-EPU and post-EPU metric values allows for inspection of potential differences that may have been a result of the increase in temperature from the EPU. Figure 6-11 through Figure 6-15 provide box plots of the six metrics that comprise the IBI Score. pre- and post-EPU metric values for Total Richness, EPT Richness and Ephemeroptera Richness were comparable for most stations with the exception of Station 189. Lower values for all three metrics at this station were observed during May post-EPU monitoring. For all other stations Total Richness, EPT richness and Ephemeroptera richness metric values were comparable or higher during the post-EPU monitoring period. For Trichoptera richness the post-EPU values were within the range observed pre-EPU. Similarly, Shannon Diversity values were comparable to or higher during the post-EPU monitoring period. Beck's Index values were also comparable between pre- and post-EPU monitoring. The only exception was station 189 which had one monthly value (May collection) below the range of values observed pre-EPU. All other station post-EPU values were within the range of the pre-EPU observations. Benthic community composition as measured by these six metrics was similar to pre-EPU monitoring with no measurable impacts from the EPU on the community.

Discussion

The macroinvertebrate community composition and relative abundance observed in 2016 was similar to the pre-EPU observations. Most of the macroinvertebrate taxa collected in this study prefer lentic habitats and are considered fairly tolerant of water/habitat quality degradation. Few intolerant taxa were collected. The observed taxa are representative of a warmwater aquatic community in a lentic waterbody. The most abundant taxa were Chironomidae, *Gammarus*, and Oligochaeta. During September when measurable impacts of the thermal plume were observed

at Stations 214 and 215 several taxa were not present or present in low numbers including Ephemeroptera and Trichoptera. Overall, few taxa were present in September at these two stations and the benthic community was predominated by Oligochaeta, Chironomidae, and *Enallagma*.

Station 214 is the benthic macroinvertebrate station located closest to the end of the discharge canal. The IBI scores for May through August 2016 at Station 214 were comparable to the other non-thermal and thermal stations and higher than most pre-EPU observations at this station for July and August. However, the lowest IBI Score for all stations was observed at Station 214 in September indicating benthos effects attributable to the heated effluent. Station 215 is the next closest station to the PBAPS discharge canal. IBI scores at Station 215 were not substantially different from the other thermal or non-thermal stations from May through August. However, similar to Station 214, a low IBI score was observed at this station during September as compared to the other stations. For both stations a decline in benthic community diversity was observed in September.

Metric and IBI scores indicate that the thermal effect to the benthos community from the PBAPS thermal plume is confined to the western shoreline at Stations 214 and 215. Low IBI scores were observed at Stations 214 and 215 during September after a prolonged period of high water temperatures. Based on previous observations from pre-EPU monitoring (Normandeau and ERM 2014) improvement in both IBI scores and metric values occurred during subsequent months, indicating re-colonization and recovery of the benthic community at these stations. Metric values and IBI scores during post-EPU monitoring indicated no measurable impact to the benthic community at monitoring locations downstream from Stations 214 and 215.

These results show only a short-term seasonal effect attributable to the discharge for Stations 214 and 215 during the month of September. The shoreline area between Stations 214 and 215 likely experiences similar conditions and similar changes to the benthic community as the stations that bracket this area. Moreover, observations of IBI scores and metric values at Stations 214 and 215 were similar to the non-thermal stations. Station 215 benthic community observations were not substantially different from the non-thermal stations.

Conclusions

Benthic community effects resulting from the thermal plume are localized and temporary and consistent with the observations during pre-EPU monitoring. The area of measurable impact was limited to Station 214 and 215 and small in comparison to the amount of similar non-thermally impacted Conowingo Pond shoreline.

Benthic macroinvertebrate collections were successfully completed during 2016. The data indicate that:

- The composition and relative abundance of the benthic community observed in 2016 was similar to pre-EPU observations.
- The benthic community was characterized by similar diversity both within and outside of the thermal plume.

- IBI scores for individual monitoring stations were similar between the pre-EPU and post-EPU monitoring.
- Temporary impact, in terms of lower IBI scores, was observed at Stations 214 and 215 in September. The lower IBI scores during post-EPU monitoring occurred after a sustained period of high water temperatures. In contrast, the lowest scores for these stations during pre-EPU monitoring occurred during July and August. Relatively high IBI scores at these stations were observed in July and August during post-EPU monitoring.
- There was no observed impact to the benthic community at the two thermally-influenced Stations (189 and 216) that are farther downstream from the discharge canal.
- Similar to pre-EPU observations the benthic community effects resulting from the thermal plume are local and temporary.
- The biological modeling results for the Pre-EPU Demonstration Study were bounded by the actual sampling results during EPU operation in an extreme flow and temperature period.
- There is a balanced indigenous benthic community within Conowingo Pond.

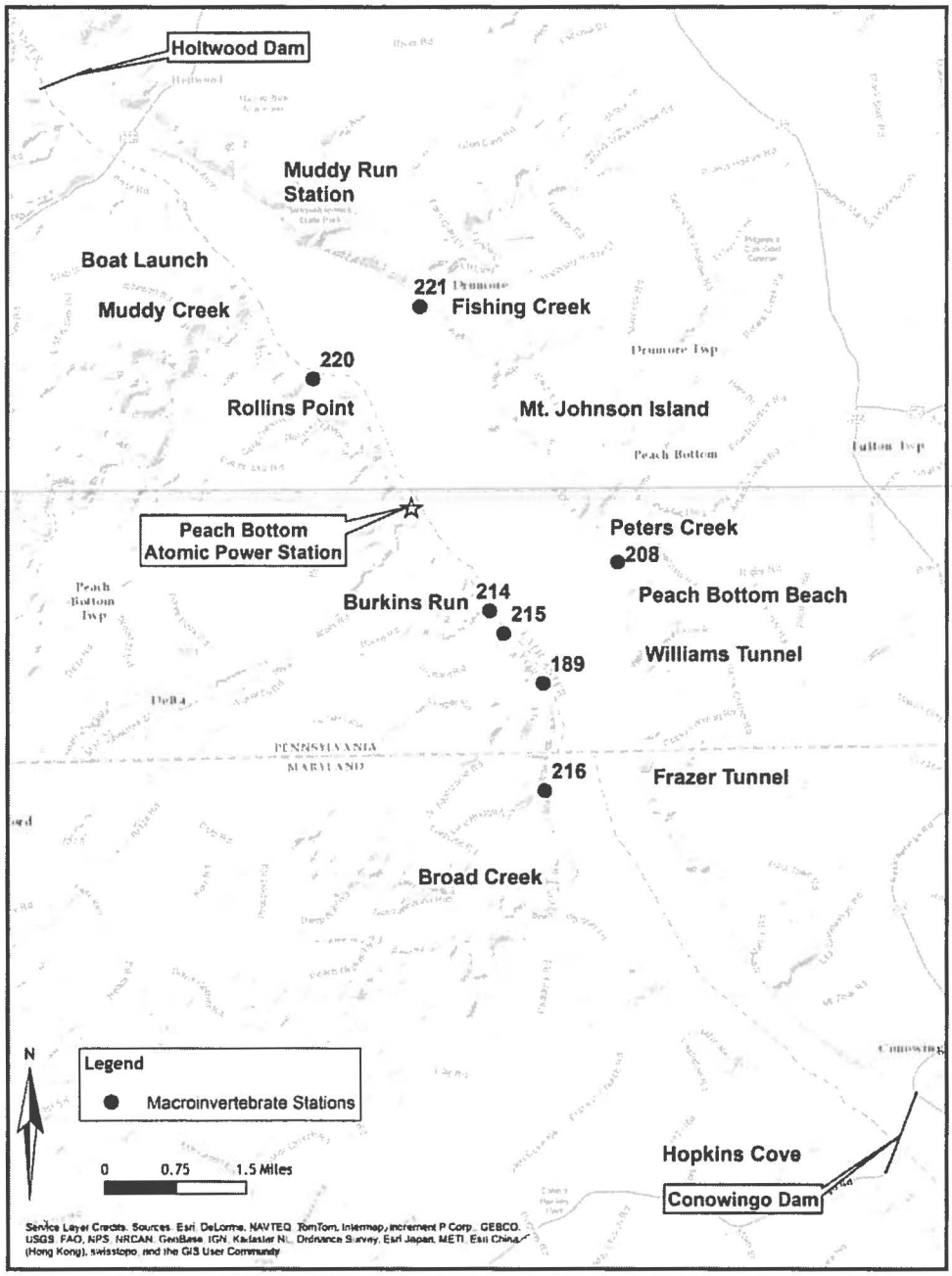


Figure 6-1. Location of benthic macroinvertebrate collection stations.

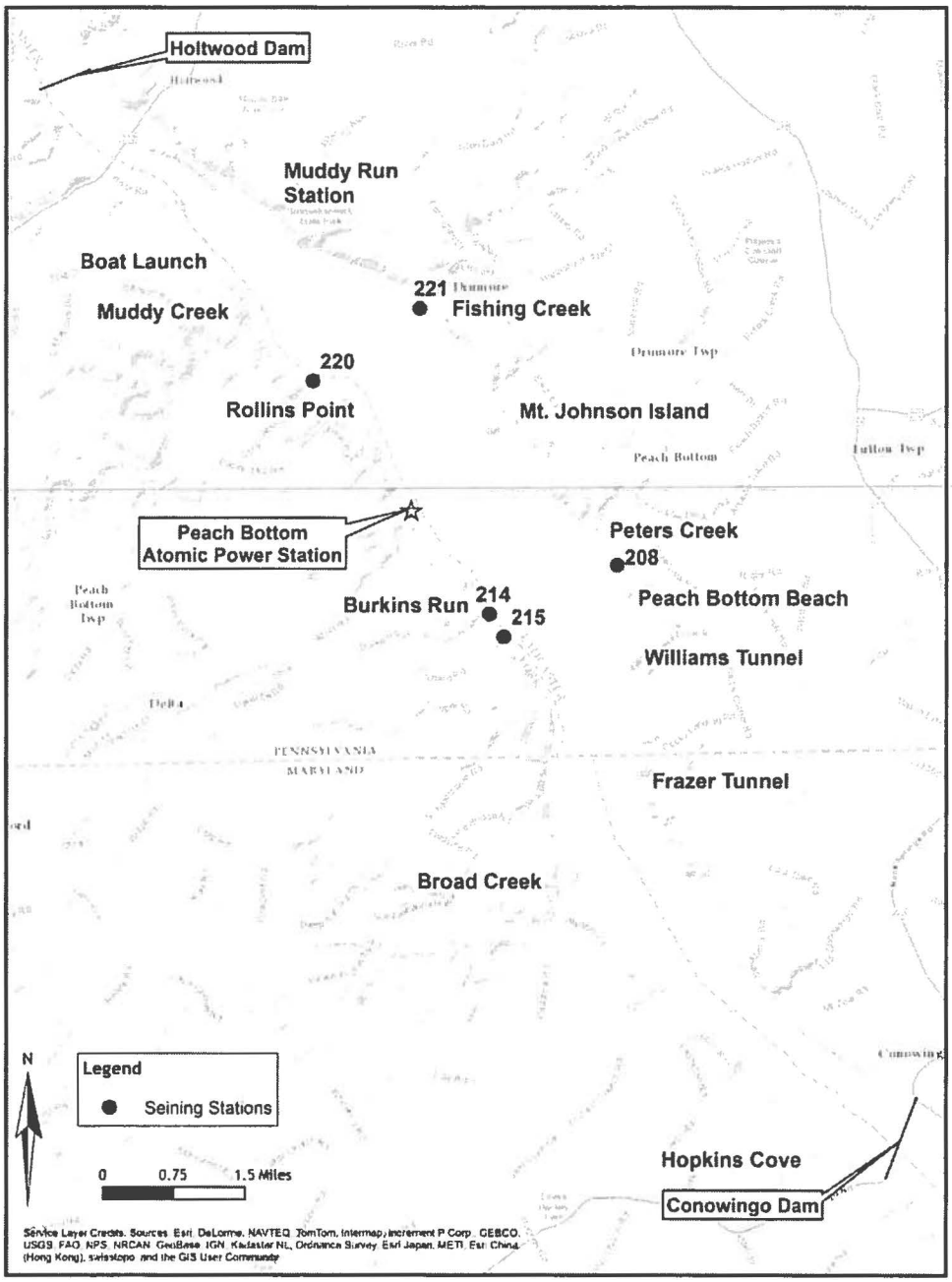


Figure 6-2 Location of seine collection stations.

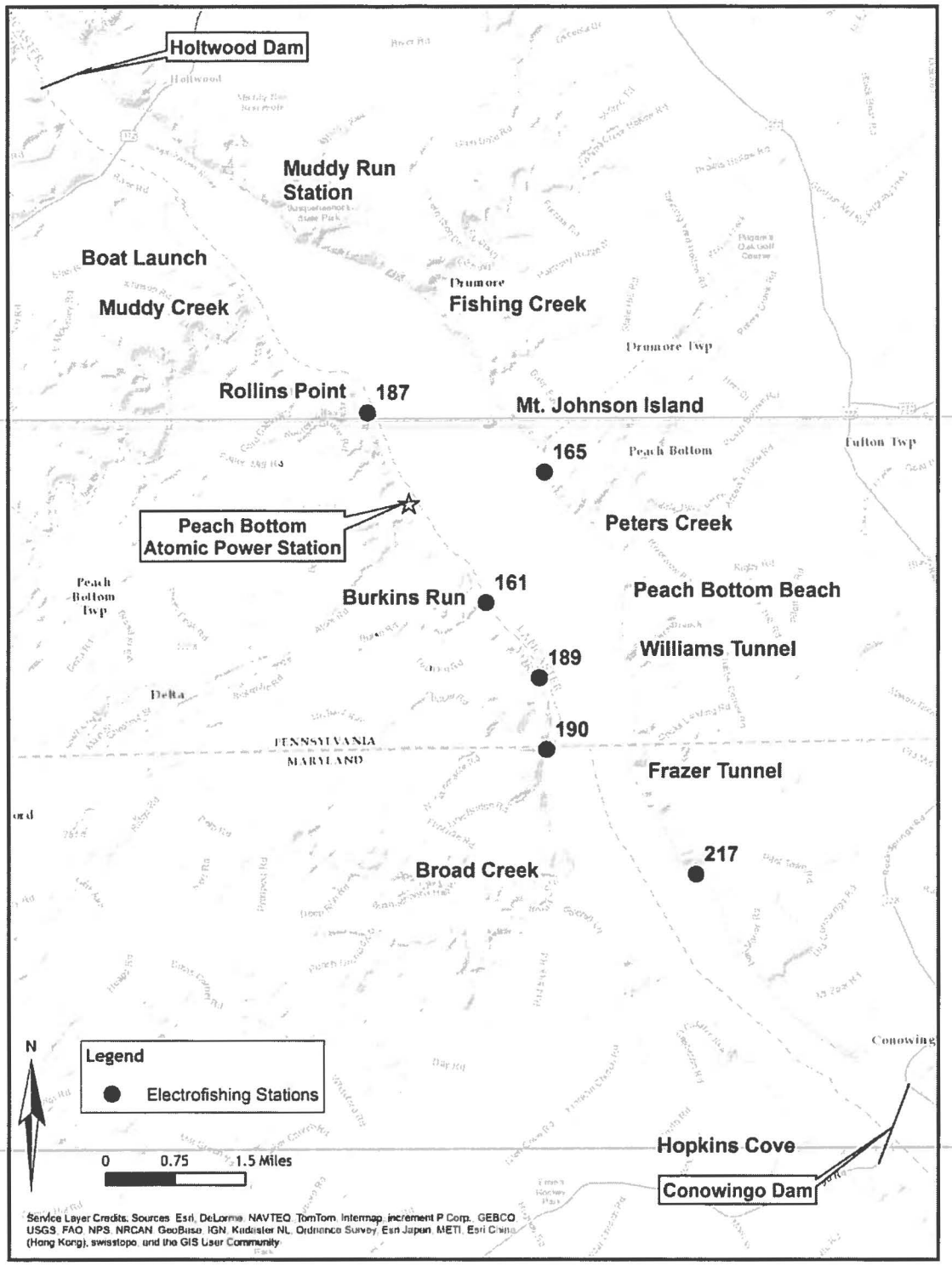


Figure 6-3. Location of electrofishing collection stations.

Table 6-1. Description of seine, benthos, electrofishing, and water temperature stations in Conowingo Pond (negative values indicate distance upstream from the discharge canal).

Station	Monitoring Description	Description	Distance From End Of Discharge Canal	
			Meters	Miles
221	B, S, T	Fishing Creek confluence - northwest side of shoal.	-4,765	-2.96
220	B, S, T	Coal Cabin boat launch.	-4,410	-2.74
187	E	South of Rollins Point to first cabin.	-3,325	-2.07
208	B, S, T	Peach Bottom Beach.	-2,449	-1.52
165	E	East shoreline above Peters Creek.	-2,159	-1.34
161	E, T[1]	Rock outcropping above Burkins Run to PBAPS discharge structure.	545	0.34
214	B, S, T	Beach at the mouth of Burkins Run.	591	0.37
215	B, S, T	Campground boat launch' - about 250 m below the mouth of Burkins Run.	1,049	0.65
189	B, E, T	Rock outcropping at north side of Michael's Run to 'McClellan's Rock'.	2,128	1.32
190	E, T	First cabin below Michaels Run to mouth.	3,285	2.04
216	B, T	Below site 190, small cove at end of Line Bridge Road	3,919	2.44
217	E, T	2,000 m above the mouth of Conowingo Creek.	6,466	4.02

S = Seine, F = Electrofish, B = Benthos, T = Temperature

[1] *Station 214 temperature monitoring representative of this location*

Table 6-2. Descriptions of benthic macroinvertebrate community metrics.

Metric	Description	Response to Impairment
Richness	The total number of taxa. The PA DEP 95th percentile value is 31 taxa.	decreases
EPT Index	A count of the number of mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) genera. The PA DEP 95th percentile value is 17 genera.	decreases
Modified Beck's 4 Index	A weighted count of taxa with Pollution Tolerance Values between 0 and 4. Taxa with Tol. Values of 0 or 1 are given 2 points. Taxa with Tol. Values between 2 and 4 are given 1 point. The PA DEP 95th percentile index value is 22.	decreases
Shannon Diversity (H')	A measure of community balance in base e based on the distribution of the taxa present ($H = -\text{Sum}\, P_i \log P_i$). The PA DEP 95th percentile index value is 2.43.	decreases
Number of Mayfly Taxa	A count of the number of genera in the order Ephemeroptera. The PA DEP 95th percentile value is 6 genera.	decreases
Number of Caddisfly Taxa	A count of the number of genera in the order Trichoptera. The PA DEP 95th percentile value is 11 genera.	decreases

Table 6-3 Average habitat assessment scores for the seven benthic macroinvertebrate collection locations, May through September 2016.

	Non-Thermal Stations			Thermal Stations			
Parameter	220	221	208	214	215	189	216
Epifaunal Substrate/Available Cover	13	10	14	13	15	11	13
Pool Substrate Characterization	17	14	15	16	16	11	15
Pool Variability	13	3	11	9	14	12	13
Channel Alteration	16	6	11	10	17	16	13
Sediment Deposition	10	10	11	10	11	10	11
Channel Flow Status	14	17	7	14	15	18	16
Condition of Banks	11	9	12	11	17	6	14
Bank Vegetative Protection	5	14	9	12	15	17	15
Riparian Vegetative Zone Width	3	18	5	12	14	18	13
Total Score	101	102	95	107	133	120	124

Table 6-4. Total number of benthic macroinvertebrates collected at each station in Conowingo Pond from May through September 2016.

	Station							
Taxon	214	215	216	189	208	220	221	Total Number
Amnicola						1		1
Anthopotamus						1		1
Argia		1	25	17	1	2		46
Baetis							1	1
Bezzia					1			1
Caecidotea			30	45	2			77
Caenis	36	18	46	11	254	31	41	437
Callibaetis	1		1		5	1	5	13
Ceraclea					1	5		6
Ceratopogon						1		1
Cheumatopsyche		1						1
Chironomidae	479	548	438	361	267	316	307	2716
Cipangopaludina			3			4		7
Climacia					2			2
Corbicula	152	68	28	89	11	27	50	425
Cyrnellus		1						1
Dasyhelea							1	1
Dromogomphus						1		1
Dubiraphia						2	1	3
Dugesia	2			1				3
Elimia			18		2	21	1	42
Enallagma	2	45	6		13	18	31	115
Erpobdella				1				1
Ferrissia			5	1		39		45
Galba		1				1	1	3
Gammarus	2	79	182	245	95	218	152	973
Gloiobdella		2						2
Gyraulus	8	1	6	1	29	161	100	306

Table 6-4. Continued.

	Station							
Taxon	214	215	216	189	208	220	221	Total Number
Helobdella			1		1		1	3
Hexagenia		56	1	3	5	7	3	75
Hyalella					1			1
Hydrachnidea	13	41	31	35	101	21	73	315
Hydroptila	1	3	1	1	4	7		17
Leptoxis							1	1
Libellulidae	1				2			3
Maccaffertium	1	8	2	11	5	1		28
Microcylloepus		1						1
Micromenetus			4	1	3	16	14	38
Nematoda			2	1			2	5
Nigronia	1							1
Oecetis	3	8	6	14	10	3	3	47
Oligochaeta	287	56	155	71	106	8	118	801
Orconectes				1	1	3		5
Orthotrichia				5	13	1		19
Oxyethira					3			3
Paraleptophlebia						1		1
Phylocentropus						1		1
Physella	45	50	12	54	80	52	65	358
Pisidium			1					1
Planorbella			2		1	1	2	6
Pleurocera			1		2	2	5	10
Probezzia		1						1
Prostoma		1						1
Sialis		1	4			1	1	7
Stenacron	3	25	13	18		13		72
Stenelmis	2	9		1				12
Stenonema		8	16			6		30
Triaenodes						1		1
Tricorythodes	2							2
Total Number	1,041	1,033	1,040	988	1,021	995	979	7,097
Total Taxa	19	25	28	23	29	36	24	59
Total Ephemeroptera Taxa	4	4	5	3	3	7	4	9
Total Trichoptera Taxa	2	3	2	3	5	6	1	8

Table 6-5. Percent composition of common benthic macroinvertebrates (>1% of total organisms) collected from Conowingo Pond, May through September 2016.

	Station						
Taxon	214	215	189	216	208	220	221
Argia			1.7	2.4			
Caecidotea			4.6	2.9			
Caenis	3.5	1.7	1.1	4.4	24.9	3.1	4.2
Chironomidae	46.0	53.0	36.5	42.1	26.2	31.8	31.4
Corbicula	14.6	6.6	9.0	2.7	1.1	2.7	5.1
Elimia				1.7		2.1	
Enallagma		4.4			1.3	1.8	3.2
Ferrissia						3.9	
Gammarus		7.6	24.8	17.5	9.3	21.9	15.5
Gyraulus					2.8	16.2	10.2
Hexagenia		5.4					
Hydrachnidea	1.2	4.0	3.5	3.0	9.9	2.1	7.5
Maccaffertium			1.1				
Micromenetus						1.6	1.4
Oecetis			1.4				
Oligochaeta	27.6	5.4	7.2	14.9	10.4		12.1
Orthotrichia					1.3		
Physella	4.3	4.8	5.5	1.2	7.8	5.2	6.6
Stenacron		2.4	1.8	1.3		1.3	
Stenonema				1.5			
Total Taxa	6	10	12	12	10	12	10
Total EPT Taxa	1	3	4	3	1	2	1

Table 6-6. Percent composition of common benthic macroinvertebrates (>1%) collected from Conowingo Pond, May through September 2010-2013.

	Station						
Taxon	214	215	189	216	208	220	221
Acariformes	1.2	2.9	3.8	2.7	14.4	2.6	4.5
Caecidotea			2.3	1.7			
Caenis	5.0	2.9		13.2	17.8	12.7	1.5
Callibaetis					1.3		
Chironomidae	55.1	45.3	39.5	32.2	30.2	43.8	49.9
Corbicula	14.9	20.1	12.0	5.2	2.0	5.8	2.4
Crangonyx				1.6			
Enallagma							1.3
Fossaria	3.5	1.6					
Gammarus	1.6	4.7	26.5	14.1	10.0	11.7	5.6
Gyraulus					5.6	3.0	6.1
Helisoma							2.1
Hexagenia		2.8	1.5			1.2	
Oecetis					1.2		
Oligochaeta	10.7	9.5	4.6	20.9	7.5	11.2	18.6
Orthotrichia					1.7		
Physa	3.2	4.6	1.2		2.0		1.1
Stenacron			2.5				
Stenelmis		1.5					
Stenonema				2.3			
Total Taxa	8	10	9	9	11	8	10
Total EPT Taxa	1	2	2	2	4	2	1

Table 6-7. Total Richness values by month for benthic macroinvertebrate collection locations in Conowingo Pond, May through September 2016.

	Station						
Month	214	215	216	189	208	220	221
May	8	12	9	7	9	15	7
June	8	14	10	9	10	13	8
July	10	15	16	14	9	17	10
August	11	13	14	15	16	15	14
September	5	9	16	12	19	17	13
Mean	8.4	12.6	13.0	11.4	12.6	15.4	10.4

Table 6-8. EPT Richness values by month for benthic macroinvertebrate collection locations in Conowingo Pond, May through September 2016.

	Station						
Month	214	215	216	189	208	220	221
May	1	3	2	0	2	2	1
June	3	6	3	2	3	3	0
July	4	6	5	5	4	7	3
August	3	5	4	6	6	6	3
September	1	3	5	4	6	6	4
Mean	2.4	4.6	3.8	3.4	4.2	4.8	2.2

Table 6-9. Ephemeroptera Richness values by month for benthic macroinvertebrate collection locations in Conowingo Pond, May through September 2016.

	Station						
Month	214	215	216	189	208	220	221
May	1	3	1	0	1	1	1
June	1	4	2	2	1	2	0
July	4	4	3	3	2	2	3
August	2	4	3	4	3	5	2
September	1	2	5	2	2	5	3
Mean	1.8	3.4	2.8	2.2	1.8	3.0	1.8

Table 6-10. Trichoptera Richness values by month for benthic macroinvertebrate collection locations in Conowingo Pond, May through September 2016.

	Station						
Month	214	215	216	189	208	220	221
May	0	0	1	0	1	1	0
June	2	2	1	0	2	1	0
July	0	2	2	2	2	5	0
August	1	1	1	2	3	1	1
September	0	1	0	2	4	1	1
Mean	0.6	1.2	1.0	1.2	2.4	1.8	0.4

Table 6-11. Modified Beck's Index values by month for benthic macroinvertebrate collection locations in Conowingo Pond, May through September 2016.

	Station						
Month	214	215	216	189	208	220	221
May	3	3	2	1	1	4	2
June	1	4	2	3	1	2	2
July	3	3	4	3	1	3	2
August	2	4	3	4	6	7	2
September	1	3	3	3	3	4	2
Mean	2.0	3.4	2.8	2.8	2.4	4.0	2.0

Table 6-12. Shannon Diversity values by month for benthic macroinvertebrate collection locations in Conowingo Pond, May through September 2016.

	Station						
Month	214	215	216	189	208	220	221
May	1.08	1.83	1.32	1.56	1.30	1.29	1.34
June	1.11	1.87	1.68	1.26	1.43	1.62	1.32
July	1.56	1.66	1.97	1.72	1.36	2.11	1.71
August	1.48	1.09	1.48	1.62	1.62	1.75	2.24
September	0.63	1.29	1.65	1.67	2.04	2.33	1.89
Mean	1.17	1.55	1.62	1.56	1.55	1.82	1.70

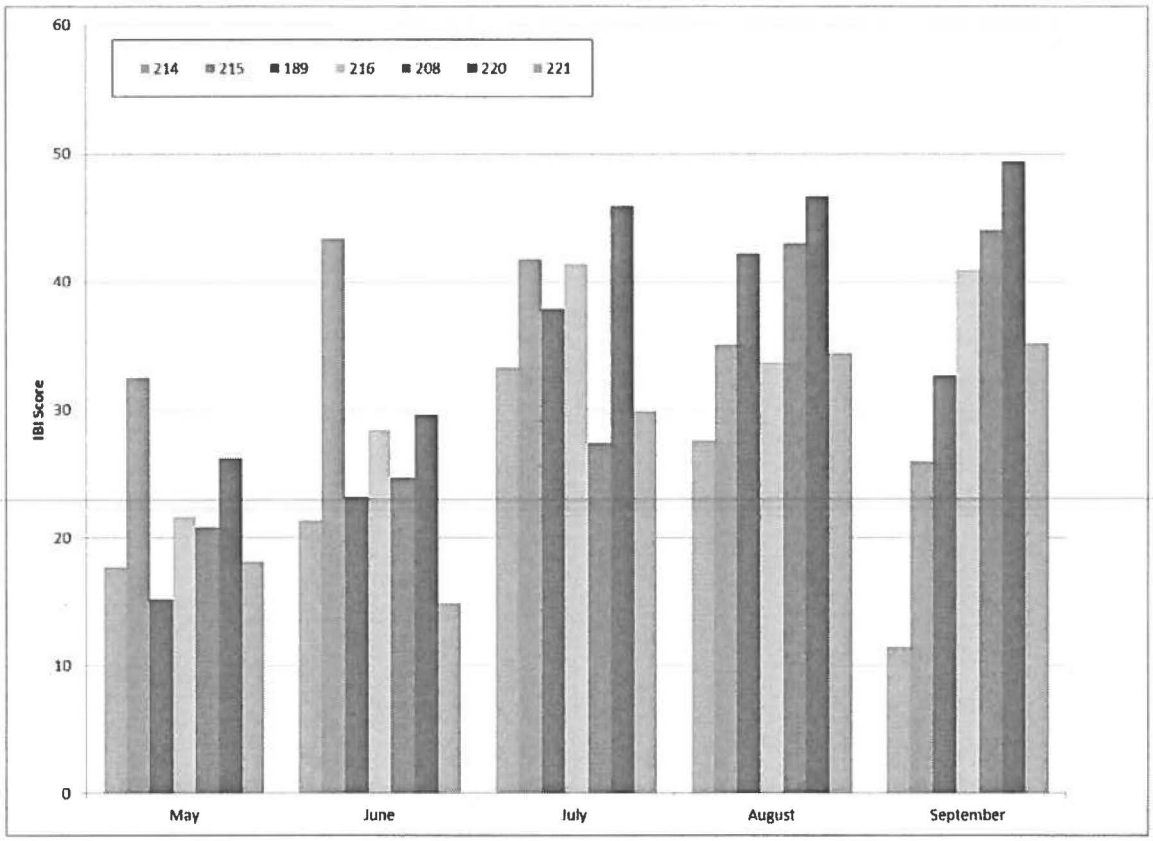


Figure 6-4. Bar chart showing the IBI scores for each station by month, May through September 2016.

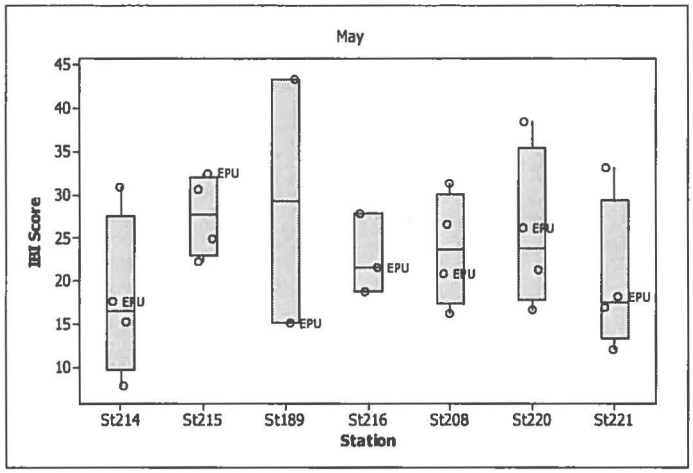


Figure 6-5. Box plot of May IBI scores for all stations during pre-EPU (2010-2013) and post-EPU (2016) monitoring. Stations 208, 220, and 221 are considered non-thermal.

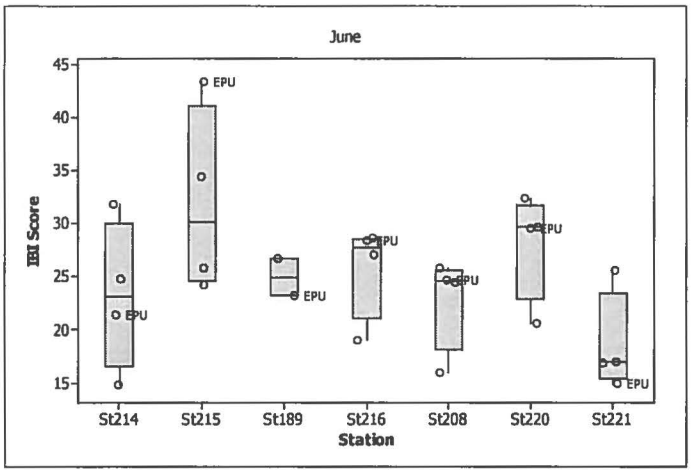


Figure 6-6. Box plot of June IBI scores for all stations during pre-EPU (2010-2013) and post-EPU (2016) monitoring. Stations 208, 220, and 221 are considered non-thermal.

(boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, open circle = IBI score, the post-EPU value is labeled EPU, and asterisk = outlier)

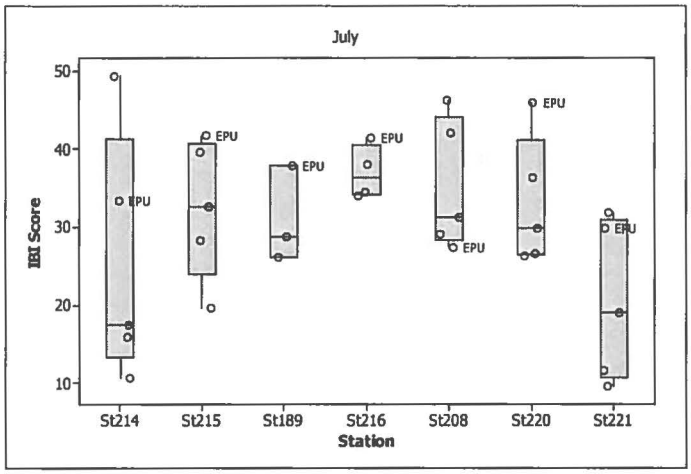


Figure 6-7. Box plot of July IBI scores for all stations during pre-EPU (2010-2013) and post-EPU (2016) monitoring. Stations 208, 220, and 221 are considered non-thermal.

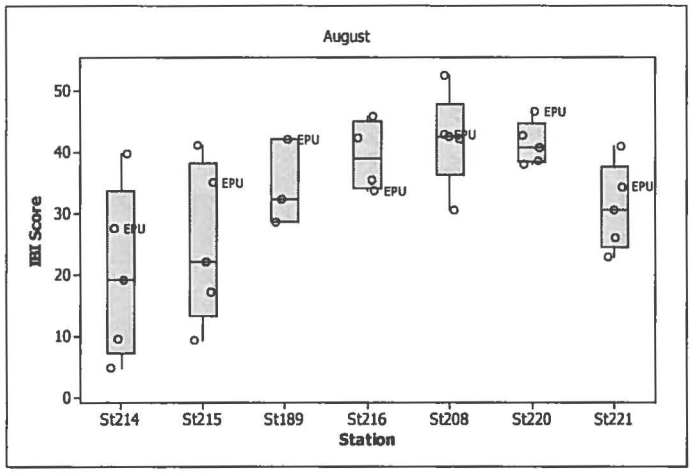


Figure 6-8. Box plot of August IBI scores for all stations during pre-EPU (2010-2013) and post-EPU (2016) monitoring. Stations 208, 220, and 221 are considered non-thermal.

(boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, open circle = IBI score, the post-EPU value is labeled EPU, and asterisk = outlier)

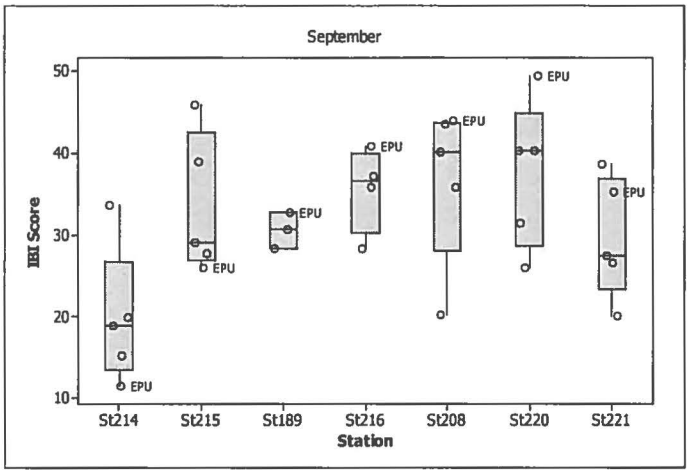


Figure 6-9. Box plot of September IBI scores for all stations during pre-EPU (2010-2013) and post-EPU (2016) monitoring. Stations 208, 220, and 221 are considered non-thermal.

(boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, open circle = IBI score, the post-EPU value is labeled EPU, and asterisk = outlier)

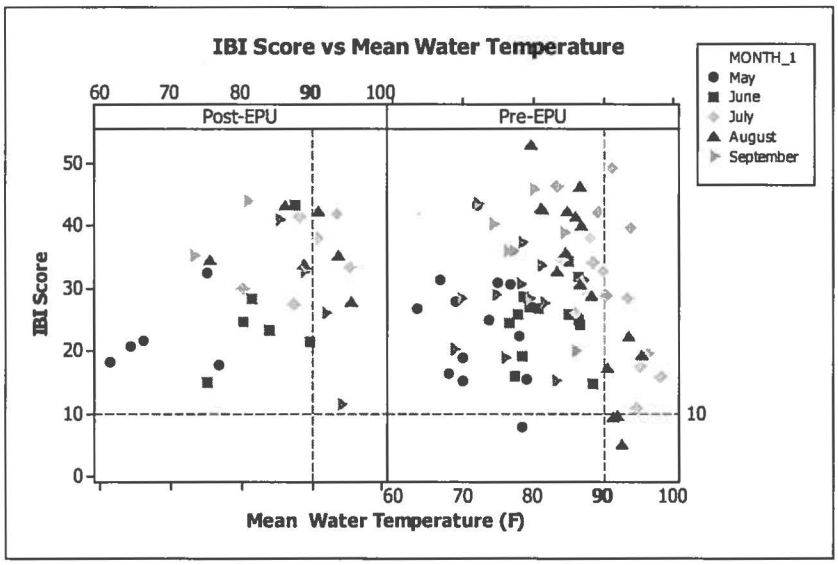


Figure 6-10. Relation of mean water temperature measured during the month of benthos collection to the corresponding IBI Score for that month for post-EPU (left panel) and pre-EPU (right panel) monitoring, May through September 2010-2016.

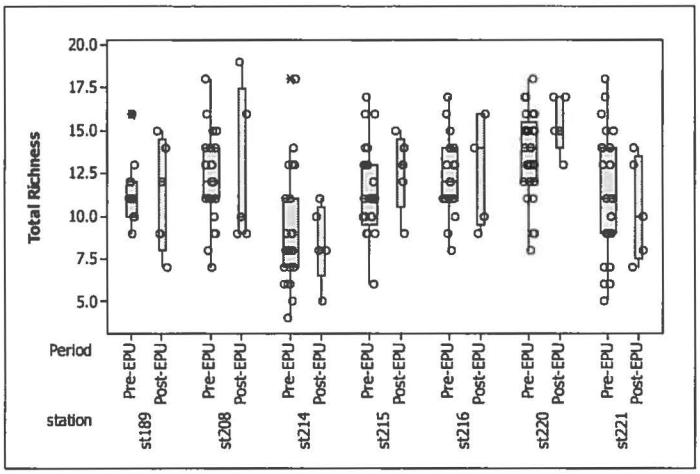


Figure 6-11. Box plot of Total Richness for all stations during pre-EPU (2010-2013) and post-EPU (2016) monitoring, May through September. Stations 208, 220, and 221 are considered non-thermal.

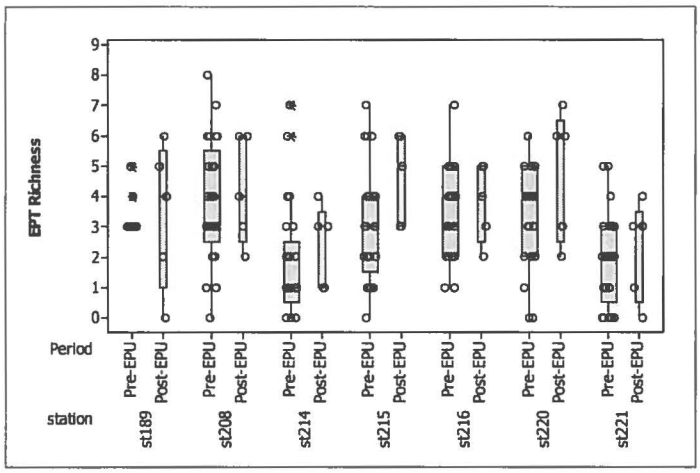


Figure 6-12. Box plot of EPT Richness for all stations during pre-EPU (2010-2013) and post-EPU (2016) monitoring, May through September. Stations 208, 220, and 221 are considered non-thermal.

(boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, open circle = metric value, and asterisk = outlier)

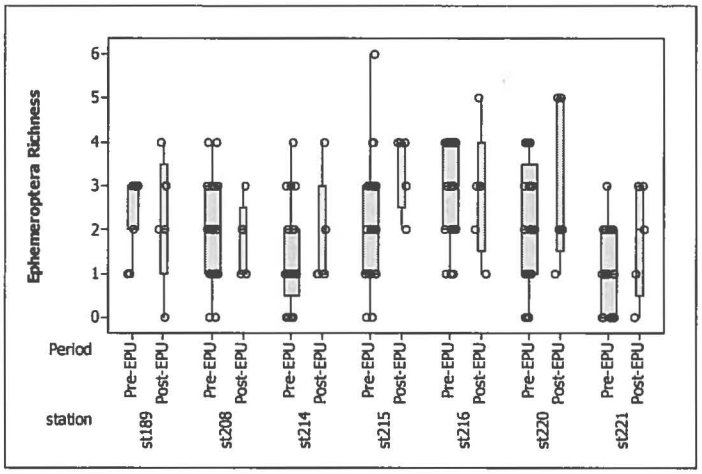


Figure 6-13. Box plot of Ephemeroptera Richness for all stations during pre-EPU (2010-2013) and post-EPU (2016) monitoring, May through September. Stations 208, 220, and 221 are considered non-thermal.

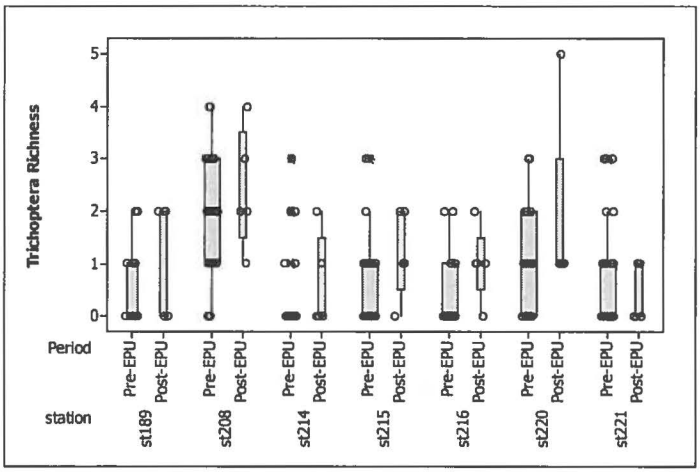


Figure 6-14. Box plot of Trichoptera Richness for all stations during pre-EPU (2010-2013) and post-EPU (2016) monitoring, May through September. Stations 208, 220, and 221 are considered non-thermal.

(boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, open circle = metric value, and asterisk = outlier)

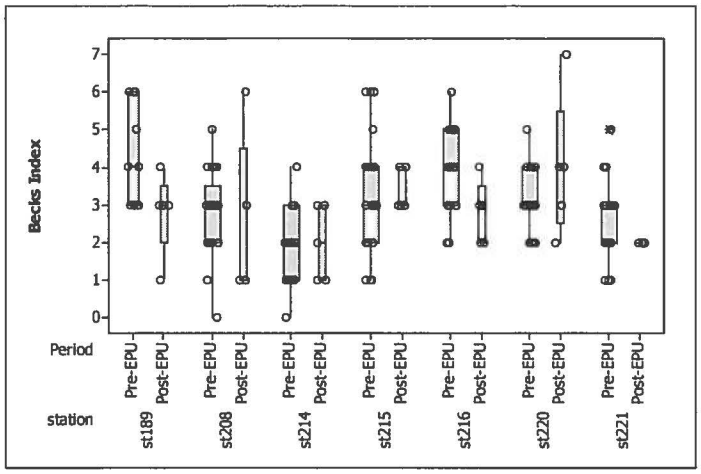


Figure 6-15. Box plot of Beck's Index for all stations during pre-EPU (2010-2013) and post-EPU (2016) monitoring, May through September. Stations 208, 220, and 221 are considered non-thermal.

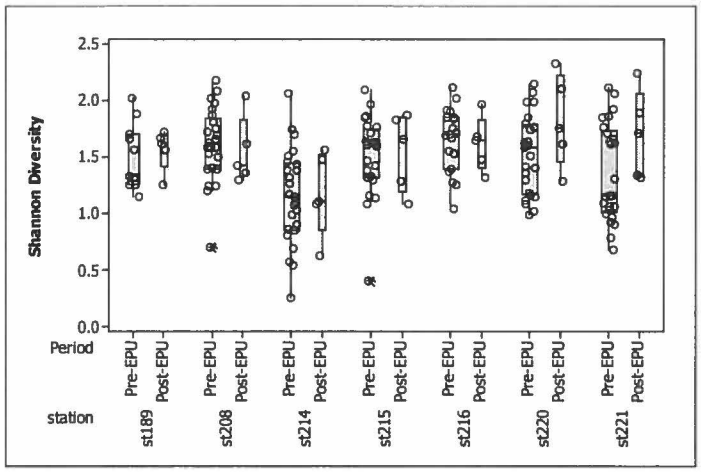


Figure 6-16. Box plot of Shannon Diversity for all stations during pre-EPU (2010-2013) and post-EPU (2016) monitoring, May through September. Stations 208, 220, and 221 are considered non-thermal.

(boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, open circle = metric value, and asterisk = outlier)

6.3 Fish Community

The spatial and temporal distribution of fish was evaluated in Conowingo Pond by monthly sampling at both thermally influenced and non-thermally influenced locations from May through September 2016. Sampling sites were separated into non-thermal and thermal stations based on their location in relation to the PBAPS thermal plume. Stations downstream of the discharge canal that experience elevated water temperatures above ambient water temperature for the entire collection period are considered to be thermally influenced (electrofisher Stations 161, 189, 190, and 217; seine Stations 214 and 215). Stations located upstream of the PBAPS thermal discharge that experience natural water temperature conditions are considered non-thermal (electrofisher Stations 165 and 187; seine Stations 208, 220, and 221). As previously discussed seine Station 208 does experience elevated water temperatures during a portion of the year resulting from thermal plume movement upstream during low flow conditions; however, this station is considered non-thermal because it does not experience a prolonged year-round thermal influence.

The relative abundance of all fish was determined by standardizing the number of individuals of each species collected per unit of collection effort for each sampling gear. Comparison between the pre-EPU and post-EPU communities was completed to evaluate the potential effect of the temperature rise associated with the EPU on the fish community.

Eleven fish species were previously designated as representative important species (RIS) for the most recent pre-EPU 316a Demonstration Study (Normandeau and ERM 2014). The species were agreed upon with PADEP. Most of these species are appropriate representative species for assessment of potential thermal impact consistent with the concept of RIS, as established by the USEPA (1977), e.g., recreational value, representative of the balanced indigenous community, or an important food item for other RIS. The eleven RIS were Bluegill, Bluntnose Minnow, Channel Catfish, Gizzard Shad, Largemouth Bass, Chesapeake Logperch, Smallmouth Bass, Spotfin Shiner, Walleye, White Crappie, and White Sucker. The composition and relative abundance of the RIS at each of the monitoring stations are evaluated and compared between pre- and post-EPU monitoring. The selected RIS did not include migratory fish species.

6.3.1 Methods

Electrofishing

Electrofishing was conducted at night at six stations located along the shores of Conowingo Pond (Table 6-1 and Figure 6-3). The electrofishing system consisted of a Smith-Root VVP-15B variable voltage pulsator, powered by a 3.5-kW generator, and mounted in an 18-ft aluminum boat equipped with a bow-mounted T-boom cathode array and flood lights. Fishes were collected using pulsed direct current to minimize fish injury. Sampling at each location consisted of a 30-minute run and was typically completed in one pass through the sampling location. The electrofishing boat was maneuvered slowly through the site, as close to shore as possible.

Stunned fish were netted at the bow and placed in a live well. Large stunned specimens of Common Carp and Quillback were not netted, but were counted by the netting crew and recorded. At the end of 30 minutes, the boat was returned to the center of the station, and the catch processed. Each fish was identified to species, measured to the nearest millimeter (mm) total length (TL), weighed to the nearest gram, and released. When a large number (>50) of a single species was collected, a subsample of 50 specimens was measured into 10 mm TL intervals, batch weighed, and an exact count was made of the remainder and released.

Seine

Seining was conducted at five shoreline stations (Table 6-1, Figure 6-1) Conowingo Pond. A 10 x 4-ft straight seine with ¼-inch mesh was used. The seine was deployed and moved parallel to shore for a short distance, then moved into shore to trap fish; this effort constituted one seine haul. Since size and habitat of seine stations varied, an effort was made to collect a representative sample based on complete coverage of all available habitats, limiting the number of hauls at each station to five. All specimens were identified, counted, and released near the capture site. Specimens that were too small to accurately identify to species in the field were only identified to genus.

Catch Overview

This section provides a general summary of the fish catch information produced by the seine, and electrofishing sampling conducted in 2016. Table 6-13 provides a list of common and scientific names of fish species observed in Conowingo Pond during the course of this study. The sampling methods used in this study were deployed in similar habitats but targeted certain species and sizes of fish. Seining targeted small-bodied fishes (Cyprinidae) and young of year of large-bodied fishes (Centrarchidae). Electrofishing was effective for both large and small fish.

A total of 14,568 individuals representing 34 species was collected in this study by seining and electrofishing in Conowingo Pond. A diverse warmwater fish community was represented by eight families of fish with three families (Cyprinidae, Centrarchidae, and Percidae) predominating the catch. Twenty-four of the species collected were within these three families.

The summary of the electrofishing data, with the results grouped by thermally affected and non-thermally affected stations, are presented in Table 6-14. A total of 12,879 individuals and 31 species was collected with boat electrofisher in 2016. Bluegill and Gizzard Shad was the most numerous species taken by boat electrofisher. Other numerous species included Channel Catfish, Comely Shiner, Green Sunfish, Smallmouth Bass, and Spotfin Shiner. Table 6-15 through Table 6-19 provide the monthly electrofishing catch for each station.

The summary of the seine data, with the results grouped by thermally affected and non-thermally affected stations are presented in Table 6-20. A total of 1,689 individuals and 17 species was collected with seine in 2016. Bluegill and Spotfin Shiner was the most numerous species taken by seine. Other numerous species included Banded Killifish, Golden Shiner, and Comely Shiner. Table 6-21 through Table 6-25 provide the monthly seine catch for each station.

Table 6-13. List of common and scientific names of fishes collected in Conowingo Pond, May through September 2016.

Anguillidae	**Eels**
Anguilla rostrata	American eel
Clupeidae	**Herrings**
Dorosoma cepedianum	Gizzard shad
Cyprinidae	**Carps and minnows**
Campostoma anomalum	Central stoneroller
Cyprinella spiloptera	Spotfin shiner
Cyprinus carpio	Common carp
Notemigonus crysoleucas	Golden shiner
Notropis amoenus	Comely shiner
Notropis hudsonius	Spottail shiner
Notropis volucellus	Mimic shiner
Pimephales notatus	Bluntnose minnow
Rhinichthys atratulus	Blacknose dace
Semotilus corporalis	Fallfish
Catostomidae	**Suckers**
Carpiodes cyprinus	Quillback
Catostomus commersoni	White sucker
Hypentelium nigricans	Northern hogsucker
Moxostoma macrolepidotum	Shorthead redhorse
Ictaluridae	**Bullhead catfishes**
Ictalurus punctatus	Channel catfish
Pylodictis olivaris	Flathead catfish
Cyprinodontidae	**Killifishes**
Fundulus diaphanus	Banded killifish
Percichthyidae	**Temperate basses**
Morone americana	White perch
Centrarchidae	**Sunfishes**
Ambloplites rupestris	Rock bass
Lepomis auritus	Redbreast sunfish
Lepomis cyanellus	Green sunfish
Lepomis gibbosus	Pumpkinseed
Lepomis macrochirus	Bluegill
Micropterus dolomieu	Smallmouth bass
Micropterus salmoides	Largemouth bass
Pomoxis annularis	White crappie
Percidae	**Perches**
Etheostoma blennioides	Greenside darter
Etheostoma olmstedi	Tessellated darter
Perca flavescens	Yellow perch
Percina bimaculata	Chesapeake logperch
Percina peltata	Shield darter
Stizostedion vitreum	Walleye

Table 6-14. Total number of fish collected with boat electrofisher from Conowingo Pond, May through September 2016.

Taxon	Thermally Affected				Non-thermally Affected		Total Number
	161	189	190	217	165	187	
American Eel			1				1
Banded killifish					1		1
Bluegill	**168**	**384**	**615**	**1141**	**364**	**2194**	**4866**
Bluntnose minnow		**16**	**12**	**1**	**12**	**33**	**74**
Channel catfish	**97**	**34**	**58**	**74**	**83**	**60**	**406**
Comely shiner	119	26	73	2	116	25	361
Common carp	19	10	11	17	3	9	69
Fallfish		2				2	4
Flathead catfish	8	12	9		5	4	38
Gizzard shad	**1010**	**170**	**1620**	**291**	**81**	**1128**	**4300**
Golden shiner		137	22	51	1		211
Green sunfish	156	126	234	235	100	19	870
Greenside darter			1				1
Largemouth bass	**3**	**25**	**18**	**38**	**12**	**10**	**106**
Chesapeake Logperch		**3**	**7**	**21**	**17**	**24**	**72**
Northern hogsucker						2	2
Pumpkinseed		1	2	1	2	1	7
Quillback	1			1	1		3
Redbreast sunfish		1		1			2
Rock bass	2	12	9	42	80	94	239
shield darter					2		2
Shorthead redhorse		4	1	7	1	5	18
Smallmouth bass	**45**	**88**	**149**	**176**	**209**	**117**	**784**
Spotfin shiner	**70**	**48**	**94**	**17**	**13**	**37**	**279**
Spottail shiner		1	2	13	9	20	45
Tessellated darter				3	3	20	26
Walleye	**1**	**1**	**1**	**2**	**2**	**30**	**37**
White crappie						**1**	**1**
White perch	18			6		3	27
White sucker				**1**			**1**
Yellow perch		6			3	17	26
Total Number	1717	1101	2939	2141	1117	3838	12879
Total Species	14	20	20	22	22	22	31
Total RIS species	5	6	7	7	8	8	10

Species designated as Representative Important Species (RIS) during the 316a Demonstration Study are represented with bold font

Table 6-15. Total number (no./0.5 hour) of fish collected with boat electrofisher from Conowingo Pond, May 2016.

Taxon	Thermally Affected				Non-thermally Affected		Total Number
	161	189	190	217	165	187	
American Eel			1				1
Bluegill	**71**	**31**	**107**	**128**	**35**	**14**	**386**
Bluntnose minnow		**2**	**5**		**2**	**17**	**26**
Channel catfish	**8**	**13**	**28**	**26**	**14**	**10**	**99**
Comely shiner	113	1	4		1	22	141
Common carp	15	2	2	2		1	22
Fallfish		2				2	4
Flathead catfish	5	4					9
Gizzard shad	**300**	**7**	**14**	**12**	**1**		**334**
Golden shiner		1	1	4			6
Green sunfish	28	14	80	13	14	2	151
Largemouth bass	**3**	**22**	**17**	**22**	**11**	**7**	**82**
Northern hogsucker						1	1
Pumpkinseed			2	1	1		4
Rock bass	2	4	4	15	36	35	96
Shorthead redhorse		4				3	7
Smallmouth bass	**26**	**26**	**59**	**73**	**76**	**35**	**295**
Spotfin shiner	**56**	**7**	**1**		**5**	**18**	**87**
Spottail shiner						7	7
Tessellated darter					1	15	16
Walleye	**1**	**1**	**1**	**1**	**2**	**12**	**18**
White crappie						**1**	**1**
White perch	18			6		3	27
White sucker				**1**			**1**
Yellow perch		6			3	13	22
Total Number	646	147	326	304	202	218	1843
Total Species	13	17	15	13	14	19	25
Total RIS species	7	8	8	7	8	8	10
Shannon Diversity	1.71	2.35	1.83	1.74	1.86	2.55	
Maximum Diversity	2.56	2.83	2.71	2.56	2.64	2.94	
Evenness	0.67	0.83	0.67	0.68	0.70	0.87	

Species designated as Representative Important Species (RIS) during the 316a Demonstration Study are represented with bold font

Table 6-16. Total number (no./0.5 hour) of fish collected with boat electrofisher from Conowingo Pond, June 2016.

Taxon	Thermally Affected				Non-thermally Affected		Total Number
	161	189	190	217	165	187	
Banded killifish					1		1
Bluegill	**2**	**31**	**64**	**93**	**8**	**3**	**201**
Bluntnose minnow		**5**					**5**
Channel catfish	**4**	**4**	**8**	**8**	**18**	**7**	**49**
Comely shiner	4	5	11	1		1	**22**
Common carp	1			2			**3**
Flathead catfish	2	6	5		1	1	**15**
Gizzard shad	**3**	**1**				**29**	**33**
Green sunfish	30	14	34	30	8	1	**117**
Largemouth bass					**1**	**1**	**2**
Chesapeake Logperch			**2**	**2**	**1**	**1**	**6**
Northern hogsucker						1	**1**
Pumpkinseed		1					**1**
Quillback	1						**1**
Redbreast sunfish				1			**1**
Rock bass		1	1	5	17	32	**56**
Shorthead redhorse				1		1	**2**
Smallmouth bass	**13**	**10**	**25**	**10**	**33**	**35**	**126**
Spotfin shiner	**5**	**14**	**36**	**3**		**4**	**62**
Spottail shiner						1	**1**
Walleye				**1**		**1**	**2**
Yellow perch						1	**1**
Total Number	65	92	186	157	88	120	708
Total Species	10	11	9	12	9	16	22
Total RIS Species	5	6	5	6	5	8	9
Shannon Diversity	1.70	1.96	1.74	1.38	1.65	1.83	
Maximum Diversity	2.30	2.40	2.20	2.48	2.20	2.77	
Evenness	0.74	0.82	0.79	0.55	0.75	0.66	

Species designated as Representative Important Species (RIS) during the 316a Demonstration Study are represented with bold font

Table 6-17. Total number (no./0.5 hour) of fish collected with boat electrofisher from Conowingo Pond, July 2016.

Taxon	Thermally Affected				Non-thermally Affected		Total Number
	161	189	190	217	165	187	
Bluegill	**27**	**67**	**300**	**331**	**55**	**19**	**799**
Bluntnose minnow		**7**	**3**		**3**	**6**	**19**
Channel catfish	**72**	**7**	**3**	**3**	**30**	**15**	**130**
Comely shiner		17	36		22	1	76
Common carp	2	4	3	1	2	5	17
Flathead catfish	1	1	3		3	2	10
Gizzard shad		**27**	**390**	**17**	**23**	**4**	**461**
Golden shiner		69	9	29			107
Green sunfish	40	49	64	52	20	10	235
Largemouth bass		**3**	**1**	**8**			**12**
Chesapeake Logperch		**3**	**4**	**17**	**8**	**20**	**52**
Quillback				1			1
Redbreast sunfish		1					1
Rock bass		5	1	15	17	20	58
shield darter					2		2
Shorthead redhorse				4			4
Smallmouth bass	**1**	**20**	**25**	**25**	**39**	**32**	**142**
Spotfin shiner	**3**	**21**	**26**	**7**	**1**	**6**	**64**
Spottail shiner		1	2	13	3	8	27
Tessellated darter				3	1	5	9
Walleye						**14**	**14**
Yellow perch						3	3
Total Number	146	302	870	526	229	170	2243
Total Species	7	16	15	15	15	16	22
Total RIS Species	4	8	8	7	6	7	9
Shannon Diversity	1.22	2.16	1.44	1.48	2.19	2.48	
Maximum Diversity	1.95	2.77	2.71	2.71	2.71	2.77	
Evenness	0.63	0.78	0.53	0.55	0.81	0.89	

Species designated as Representative Important Species (RIS) during the 316a Demonstration Study are represented with bold font

Table 6-18. Total number (no./0.5 hour) of fish collected with boat electrofisher from Conowingo Pond, August 2016.

Taxon	Thermally Affected				Non-thermally Affected		Total Number
	161	189	190	217	165	187	
Bluegill	**34**	**160**	**82**	**223**	**142**	**2050**	**2691**
Bluntnose minnow		**2**	**4**			**6**	**12**
Channel catfish	**9**		**6**	**4**	**10**	**7**	**36**
Comely shiner	2	3	9	1	50	1	66
Common carp		2	2	2		1	7
Flathead catfish		1	1		1		3
Gizzard shad	**79**	**81**	**1094**	**236**	**35**	**1047**	**2572**
Golden shiner		26	6	17			49
Green sunfish	34	25	26	2	44		131
Largemouth bass				**1**		**1**	**2**
Logperch				**1**	**4**		**5**
Rock bass		2	1	1	4	2	10
Shorthead redhorse			1	1			2
Smallmouth bass	**5**	**10**	**13**	**39**	**19**	**5**	**91**
Spotfin shiner	**6**	**5**	**14**	**1**		**4**	**30**
Spottail shiner						4	4
Tessellated darter					1		1
Walleye						**1**	**1**
Total Number	169	317	1259	529	310	3129	5713
Total Species	7	11	13	13	10	12	18
Total RIS Species	5	5	6	7	5	8	9
Shannon Diversity	1.43	1.43	0.61	1.18	1.61	0.71	
Maximum Diversity	1.95	2.40	2.56	2.56	2.30	2.48	
Evenness	0.74	0.60	0.24	0.46	0.70	0.29	

Species designated as Representative Important Species (RIS) during the 316a Demonstration Study are represented with bold font

Table 6-19. Total number (no./0.5 hour) of fish collected with boat electrofisher from Conowingo Pond, September 2016.

Taxon	Thermally Affected				Non-thermally Affected		Total Number
	161	189	190	217	165	187	
Bluegill	**34**	**95**	**56**	**366**	**124**	**108**	**783**
Bluntnose minnow				**1**	**7**	**4**	**12**
Channel catfish	**4**	**10**	**13**	**33**	**11**	**21**	**92**
Comely shiner			13		43		56
Common carp	1	2	4	10	1	2	20
Flathead catfish						1	1
Gizzard shad	**628**	**54**	**122**	**26**	**22**	**48**	**900**
Golden shiner		41	6	1	1		49
Green sunfish	24	24	30	138	14	6	236
Greenside darter			1				1
Largemouth bass				**7**		**1**	**8**
Chesapeake Logperch			**1**	**1**	**4**	**3**	**9**
Pumpkinseed					1	1	2
Quillback					1		1
Rock bass			2	6	6	5	19
Shorthead redhorse				1	1	1	3
Smallmouth bass		**22**	**27**	**29**	**42**	**10**	**130**
Spotfin shiner		**1**	**17**	**6**	**7**	**5**	**36**
Spottail shiner					6		6
Walleye						**2**	**2**
Total Number	691	249	292	625	291	218	2366
Total Species	5	8	12	13	16	15	20
Total RIS Species	3	4	6	7	7	7	9
Shannon Diversity	0.39	1.63	1.79	1.32	1.81	1.59	
Maximum Diversity	1.61	2.08	2.48	2.56	2.77	2.71	
Evenness	0.24	0.78	0.72	0.52	0.65	0.59	

Species designated as Representative Important Species (RIS) during the 316a Demonstration Study are represented with bold font

Table 6-20. Total number of fish collected in seine collections from Conowingo Pond, May through September 2016.

Taxon [1]	Station [2]					Total Number
	Thermally Affected		Non-thermally Affected			
	214	215	208	220	221	
Banded killifish	53	1	19	1	208	282
blacknose dace	1					1
Bluegill	**193**	**76**	**105**	**180**	**2**	**556**
Bluntnose minnow	**3**	**9**	**3**	**18**	**1**	**34**
central stoneroller	1					1
Comely shiner	92	1		5		98
Gizzard shad			**1**			**1**
Golden shiner	187					187
Green sunfish	24	9	4	5		42
Largemouth bass			**1**			**1**
Chesapeake Logperch				**2**		**2**
Mimic shiner	1			1		2
Pumpkinseed			1			1
Rock bass			2	9		11
Smallmouth bass			**2**	**1**		**3**
Spotfin shiner	**165**	**108**	**3**	**157**	**12**	**445**
Spottail shiner		3		11	6	20
Tessellated darter			2			2
Total Number	720	207	143	390	229	1689
Total Species	10	7	10	11	5	17
Total RIS	3	3	6	5	3	7

[1] Representative Important Species represented with bold font

[2] Five seine hauls completed during each month at each station; therefore, total number equivalent to CPUE

Table 6-21. Total number (CPUE) of fish collected with seine from Conowingo Pond, May 2016.

Taxon [1]	Station [2]					Total Number
	Thermally Affected		Non-thermally Affected			
	214	215	208	220	221	
Banded killifish	40	1	2	1	155	199
Blacknose Dace	1					1
Bluntnose minnow	**3**				**1**	**4**
Comely shiner	92					92
Mimic shiner	1					1
Spotfin shiner	**34**	**20**				**54**
Total Number	171	21	2	1	156	351
Total Species	6	2	1	1	2	6
Total RIS	2	1	0	0	1	2
Shannon Diversity	1.13	0.19	0.00	0.00	0.04	
Maximum Diversity	1.79	0.69	0.00	0.00	0.69	
Evenness	0.63	0.28	0.00	0.00	0.06	

[1] Representative Important Species represented with bold font

[2] Five seine hauls completed at each station; therefore, total number equivalent to CPUE

Table 6-22. Total number (CPUE) of fish collected with seine from Conowingo Pond, June 2016.

Taxon [1]	Station [2]					Total Number
	Thermally Affected		Non-thermally Affected			
	214	215	208	220	221	
Banded killifish	6		2		15	23
Bluegill	**1**			**3**		**4**
Bluntnose minnow				**1**		**1**
Largemouth bass			**1**			**1**
Rock bass			1	1		2
Smallmouth bass			**2**			**2**
Spotfin shiner	**10**	**1**	**2**	**7**	**2**	**22**
Spottail shiner		1				1
Total Number	17	2	8	12	17	56
Total Species	3	2	5	4	2	8
Total RIS	2	1	3	3	1	5
Shannon Diversity	0.85	0.69	1.56	1.08	0.36	
Maximum Diversity	1.10	0.69	1.61	1.39	0.69	
Evenness	0.77	1.00	0.97	0.78	0.52	

[1] Representative Important Species represented with bold font

[2] Five seine hauls completed at each station; therefore, total number equivalent to CPUE

Table 6-23. Total number (CPUE) of fish collected with seine from Conowingo Pond, July 2016.

Taxon [1]	Station [2]					Total Number
	Thermally Affected		Non-thermally Affected			
	214	215	208	220	221	
						17
Banded killifish	2		1		14	214
Bluegill	**97**	**52**	**2**	**63**		**6**
Bluntnose minnow		**6**				**1**
central stoneroller	1					3
Comely shiner				3		187
Golden shiner	187					18
Green sunfish	16	1		1		1
Mimic shiner				1		1
Smallmouth bass				**1**		**146**
Spotfin shiner	56	56		31	3	15
Spottail shiner		**2**		**7**	**6**	**609**
Total Number	359	117	3	107	23	1201
Total Species	6	5	2	7	3	12
Total RIS	1	3	1	3	1	4
Shannon Diversity	1.17	0.98	0.64	1.08	0.92	
Maximum Diversity	1.79	1.61	0.69	1.95	1.10	
Evenness	0.65	0.61	0.92	0.56	0.84	

[1] Representative Important Species represented with bold font

[2] Five seine hauls completed at each station; therefore, total number equivalent to CPUE

Table 6-24. Total number (CPUE) of fish collected with seine from Conowingo Pond, August 2016.

Taxon [1]	Station [2]					Total Number
	Thermally Affected		Non-thermally Affected			
	214	215	208	220	221	
Banded killifish			12		14	26
Bluegill	**12**	**20**	**37**	**85**	**2**	**156**
Bluntnose minnow			**3**	**2**		**5**
Gizzard shad			**1**			**1**
Green sunfish		8		2		10
Pumpkinseed			1			1
Rock bass				8		8
Spotfin shiner	**24**	**8**	**1**	**29**	**7**	**69**
Spottail shiner				4		4
Tessellated darter			1			1
Total Number	36	36	56	130	23	281
Total Species	2	3	7	6	3	10
Total RIS	2	2	4	3	2	4
Shannon Diversity	0.64	1.00	1.05	1.02	0.88	
Maximum Diversity	0.69	1.10	1.95	1.79	1.10	
Evenness	0.92	0.91	0.54	0.57	0.80	

[1] Representative Important Species represented with bold font

[2] Five seine hauls completed at each station; therefore, total number equivalent to CPUE

Table 6-25. Total number (CPUE) of fish collected with seine from Conowingo Pond, September 2016.

Taxon [1]	Station [2]					Total Number
	Thermally Affected		Non-thermally Affected			
	214	215	208	220	221	
Banded killifish	5		2		10	17
Bluegill	**83**	**4**	**66**	**29**		**182**
Bluntnose minnow		**3**		**15**		**18**
Comely shiner		1		2		**3**
Green sunfish	8		4	2		14
Chesapeake Logperch				**2**		**2**
Rock bass			1			1
Spotfin shiner	**41**	**23**		**90**		**154**
Tessellated darter			1			1
Total Number	137	31	74	140	10	392
Total Species	4	4	5	6	1	9
Total RIS	2	3	1	4	0	4
Shannon Diversity	0.95	0.82	0.47	1.03	0.00	
Maximum Diversity	1.39	1.39	1.61	1.79	0.00	
Evenness	0.69	0.59	0.29	0.58	0.00	

[1] Representative Important Species represented with bold font

[2] Five seine hauls completed at each station; therefore, total number equivalent to CPUE

Fish Metrics and CPUE

Comparison of catch per unit effort (CPUE) and community based metrics among collection locations is useful in describing differences in the fish community among stations. Gear specific CPUE normalizes the catch based on level of effort and, therefore, allows standardized comparisons of relative abundance. Several metrics that describe the fish community at individual stations were calculated for the seine and electrofishing collections. Monthly metric values were compared among locations to determine if differences existed between individuals stations.

For this analysis stations are discussed as either non-thermal or thermal based on their location in relation to the PBAPS thermal plume. Electrofishing Stations 161, 189, 190, and 217 are considered thermally influenced and Stations 187 and 165 are considered non-thermal. Seine Stations 214 and 215 are considered thermally influenced and Stations 220, 221, and 208 are considered non-thermal. As previously discussed, Station 208 does experience elevated water

temperatures during a portion of the year resulting from thermal plume movement upstream during low flow conditions. However, this station is considered non-thermal because it does not experience a prolonged thermal influence.

6.3.2 Electrofishing Results 2016

Four metrics were calculated to provide a description of the fish community among stations and across monthly collections in Conowingo Pond from May to September 2016. Table 6-26 through Table 6-29 provide the metric values for each station and Figure 6-17 through Figure 6-20 provide box plots which graphically illustrate the monthly metric values among stations. Catch per unit effort (no./0.5 hour) was generally similar among stations during each month with the lowest CPUE of 65 fish observed at Station 161 in June and the highest CPUE of 3,129 fish observed at Station 187 in August. CPUE for most stations was highest in August with exception of Station161 which had the highest catch during September. Total species richness ranged from five species at Station 161 in September to 19 species at Station 187 in May. Species richness was highest for most stations during May and July. The highest total richness was observed at Station 187 (non-thermal) during most months. Total richness at Station 161 was noticeably lower (range between five and seven species) during July through September compared to all other stations. RIS richness ranged from three species at Station 161 in September to eight species collected at multiple stations during June to August. Similar to species richness, RIS richness was highest for most stations during May and July. RIS richness for Station 187 was generally higher or equal to the other stations for each month of collection. Shannon Diversity values ranged from 0.39 at Station 161 in September to 2.55 at Station 187 in May. Shannon Diversity values were highest for most stations during May and July.

Post-EPU Metric comparison to Pre-EPU

A comparison of pre- and post-EPU electrofishing metric values allows for inspection of potential differences that may have been a result of the increase in temperature from the EPU. Figure 6-17 through Figure 6-20 provide box plots of the four metrics selected to describe the fish community. The metrics include square root transformed CPUE, Total Richness, Total RIS, and Shannon Diversity. pre- and post-EPU metric values for the four metrics were generally comparable for most stations and months. For CPUE the observed values during post-EPU monitoring were comparable to pre-EPU at all electrofishing stations with all post-EPU values within the range of the pre-EPU values. For total species, Stations 189, 190, 165, and 187 values observed post-EPU were greater than or equal to pre-EPU monitoring. For Station 161 during September of the post-EPU monitoring the total of five species was less than pre-EPU observations with six species being the lowest number collected during pre-EPU monitoring. Similarly,12 species were collected post-EPU at Station 217, the lowest number total species at this station was 13 species during pre-EPU monitoring. For Total RIS, Stations 189, 190, 165, and 187 values observed post-EPU were greater than or equal to pre-EPU monitoring. Two Stations, 161 and 189, had one monthly post-EPU value less than pre-EPU monitoring. For both of the stations the post-EPU value was slightly less (one species) compared to pre-EPU observations. Shannon Diversity values during post-EPU monitoring were generally within the range of pre-EPU observations with a few exceptions at Stations 190 (thermally influenced) and

Stations 165 and 187 (non-thermally influenced). Overall, the metrics values for each month of monitoring during post-EPU were comparable to pre-EPU observations indicating that the fish community relative abundance, richness and composition has not measurably changed with the EPU.

6.3.3 Seine Results 2016

Four metrics were calculated to provide a description of the fish community among stations and across monthly collections in Conowingo Pond from May to September 2016. Table 6-30 through Table 6-33 provide the metric values for each station and Figure 6-21 through Figure 6-24 provide box plots which graphically illustrate the monthly metric values among stations. Catch per unit effort (no./five seine hauls) was generally similar among stations during each month with lowest CPUE of one fish observed at Station 220 in May and the highest CPUE of 359 fish observed at Station 214 in July. Total species richness ranged from one species at Stations 208 and 220 to seven species at Stations 208 and 220. RIS richness ranged from zero species at Stations 208, 220, and 221 to four species collected at Stations 208 and 220. Shannon Diversity values ranged from 0.0 at Stations 208, 220, and 221 to 1.55 at Station 208. For each metric the observed values were variable with no consistent seasonal pattern observed.

Post-EPU Metric Comparison to Pre-EPU

A comparison of pre- and post-EPU seine metric values allows for inspection of potential differences that may have been a result of the increase in water temperature from the EPU. Figure 6-21 through Figure 6-24 provide box plots of four metrics selected to describe the fish community. The metrics include square root transformed CPUE, Total Richness, Total RIS, and Shannon Diversity. Pre- and post-EPU metric values for the four metrics were generally comparable for most stations and months. For CPUE the observed values during post-EPU monitoring were comparable to pre-EPU at most seine stations with the exception of Stations 220 and 208 (non-thermal). For total species, Stations 214 and 215 values observed post-EPU were greater than or equal to pre-EPU monitoring. For Stations 208, 220 and 221 a few monthly post-EPU observations were less than pre-EPU with the difference being one species. For Total RIS, the values observed at Stations 214 and 215 during post-EPU monitoring were greater than or equal to pre-EPU monitoring. For Stations 208, 220 and 221 a few monthly post-EPU observations were less than pre-EPU with the difference being one species. Shannon Diversity values during post-EPU monitoring were generally within the range of pre-EPU observations with a few exceptions. At Stations 208, 220, and 221 a few observations during post-EPU monitoring were less than pre-EPU observations. Overall, the metrics values for each month of monitoring post-EPU are comparable to pre-EPU observations indicating that the fish community relative abundance, richness and composition has not measurably changed with the EPU.

6.3.4 Discussion

The community metrics and CPUE provide a description of the fish community both spatially (station) and temporally (month) within Conowingo Pond. The electrofishing results illustrate variation in the data across stations and months. The metrics indicate that fewer fish species were present at Station 161 during July through September. Fishes likely avoided this area because of the elevated water temperatures resulting from the PBAPS thermal discharge. Station 161 is the station closest to PBAPS and experienced the highest water temperatures observed at the electrofishing stations. Patterns of avoidance were not readily apparent from the monthly metric values for most of the other thermally affected electrofishing stations. One exception was Station 189 where species richness was lower indicating avoidance in September. However, species richness at Station 189 was comparable to observations during pre-EPU monitoring at this station. Patterns of avoidance were not readily apparent for the monthly metrics at the thermally affected seine stations.

For both electrofishing and seining collections the metrics values were useful in evaluating differences in the fish community and relative abundance of common species across locations and months of collection. Fish tended to avoid stations that experienced the highest water temperatures during the summer months. This was most clearly evident at electrofishing Station 161 from July through in September where six to eight fewer species were collected as compared to May or June.

6.3.5 Conclusions

- A diverse fish community of 34 species was observed in Conowingo Pond during 2016; Characteristics of the fish community were similar between pre-EPU and post-EPU observations;
- CPUE among species, and between stations, was variable due to differences in year class strength, habitat preferences, and other environmental variables;
- Avoidance was observed at electrofishing Station 161 at high water temperatures from July through September –;
- Avoidance was not observed at the seine stations.

Table 6-26. CPUE of fish by month for electrofishing collection locations in Conowingo Pond, May through September 2016.

	Station					
Month	161	189	190	217	165	187
May	646	147	326	304	202	218
June	65	92	186	157	88	120
July	146	302	870	526	229	170
August	169	317	1229	529	310	3129
September	691	249	292	625	291	218
Mean	343	221	581	428	224	771

Table 6-27. Total RIS by month for electrofishing collection locations in Conowingo Pond, May through September 2016.

	Station					
Month	161	189	190	217	165	187
May	7	8	8	7	8	8
June	5	6	5	6	5	8
July	4	8	8	7	6	7
August	5	5	6	7	5	8
September	3	4	6	7	7	7
Mean	4.8	6.2	6.6	6.8	6.2	7.6

Table 6-28. Total Species by month for electrofishing collection locations in Conowingo Pond, May through September 2016.

	Station					
Month	161	189	190	217	165	187
May	13	17	15	13	14	19
June	10	11	9	12	9	16
July	7	16	15	15	15	16
August	7	11	13	13	10	12
September	5	8	12	13	16	15
Mean	8.4	12.6	12.8	13.2	12.8	15.6

Table 6-29. Shannon Diversity by month for electrofishing collection locations in Conowingo Pond, May through September 2016.

	Station					
Month	161	189	190	217	165	187
May	1.71	2.35	1.83	1.74	1.86	2.55
June	1.70	1.96	1.74	1.38	1.65	1.83
July	1.22	2.16	1.44	1.48	2.19	2.48
August	1.43	1.43	0.61	1.18	1.61	0.71
September	0.39	1.63	1.79	1.32	1.81	1.59
Mean	1.29	1.90	1.48	1.42	1.82	1.83

Table 6-30. CPUE of fish by month for seine collection locations in Conowingo Pond, May through September 2016.

	Station				
Month	214	215	208	220	221
May	171	21	2	1	156
June	17	2	8	12	17
July	359	117	3	107	23
August	36	36	56	130	23
September	137	31	74	140	10
Mean	144	41.4	28.6	78	45.8

Table 6-31. Total RIS by month for seine collection locations in Conowingo Pond, May through September 2016.

	Station				
Month	214	215	208	220	221
May	2	1	0	0	1
June	2	1	3	3	1
July	1	3	1	3	1
August	2	2	4	3	2
September	2	3	1	4	0
Mean	1.8	2	1.8	2.6	1

Table 6-32. Total Species by month for seine collection locations in Conowingo Pond, May through September 2016.

	Station				
Month	214	215	208	220	221
May	6	2	1	1	2
June	3	2	5	4	2
July	6	5	2	7	3
August	2	3	7	6	3
September	4	4	5	6	1
Mean	4.2	3.2	4	4.8	2.2

Table 6-33. Shannon Diversity by month for seine collection locations in Conowingo Pond, May through September 2016.

	Station				
Month	214	215	208	220	221
May	1.1	0.2	0.0	0.0	0.0
June	0.8	0.7	1.6	1.1	0.4
July	1.2	1.0	0.6	1.1	0.9
August	0.6	1.0	1.0	1.0	0.9
September	1.0	0.8	0.5	1.0	0.0
Mean	0.9	0.7	0.7	0.8	0.4

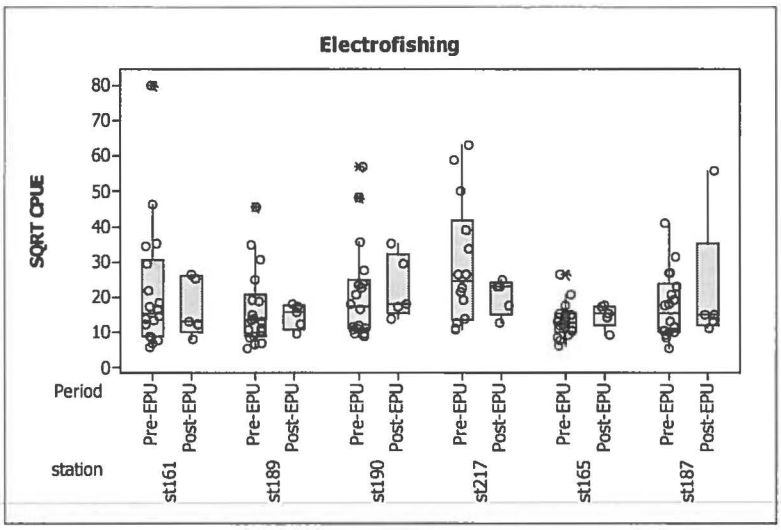


Figure 6-17. Box plot of square root transformed CPUE (no./0.5hr) for all electrofishing stations, May to September, pre-EPU (2010-2013) and post-EPU (2016).

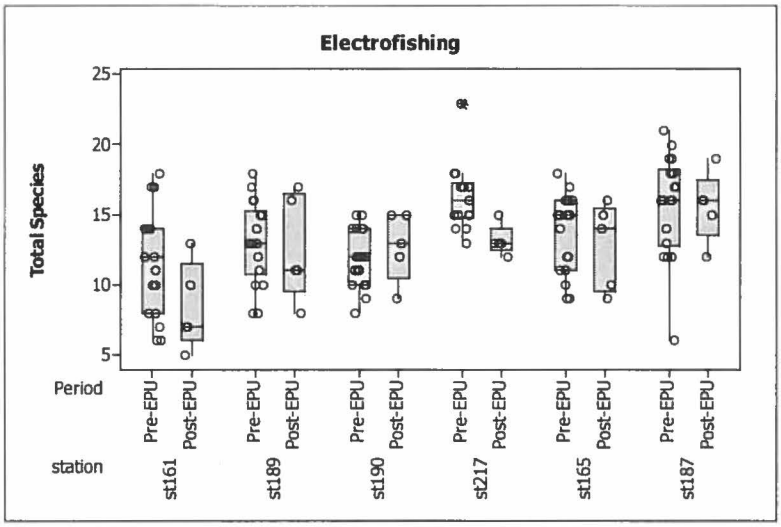


Figure 6-18. Box plot of total species for all electrofishing stations, May to September, pre-EPU (2010-2013) and post-EPU (2016).

(boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, circle = metric value, and asterisk = outlier)

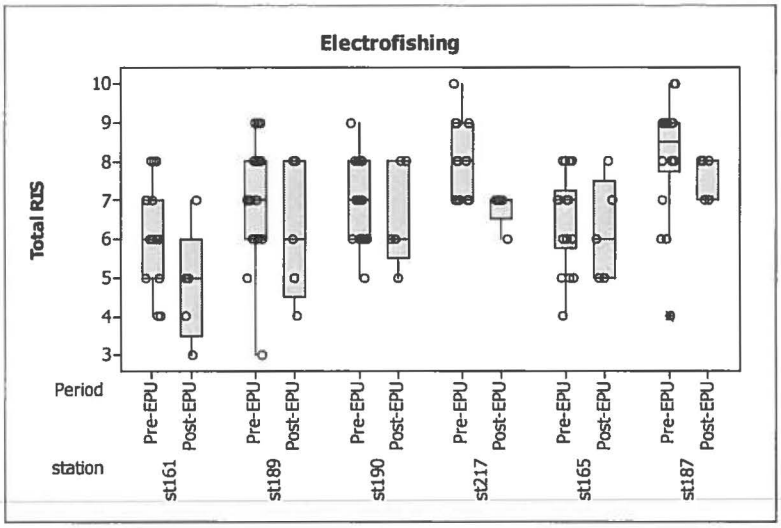


Figure 6-19. Box plot of total RIS for all electrofishing stations, May to September, pre-EPU (2010-2013) and post-EPU (2016).

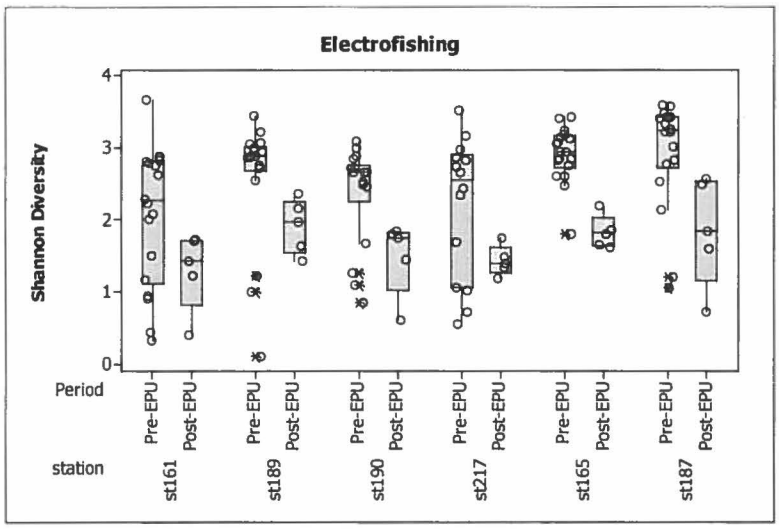


Figure 6-20. Box plot of Shannon Diversity for all electrofishing stations, May to September, pre-EPU (2010-2013) and post-EPU (2016).

(boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, circle = metric value, and asterisk = outlier)

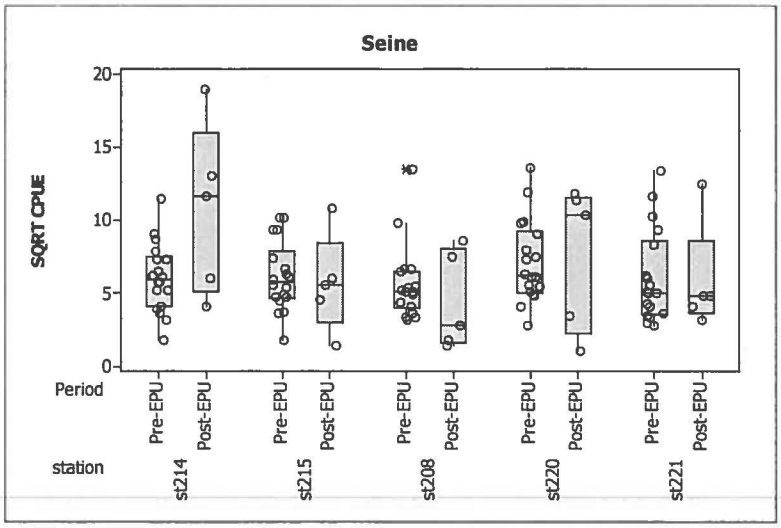


Figure 6-21. Box plot of CPUE for all seine stations, May to September, pre-EPU (2010-2013) and post-EPU (2016).

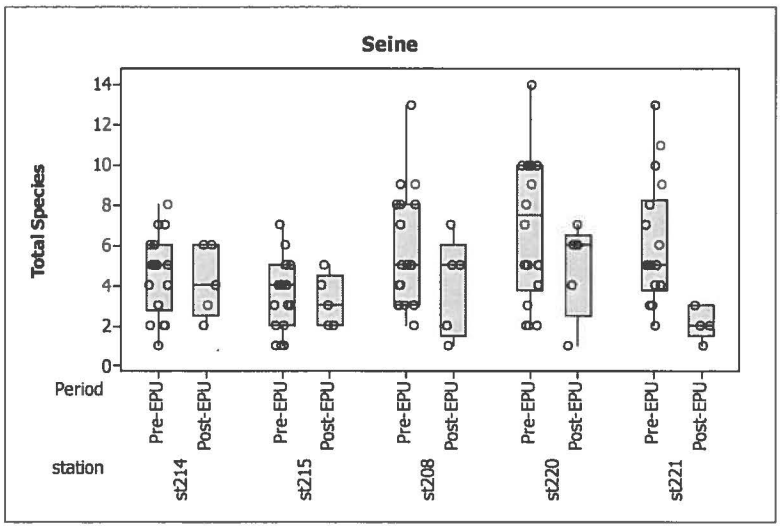


Figure 6-22. Box plot of total species for all seine stations, May to September, pre-EPU (2010-2013) and post-EPU (2016).

(boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, circle = metric value, and asterisk = outlier)

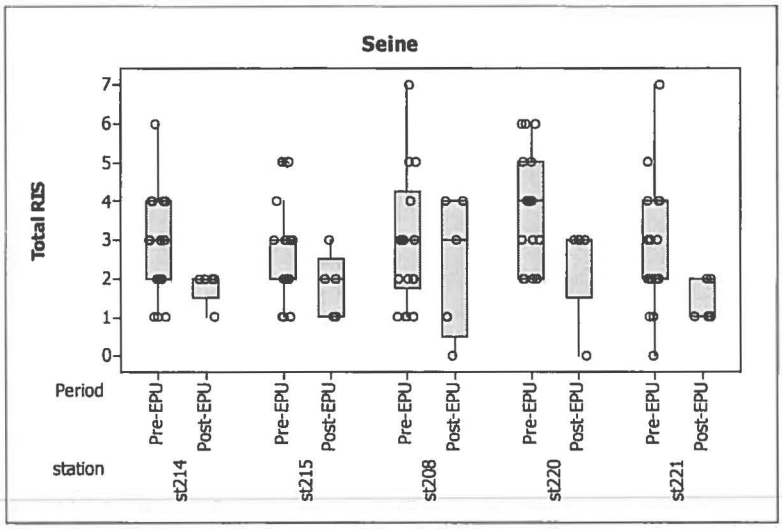


Figure 6-23. Box plot of total RIS for all seine stations, May to September, pre-EPU (2010-2013) and post-EPU (2016).

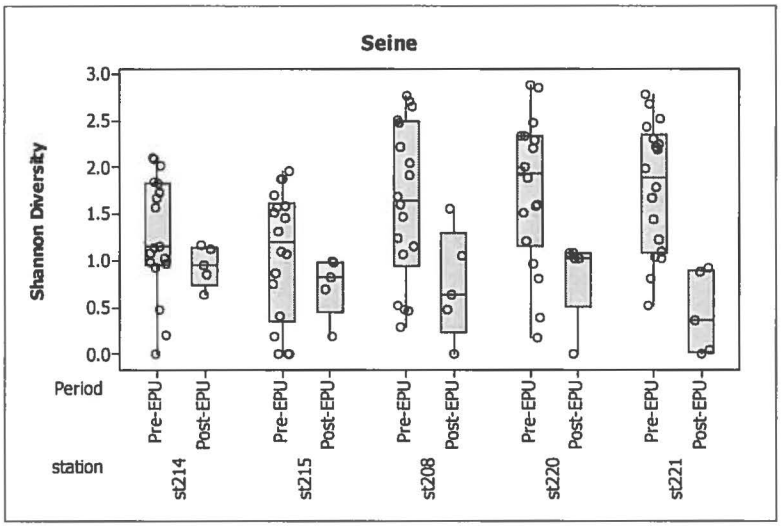


Figure 6-24. Box plot of Shannon Diversity for all seine stations, May to September, pre-EPU (2010-2013) and post-EPU (2016).

(boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, circle = metric value, and asterisk = outlier)

6.3.6 Length-Frequency Distribution

Length-frequency distributions of fish populations can provide an indication of rates of reproduction, recruitment, growth, and mortality of the age groups present. The length distributions and their changes over time can help in understanding population variations and identifying problems such as year-class failures or low recruitment, slow growth, or excessive

annual mortality (Anderson and Neumann 1996). The presence of small-sized fish represents successful spawning and subsequent survival and multimodal distribution is indicative of several age classes. Only fish collected during May through September were included in this analysis. Stations were grouped into thermal and non-thermal stations as described previously.

Bluegill

The length frequencies of Bluegill collected at the thermal and non-thermal stations exhibit similar multimodal distributions during pre- and post-EPU monitoring with a preponderance of the fish smaller than 60 mm (Figure 6-25). During each period the number of small individuals (<60 mm) collected at the thermal stations was high, suggesting spawning activity in areas affected by the thermal plume. The annual mode of small (<70-mm) Bluegill for the pre- and post-EPU monitoring was within the 45 to 60-mm intervals for both the thermal and non-thermal locations. Additionally, other modes were present, indicating multiple age classes were present at both thermal and non-thermal stations during both periods. The overall similarity of the length frequency distributions indicates substantially similar successful reproduction, recruitment and growth of Bluegill in and near the thermally affected and non-thermally affected habitats represented by the sampling stations during both pre- and post-EPU monitoring.

Bluntnose Minnow

Although the sample sizes were small, comparisons of the length frequencies of Bluntnose Minnow between the thermal and non-thermal stations during both pre- and post-EPU monitoring exhibited similar multimodal distributions (Figure 6-26). Each mode roughly corresponds to a separate age group. Smaller (<50 mm) Bluntnose Minnow were collected in similar numbers at the thermal stations and the non-thermal stations during both pre- and post-EPU monitoring. The presence of fish <50 mm suggests spawning activity in the thermally and non-thermally affected areas.

Channel Catfish

Comparisons of the length frequencies of Channel Catfish between the thermal and non-thermal stations exhibit similar multimodal distributions for the both the pre- and post-EPU monitoring (Figure 6-27). Each mode roughly corresponds to a separate age group. Like the other species, small (<100 mm) Channel Catfish were collected at the thermal stations suggesting spawning activity in the thermally affected areas during both periods.

Gizzard Shad

Comparisons of the length frequencies of Gizzard Shad between the pre- and post-EPU monitoring exhibited similar distributions with a preponderance of the fish being smaller than 100 mm; few adult fish were collected (Figure 6-28). Gizzard Shad was collected in greater numbers at the thermal stations than the non-thermal stations, including large numbers of individuals less than 100 mm, suggesting spawning activity near the thermally affected areas.

Largemouth Bass

Size structure of Largemouth Bass was similar between pre- and post-EPU monitoring (Figure 6-29). Smaller fish (<100 mm) were collected in similar numbers at both thermally and non-thermally influenced locations during both periods. Most individuals were between 120 and 240 mm in length with few fish greater than 300 mm being collected during either period.

Chesapeake Logperch

A similar size structure was observed between pre- and post-EPU monitoring (Figure 6-30). Most fish were between 50-75 mm in total length. During both periods smaller fish (<60 mm) were collected at both thermally and non-thermally influenced locations suggesting spawning activity near the collection stations. The mean length and length range were similar between pre- and post-EPU monitoring (Table 6-34).

Smallmouth Bass

Length frequencies of Smallmouth Bass at the thermal and non-thermal stations during both pre- and post-EPU monitoring exhibited similar multimodal distributions (Figure 6-31). Each mode roughly corresponds to a separate age group. During both periods smaller fish (<100 mm) were collected at both thermally and non-thermally influenced locations suggesting spawning activity near the collection stations. Greater numbers of Smallmouth Bass greater than 250 mm were collected during post-EPU at both thermally influence and non-thermally influenced locations compared to pre-EPU monitoring. The average size of Smallmouth Bass was greater during post-EPU monitoring (Table 6-34).

Spotfin Shiner

Comparisons of the length frequencies of Spotfin Shiner between the thermal and non-thermal stations exhibit similar multimodal distributions for the both the pre- and post-EPU monitoring (Figure 6-32). Similar multimodal distributions suggest the presence of multiple age classes and spawning activity. The average size of Spotfin Shiner was similar between both periods (Table 6-34).

Walleye

A similar size structure was observed between pre- and post-EPU monitoring (Figure 6-33). Most fish were between 150-300 mm in total length. Few fish were collected during post-EPU monitoring within the thermally influenced locations. The mean length and length range were similar between pre- and post-EPU monitoring (Table 6-34).

White Crappie

A figure of length distributions for White Crappie was not generated, as only 28 individuals were collected and measured during pre-EPU monitoring and only one individual was collected during post-EPU monitoring. Due to the extremely small numbers of White Crappie that were collected

from all stations, comparisons of the length frequencies between the two periods would not have been meaningful.

White Sucker

A figure of length distributions for White Sucker was not generated, as only 18 individuals were collected and measured during pre-EPU monitoring and only one individual was collected during post-EPU monitoring. Due to the extremely small numbers of White Sucker that were collected from all stations, comparisons of the length frequencies of between the thermal and non-thermal stations would not have been meaningful.

Discussion and Conclusions

For the RIS that were evaluated multimodal length distributions indicated multiple age classes present at both the thermal and non-thermal stations during both pre- and post-EPU monitoring. Differences in length frequency distributions between pre- and post-EPU monitoring are not directly attributable to changes in the thermal plume from the EPU. Differences in length frequency distributions among species are likely due to habitat differences between stations. For most RIS, small individuals (young-of-the-year) were collected at the thermal stations, suggesting reproduction by the species near the collection location. Comparison of length frequency distributions did not indicate distorted distributions (e.g., absence of young-of-the-year or presence of only one year-class), and for most species many age-classes were present including young individuals and several age classes of mature fish. This analysis indicates that the RIS were able to reproduce, grow, and be recruited to the fish community within Conowingo Pond after the EPU was implemented. No measurable change to the length frequency distribution of fish was observed that is attributable to the EPU.

Table 6-34. Descriptive statistics for total length of RIS collected in Conowingo Pond.

Data obtained using seine and electrofisher for sample stations that were surveyed during both pre-EPU (2010-2013) and post-EPU (2016) monitoring for non-thermal and thermally influenced locations, May through September.

		Pre-EPU				Post-EPU			
Taxon	Location	Mean	Minimum	Maximum	Total Number	Mean	Minimum	Maximum	Total Number
Bluegill	Nonthermal	99	21	220	626	119	21	201	115
Bluegill	Thermal	92	11	250	1150	103	11	219	406
Bluntnose minnow	Nonthermal	58	31	91	239	62	38	91	36
Bluntnose minnow	Thermal	58	22	90	316	59	38	84	27
Channel catfish	Nonthermal	174	41	535	765	194	45	413	142
Channel catfish	Thermal	166	31	611	1294	225	41	496	210
Gizzard shad	Nonthermal	101	21	398	304	102	37	372	82
Gizzard shad	Thermal	93	19	400	494	98	7	340	107
Largemouth bass	Nonthermal	229	45	453	36	154	91	225	22
Largemouth bass	Thermal	204	52	465	168	206	66	475	82
Logperch	Nonthermal	74	40	99	121	66	44	105	36
Logperch	Thermal	71	32	112	144	63	44	102	24
Smallmouth bass	Nonthermal	174	41	508	384	187	12	490	316
Smallmouth bass	Thermal	150	32	494	551	206	34	471	428
Spotfin shiner	Nonthermal	69	11	106	298	74	36	104	47
Spotfin shiner	Thermal	66	22	108	549	72	31	108	149
Walleye	Nonthermal	216	122	470	70	182	114	424	32
Walleye	Thermal	293	97	635	67	292	222	470	4
White crappie	Nonthermal	158	131	195	4	155	155	155	1
White crappie	Thermal	136	47	263	24	*	*	*	0
White sucker	Nonthermal	136	50	260	12	*	*	*	0
White sucker	Thermal	151	96	232	6	271	271	271	1

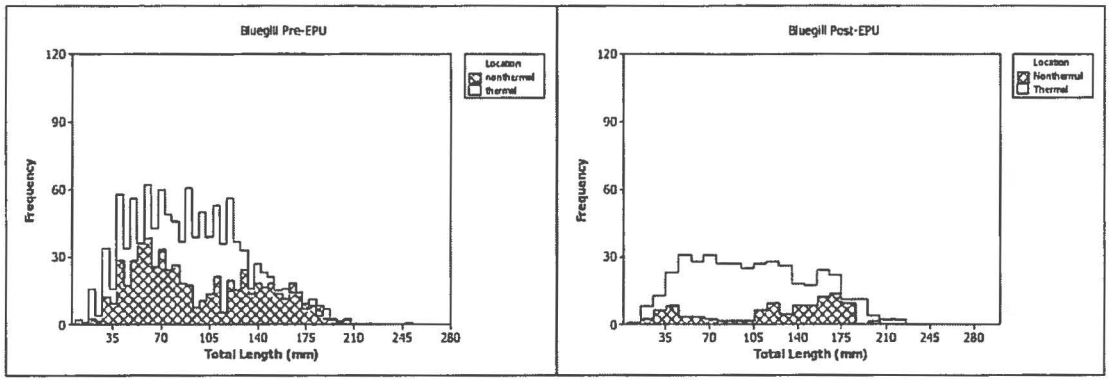


Figure 6-25. Length-frequency distribution of Bluegill collected in Conowingo Pond using seine and electrofisher for sample stations that were surveyed during both pre-EPU (2010-2013) and post-EPU (2016) monitoring for non-thermal and thermally influenced locations.

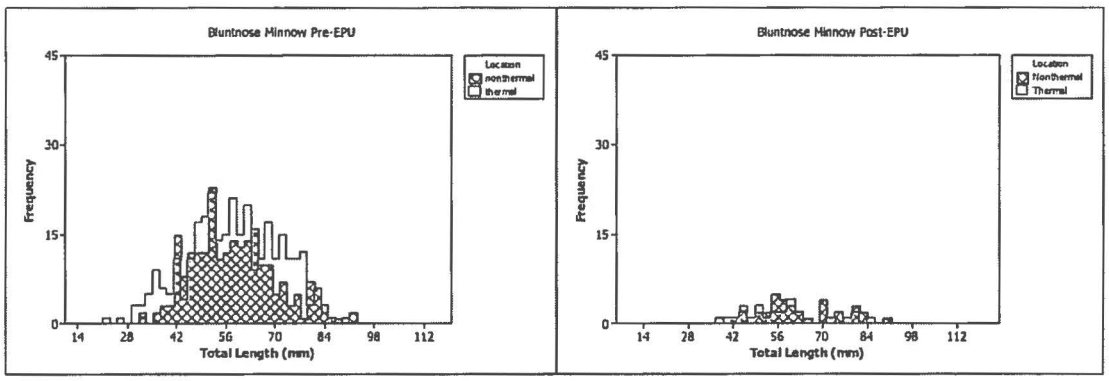


Figure 6-26. Length-frequency distribution of Bluntnose Minnow collected in Conowingo Pond using seine and electrofisher for sample stations that were surveyed during both pre-EPU (2010-2013) and post-EPU (2016) monitoring for non-thermal and thermally influenced locations.

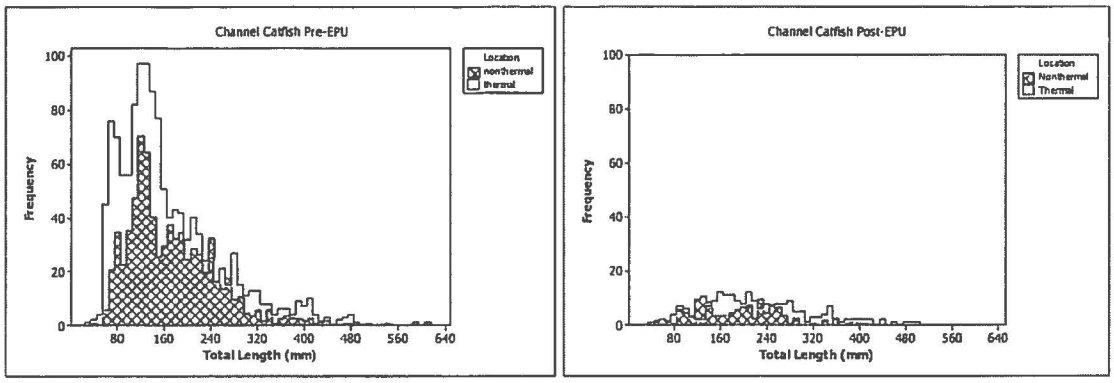


Figure 6-27. Length-frequency distribution of Channel Catfish collected in Conowingo Pond using seine and electrofisher for sample stations that were surveyed during both pre-EPU (2010-2013) and post-EPU (2016) monitoring for non-thermal and thermally influenced locations.

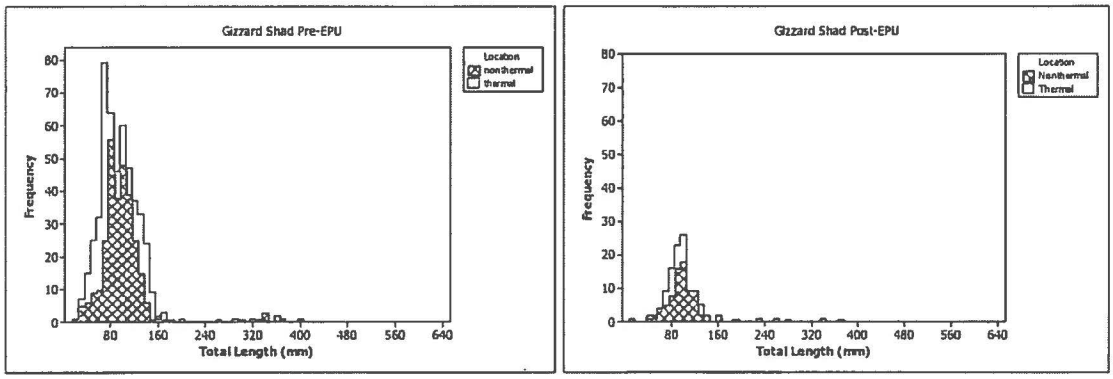


Figure 6-28. Length-frequency distribution of Gizzard Shad collected in Conowingo Pond using seine and electrofisher for sample stations that were surveyed during both pre-EPU (2010-2013) and post-EPU (2016) monitoring for non-thermal and thermally influenced locations.

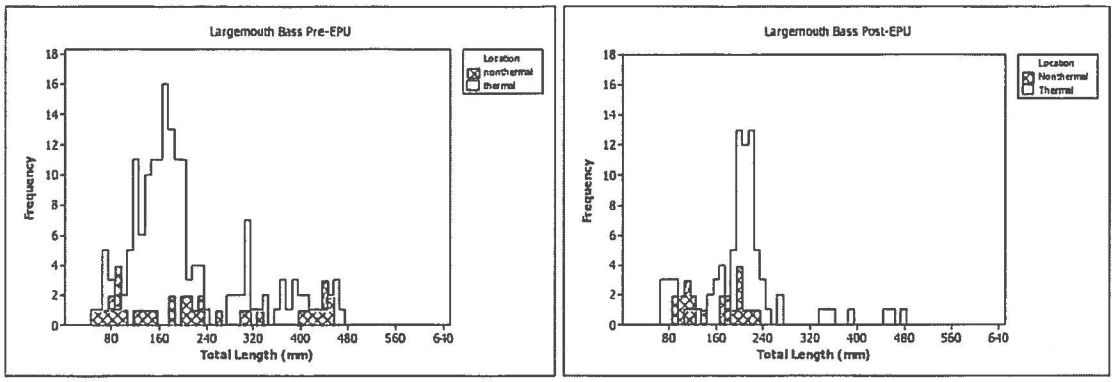


Figure 6-29. Length-frequency distribution of Largemouth Bass collected in Conowingo Pond using seine and electrofisher for sample stations that were surveyed during both pre-EPU (2010-2013) and post-EPU (2016) monitoring for non-thermal and thermally influenced locations.

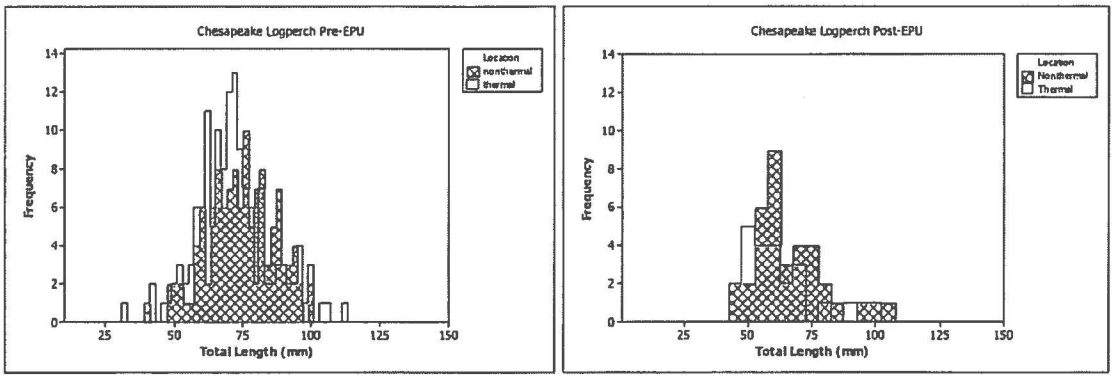


Figure 6-30. Length-frequency distribution of Chesapeake Logperch collected in Conowingo Pond using seine and electrofisher for sample stations that were surveyed during both pre-EPU (2010-2013) and post-EPU (2016) monitoring for non-thermal and thermally influenced locations.

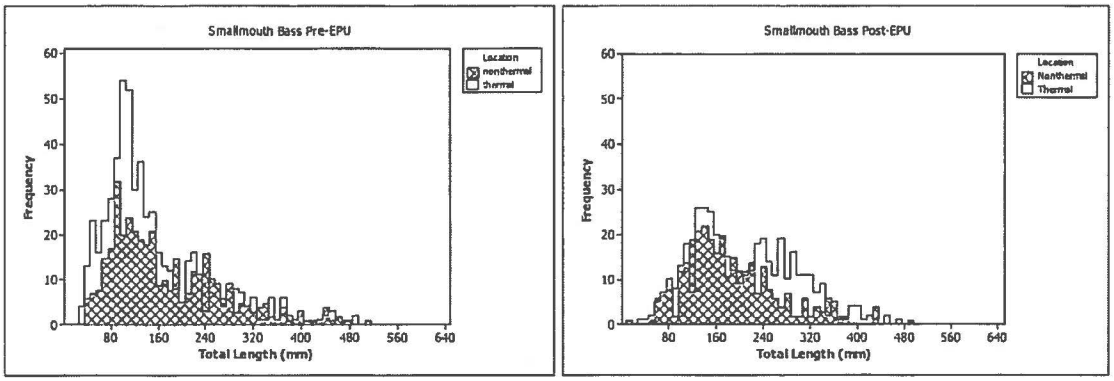


Figure 6-31. Length-frequency distribution of Smallmouth Bass collected in Conowingo Pond using seine and electrofisher for sample stations that were surveyed during both pre-EPU (2010-2013) and post-EPU (2016) monitoring for non-thermal and thermally influenced locations.

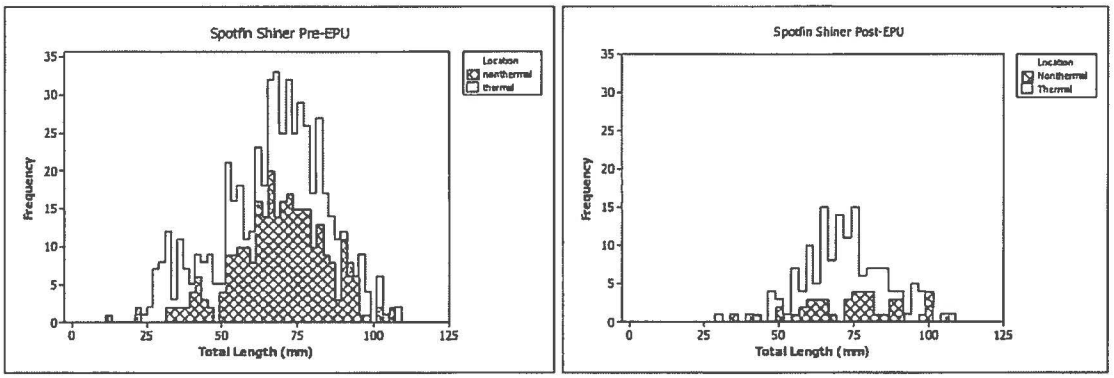


Figure 6-32. Length-frequency distribution of Spotfin Shiner collected in Conowingo Pond using seine and electrofisher for sample stations that were surveyed during both pre-EPU (2010-2013) and post-EPU (2016) monitoring for non-thermal and thermally influenced locations.

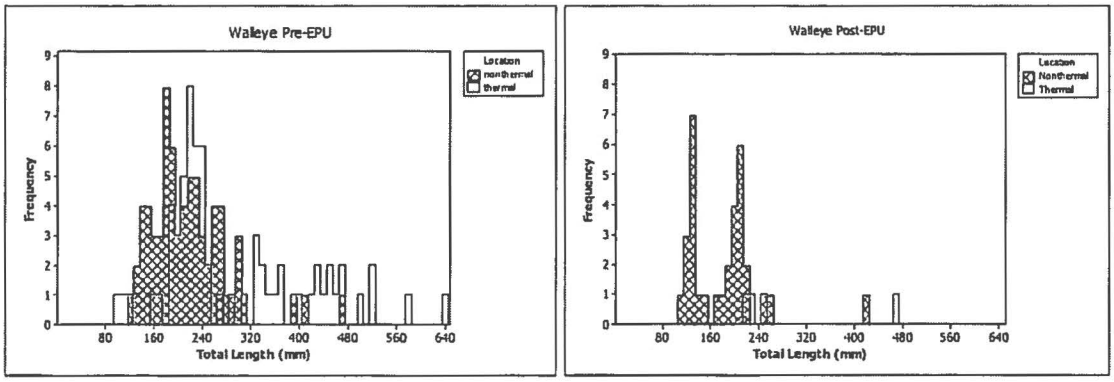


Figure 6-33. Length-frequency distribution of Walleye collected in Conowingo Pond using seine and electrofisher for sample stations that were surveyed during both pre-EPU (2010-2013) and post-EPU (2016) monitoring for non-thermal and thermally influenced locations.

6.3.7 Fish Condition

Relative weight (W_r) is an index of condition or well-being for a fish. Relative weight and other condition assessments are commonly employed by fisheries personnel for evaluating fish populations and communities. This is a standard, widely accepted and used method for assessing fish body condition. Relative weight was calculated following Murphy and Willis (1996).

Relative weight is one indicator of overall fish condition and describes the relative plumpness of an individual fish. Plump fish may be indicators of favorable environmental conditions (e.g., habitat conditions, ample prey availability); whereas, thin fish may indicate less favorable environmental conditions. A relative weight of 100 for an individual fish would indicate that the weight is equal to the average weight of a fish with the identical length for the larger population that was used to develop the standard weight equation.

Relative weights were calculated for Bluegill, Smallmouth Bass, Largemouth Bass, and Channel Catfish collected from the electrofishing stations during May through September for pre-EPU (2010-2013) and post-EPU (2016). A total of six stations were assessed (non-thermal: Stations 187 and 165; thermal: Station 161, 189, 190, and 217). Weight measurements were not taken for these four species collected using a seine because most were smaller, young individuals. These four RIS were selected for analysis because sufficient numbers of individuals and weight measurements were taken to enable valid comparisons of individuals collected at both thermal and non-thermal stations during pre- and post-EPU monitoring.

The purpose of this analysis is to determine whether W_r was different between the pre- and post-EPU monitoring periods. Conceptually, fishes living in elevated water temperatures may be affected by insufficient food availability, physiological stress associated with elevated temperatures, higher metabolic demands, and therefore, poorer body condition indicated by low W_r values. Obvious erroneous W_r values were excluded from the analysis as determined by the range of species-specific length-weight values provided in Carlander (1969 and 1977).

Relative weights were calculated for a total of 805 Bluegill with mean W_r of 103 (Table 6-35). Mean Wr was generally higher for most stations during post-EPU monitoring as compared to pre-EPU monitoring for both thermal and non-thermal stations. Mean W_r ranged from 85 at Station 189 (post-EPU) to 131 at Station 161 (post-EPU). The distribution of W_r among the sample stations was similar for non-thermal and thermal stations with post-EPU values generally higher than pre-EPU monitoring (Figure 6-34). The mean W_r was near or above 100 for most sample stations. Relative weights were calculated for a total of 176 Largemouth Bass with an overall mean W_r of 108 (Table 6-36). Mean W_r ranged from 98 at Stations 189 (pre-EPU) and 217 (post-EPU) to 119 at Station 161 (post-EPU). The distribution of W_r among the sample stations was comparable for thermal and non-thermal stations during pre- and post-EPU periods, with mean W_r above 97 for all stations (Figure 6-35). Note that W_r was calculated for few individuals at stations 165, 187, and 161.

Relative weights calculated for a total of 1,931 Channel Catfish resulted in an overall mean W_r of 112 (Table 6-37). Mean W_r ranged from 107 at Station 189 (pre-EPU) to 126 at Station 189 (post-EPU). The distribution of W_r among the sample stations was similar for non-thermal and thermal stations with median and mean W_r above 100 for all stations. Figure 6-36 provides a box plot which illustrates the spread of the Wr values for each station during pre- and post-EPU monitoring.

Relative weights calculated for 757 Smallmouth Bass resulted in a mean W_r of 99 (Table 6-38). Mean W_r ranged from 92 at Station 217 (pre-EPU) to 104 at Stations 190 and 187 (post-EPU). The distribution of W_r among the sample stations in reference to W_r of 100 was comparable with most stations having mean and median W_r near 100. Figure 6-37 provides a box plot which illustrates the spread of the Wr values for each station during pre- and post-EPU monitoring. For most stations Wr values tended to be slightly higher during post-EPU period.

Discussion and Conclusions

Relative weights for all four species (i.e., Bluegill, Smallmouth Bass, Largemouth Bass, and Channel Catfish) were similar between non-thermal and thermal stations during pre- and post-EPU monitoring. Although mean and median W_r values showed some variation among the stations, the relative weight observations did not indicate low W_r values for the near-field or far-field thermal stations during pre- or post-EPU monitoring. Differences in W_r were likely due to seasonality, reproductive status (pre- or post-spawn), length frequency distribution of individuals at a station, and differences between the sexes. The observations for these four species indicate no detrimental effect of the thermal plume on fish condition as measured by relative weight. Fish condition of these four species was similar between the pre- and post-EPU monitoring.

Table 6-35. Descriptive statistics for Bluegill relative weight by station for individuals collected during pre-EPU and post-EPU monitoring, May through September.

		Relative Weight (Wr)			
Station	Period	Mean	Standard Error	Median	Total Number
st161	Pre-EPU	101	3.4	94	92
st161	Post-EPU	131	2.7	128	80
st189	Pre-EPU	97	3.2	94	99
st189	Post-EPU	85	3.2	82	53
st190	Pre-EPU	88	3.2	81	91
st190	Post-EPU	107	3.1	109	56
st217	Pre-EPU	108	3.3	105	94
st217	Post-EPU	108	2.9	105	23
st165	Pre-EPU	97	2.6	99	106
st165	Post-EPU	107	1.8	106	44
st187	Pre-EPU	102	4.2	100	41
st187	Post-EPU	126	2.8	127	26
Overall		103	1.1	104	805

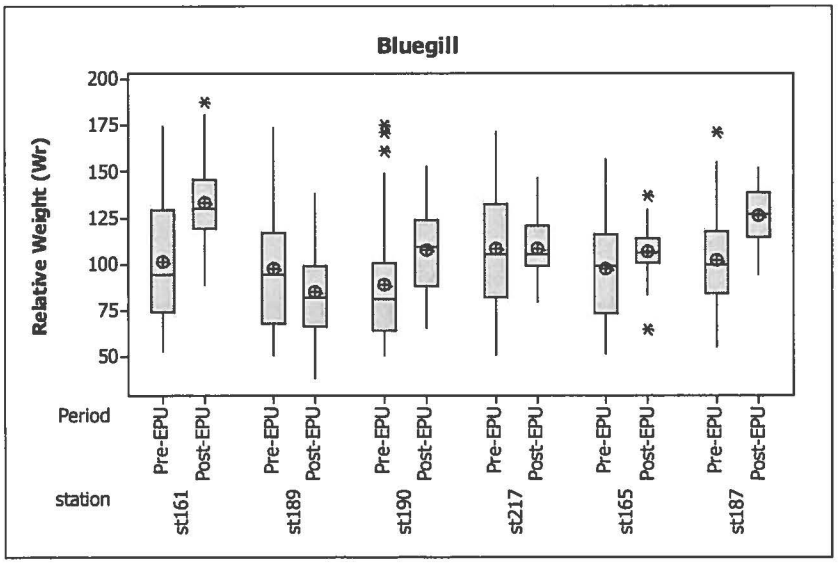


Figure 6-34. Box plot of Bluegill relative weight by station during pre-EPU and post-EPU monitoring, May through September.

(boxes = interquartile range containing 50% of the values, the line across the box = median value, circle = mean, and the vertical lines extending from the box = highest and lowest values, asterisk = outlier)

Table 6-36. Descriptive statistics for Largemouth Bass relative weight by station for individuals collected during pre-EPU and post-EPU monitoring, May through September.

		Relative Weight (Wr)			
Station	Period	Mean	Standard Error	Median	Total Number
st161	Pre-EPU	*	*	*	0
st161	Post-EPU	114	3.1	113	3
st189	Pre-EPU	98	4.1	97	17
st189	Post-EPU	117	8.9	107	22
st190	Pre-EPU	116	5.7	125	13
st190	Post-EPU	103	7.5	104	17
st217	Pre-EPU	111	2.6	110	57
st217	Post-EPU	98	2.2	94	27
st165	Pre-EPU	100	*	100	1
st165	Post-EPU	101	14.5	88	4
st187	Pre-EPU	99	10.3	100	7
st187	Post-EPU	119	14.2	105	8
Overall		108	1.9	104	176

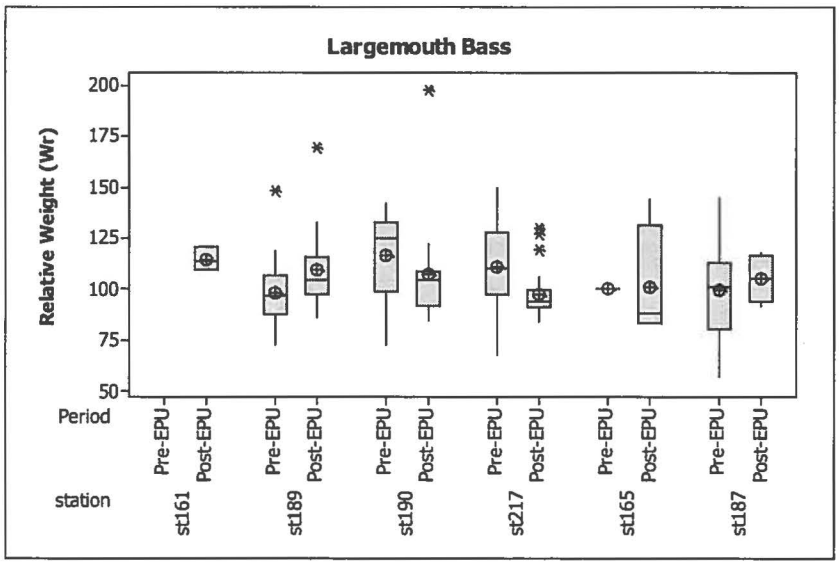


Figure 6-35. Box plot of Largemouth Bass relative weight by station during pre-EPU and post-EPU monitoring, May through September.

(boxes = interquartile range containing 50% of the values, the line across the box = median value, circle = mean, and the vertical lines extending from the box = highest and lowest values, asterisk = outlier)

Table 6-37. Descriptive statistics for Channel Catfish relative weight by station for individuals collected during pre-EPU and post-EPU monitoring, May through September.

		Relative Weight (Wr)			
Station	Period	Mean	Standard Error	Median	Total Number
st161	Pre-EPU	112	2.1	109	236
st161	Post-EPU	116	4.4	109	25
st189	Pre-EPU	107	1.8	106	251
st189	Post-EPU	126	5.8	119	34
st190	Pre-EPU	110	1.9	103	287
st190	Post-EPU	115	4.7	104	58
st217	Pre-EPU	118	2.1	118	204
st217	Post-EPU	116	3.9	109	74
st165	Pre-EPU	111	1.9	103	345
st165	Post-EPU	118	2.7	115	80
st187	Pre-EPU	112	1.9	109	279
st187	Post-EPU	115	2.4	111	58
Overall		112	0.7	108	1931

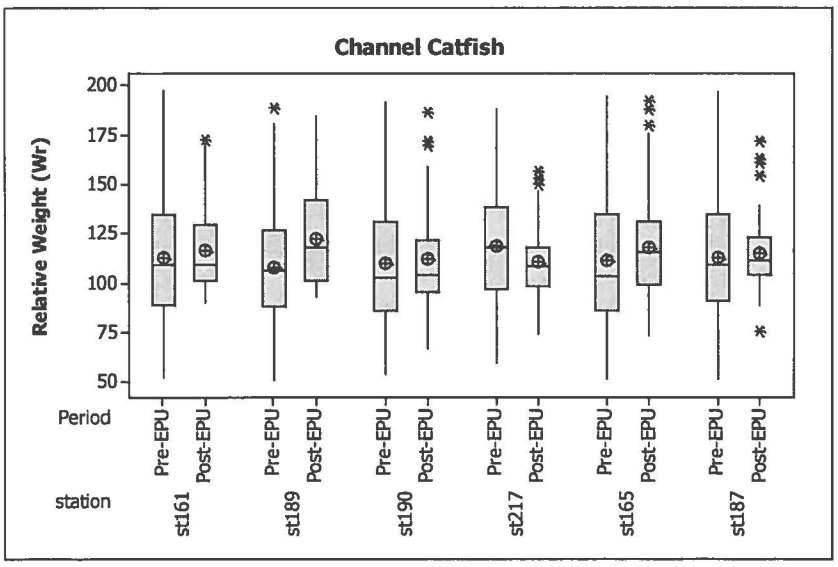


Figure 6-36. Box plot of Channel Catfish relative weight by station during pre-EPU and post-EPU monitoring, May through September.

Table 6-38. Descriptive statistics for Smallmouth Bass relative weight by station for individuals collected during pre-EPU and post-EPU monitoring, May through September.

		Relative Weight (Wr)			
Station	Period	Mean	Standard Error	Median	Total Number
st161	Pre-EPU	98	1.8	96	86
st161	Post-EPU	99	4.3	94	28
st189	Pre-EPU	97	4.4	92	11
st189	Post-EPU	97	2.9	95	33
st190	Pre-EPU	87	4.7	87	21
st190	Post-EPU	104	1.8	102	101
st217	Pre-EPU	92	2.8	89	27
st217	Post-EPU	95	1.5	93	123
st165	Pre-EPU	99	2.1	94	78
st165	Post-EPU	99	1.5	97	121
st187	Pre-EPU	98	2.1	97	56
st187	Post-EPU	104	2.5	100	72
Overall		99	0.7	96	757

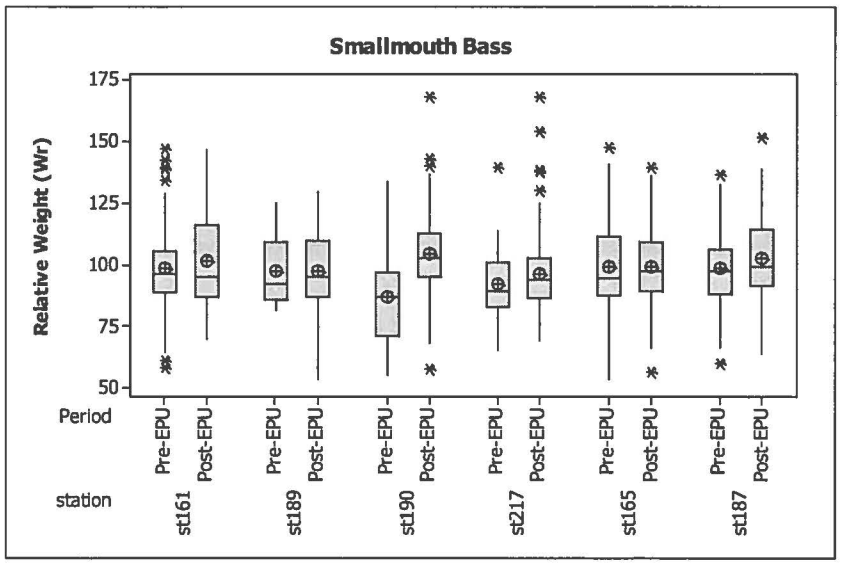


Figure 6-37. Box plot of Smallmouth Bass relative weight by station during pre-EPU and post-EPU monitoring, May through September.

(boxes = interquartile range containing 50% of the values, the line across the box = median value, circle = mean, and the vertical lines extending from the box = highest and lowest values, asterisk = outlier)

External Anomalies (DELTs)

During the course of field processing fish were examined for external anomalies or DELTs. The term DELTs refers to deformities, erosions, lesions, and tumors. This examination is a visual assessment completed with the naked eye that is commonly used during fisheries investigations to document the external condition of captured fish. Types of external anomalies that were determined during the course of study included deformities, eroded fins, lesions, tumors, anchor worm, black spot, leeches, and fungal infections. See PADEP protocol provided in the Study Plan (Appendix 11.1).

The occurrence of DELTs was tabulated for both non-thermally influenced and thermally influenced stations during post-EPU monitoring. The incidence of DELTs in the Conowingo Pond fish community was low during the post-EPU monitoring. DELTs were observed on 21 individuals of six species with 15 individual observed at thermal stations and six observed at non-thermal stations. The most commonly observed DELTs were eroded fins and lesions. The highest incidence of DELTs for a species was 12 Smallmouth Bass observed with DELTs; a proportion of 1.6% of the Smallmouth Bass examined during 2016.

Overall, 5,324 fish collected with electrofisher were examined with 0.40% of all individuals with DELTs. The incidence of DELTs was similar, given the number of sampling locations and fish collected, for those stations closest to the end of the PBAPS discharge canal as compared to the non-thermal monitoring locations. No DELTs were observed on fish collected with seine.

During the 4 years of pre-EPU field investigations DELTs were observed on 103 individuals of 18 species. The highest incidence of DELTs for any species or year occurred in 2013 with 10 Smallmouth Bass observed with DELTs; a proportion of 1.2% of the Smallmouth Bass examined during the year. The occurrence of DELTs was low and comparable between the pre-EPU and post-EPU monitoring.

The low proportion of fishes with DELTs during recent monitoring indicates an aquatic environment where stressful water quality conditions are minimal or such that conditions did not result in significant occurrence of DELTs. It is important to note that we do not know for certain where fishes lived prior to being collected at individual stations, thus, the thermal history is assumed to be that of the collection station. The occurrence of DELTs in Conowingo Pond is comparable or lower than other monitoring locations within the Susquehanna River, in particular, for Smallmouth Bass where higher disease rates have been observed for young of year fish at several upstream monitoring locations in the vicinity of Harrisburg, PA. Typical background occurrence of DELTs for Age 1 or older Smallmouth Bass and other fish species in the Susquehanna River is approximately 1-2% (G. Smith PAFBC, personal communication).

Table 6-39. Total number of each species with DELTs for all sample locations in Conowingo Pond, May through September 2016.

Species [1]	Total number of DELTs		Total Individuals of Species Processed	Total DELTs	Percent of species with DELTs
	Thermal Stations	Non-thermal Stations			
Bluegill	3		1296	3	0.23
Channel catfish	2	1	387	3	0.78
Flathead catfish	1		38	1	2.63
Largemouth bass	1		104	1	0.96
Smallmouth bass	7	5	749	12	1.60
White sucker	1		1	1	100
Total	15	6		21	

[1] *All fish collected during electrofishing; no external anomalies observed for fish collected with seine*

Table 6-40. Types of external anomalies observed by species for fish collected in Conowingo Pond, May through September 2016.

Species	Deformities	Eroded fins	Emaciated	Fungal infection	Leech	Open sore	Open Sore/Tumor	Trematode	Tumor	Total
Bluegill	1					2				3
Channel catfish					1	1	1			3
Flathead catfish									1	1
Largemouth bass			1							1
Smallmouth bass	1	5	3	1		1		1		12
White sucker						1				1
Total	2	5	4	1	1	5	1	1	1	21

6.3.8 Relative Abundance and Retrospective Analysis of RIS

Knowledge of the abundance of fish populations is an important component in management of fisheries. The most common indices of relative abundance are computed from catch per unit effort (CPUE) data for samples from a fish population. A common application in fisheries management is using CPUE to evaluate temporal patterns in relative abundance. Here, relative abundance is illustrated with time series plots for select RIS in Conowingo Pond.

Temporal patterns in CPUE are illustrated for both seine and electrofishing gears. A long-term data set for select RIS is available for the Pond for the period 1966 to 2016. This period covers fish collections at many locations throughout Conowingo Pond prior to operation of PBAPS (1966-1973) and after PBAPS became operational (1974-2016). Electrofishing surveys were not initiated until 1974, thus no pre-operational relative abundance data for this sampling gear are available. The data set for 1993 includes only October sampling and the 1996 data set includes multiple samples each month. This data set includes several time intervals associated with prior PBAPS 316(a) demonstration studies (PECO 1975, and 1979; Normandeau Associates 1997-2000a; Normandeau and ERM 2014).

Relative abundance data provided in each figure includes fish collections throughout the entire Conowingo Pond. Sampling station locations varied throughout the course of these studies within the Pond, thus not all stations sampled previously are the same as the present study. However, the long-term data set still provides useful information regarding abundance trends and although station locations differed over time, the collections occurred in similar habitats. The data reflect collections that occurred from June-October for 1974 through 2013 and May-September for 2016. CPUE data were square root transformed to decrease the effects of single year extreme CPUE values.

Seine

Relative abundance data from all stations surveyed in the Pond using a seine are provided for Bluegill, Smallmouth Bass, Spotfin Shiner, Bluntnose Minnow, and Chesapeake Logperch. This subset of RIS represents species that are more commonly collected using a seine. CPUE values during 2016 were within or above the historical range for all species (Figure 6-38 through Figure 6-42). CPUE for Bluegill, Smallmouth Bass, and Spotfin Shiner during 2016 was comparable to pre-EPU observations. For Bluntnose Minnow and Chesapeake Logperch the post-EPU CPUE was lower than the pre-EPU observations but within the range of historic values. No long-term temporal trends in CPUE were observed for these species. Short-term trends were observed for Spotfin Shiner and Bluntnose Minnow. Bluntnose Minnow CPUE was lower during 2016 as compared to 2010-2013 and the 1990's, but higher than most values during 1960-1970s. Spotfin Shiner CPUE was lower in 2016 and 2010-2013 as compared to historic collections which varied widely from year to year and over the short-term relative abundance appears to be declining in the Pond. Chesapeake Logperch relative abundance was higher during the 1996-2016 period compared to prior years.

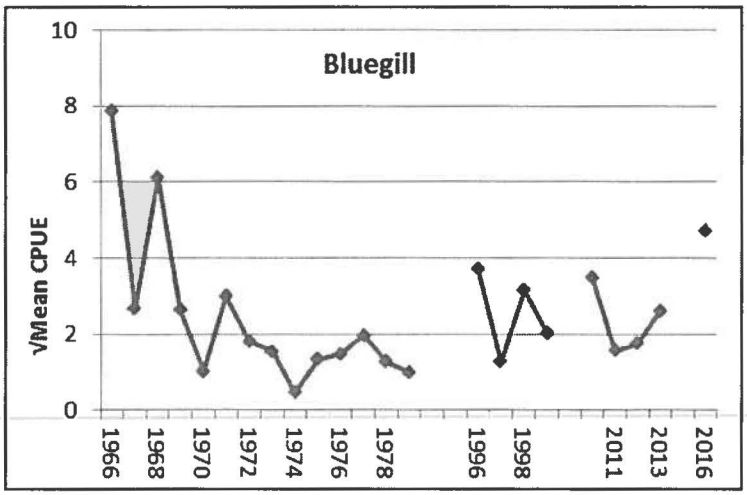


Figure 6-38. Square root transformed mean CPUE for Bluegill collected using a seine in Conowingo Pond, June-October 1966-2013 and May-September 2016.

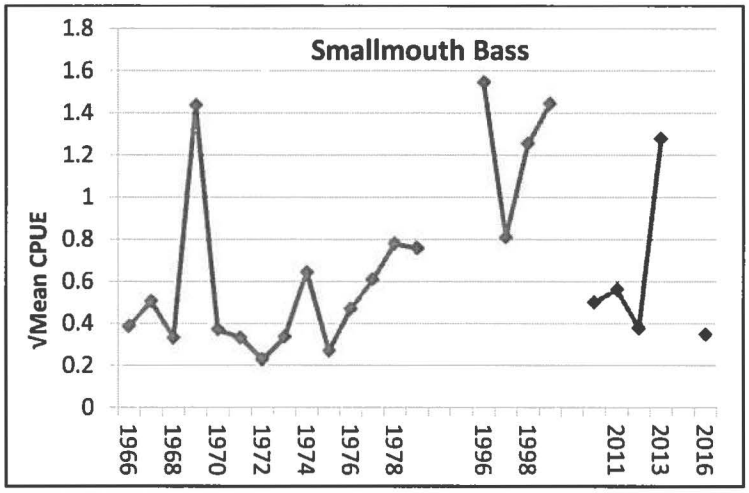


Figure 6-39. Square root transformed mean CPUE for Smallmouth Bass collected using a seine in Conowingo Pond, June-October 1966-2013 and May-September 2016.

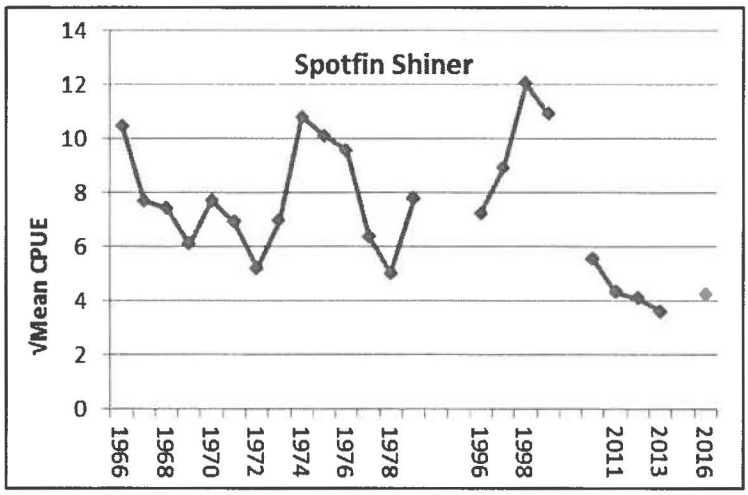


Figure 6-40. Square root transformed mean CPUE for Spotfin Shiner collected using a seine in Conowingo Pond, June-October 1966-2013 and May-September 2016.

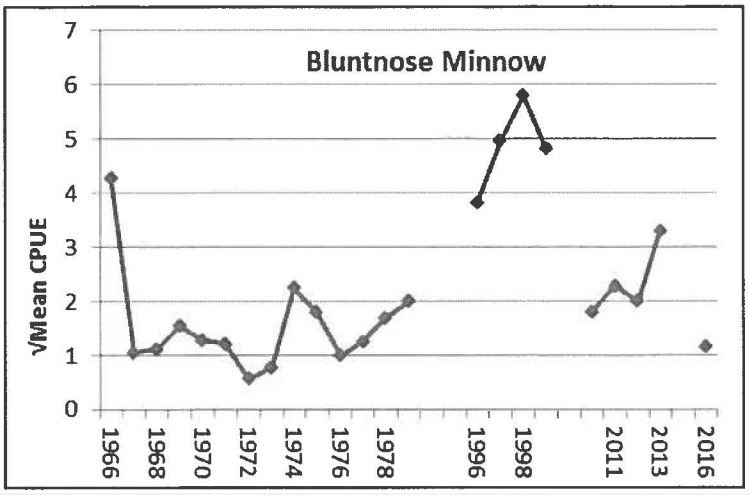


Figure 6-41. Square root transformed mean CPUE for Bluntnose Minnow collected using a seine in Conowingo Pond, June-October 1966-2013 and May-September 2016.

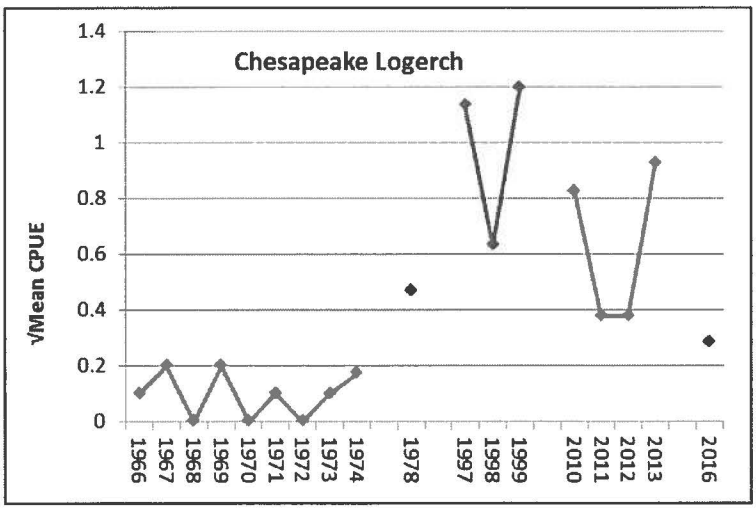


Figure 6-42. Square root transformed mean CPUE for Chesapeake Logperch collected using a seine in Conowingo Pond, June-October 1966-2013 and May-September 2016.

Electrofishing

Relative abundance data from all stations surveyed in the Pond using boat electrofisher are provided for Bluegill, Smallmouth Bass, Gizzard Shad, White Crappie, Channel Catfish, Walleye, and Chesapeake Logperch. Figure 6-43 through Figure 6-49 compare the annual mean CPUE for each species during the period of available electrofishing data from 1975-2016. This subset of RIS represent species that are commonly collected using a boat electrofisher in the Pond.

CPUE values during 2016 were within or above the pre-EPU observations for most species. Gizzard Shad relative abundance was comparable to pre-EPU and much higher than historic

observations. White Crappie relative abundance was comparable to pre-EPU but lower than previous years. Smallmouth Bass and Channel Catfish CPUE was comparable to pre-EPU values and within the historic range of observations. Bluegill relative abundance was comparable to pre-EPU and much higher than historic observations. Long-term trends for White Crappie and Gizzard Shad were evident. White Crappie relative abundance showed a long-term decline over time and Gizzard Shad relative abundance indicated a long-term increase over time. CPUE of Chesapeake Logperch in 2016 was within the range observed pre-EPU and higher than the historic values. Walleye CPUE was slightly lower in 2016 than pre-EPU observations but within the range of historic values.

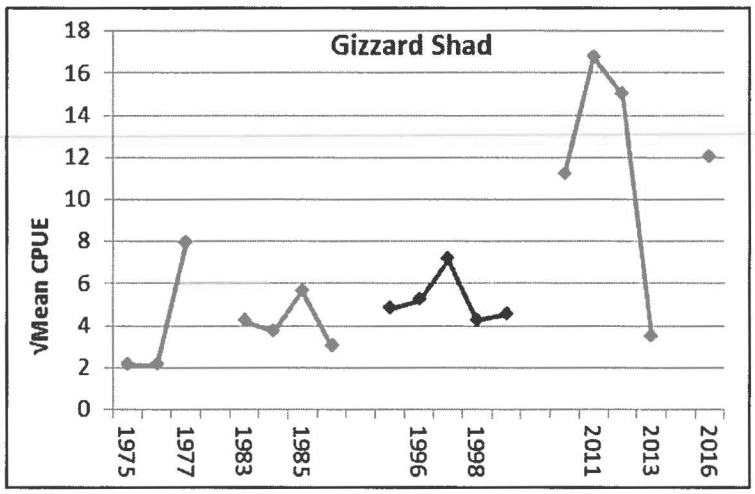


Figure 6-43. Square root transformed mean CPUE(no/0.5hr) for Gizzard Shad collected using a boat electrofisher in Conowingo Pond, June-October 1975-2013 and May-September 2016.

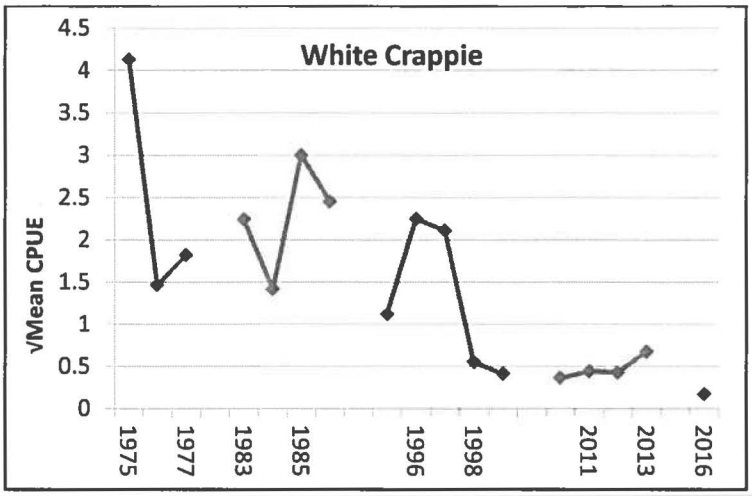


Figure 6-44. Square root transformed mean CPUE(no/0.5hr) for White Crappie collected using a boat electrofisher in Conowingo Pond, June-October 1975-2013 and May-September 2016.

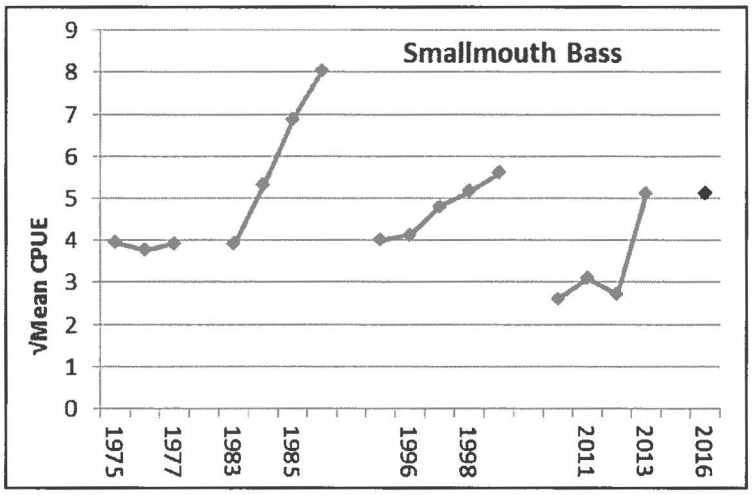


Figure 6-45. Square root transformed mean CPUE(no/0.5hr) for Smallmouth Bass collected using a boat electrofisher in Conowingo Pond, June-October 1975-2013 and May-September 2016.

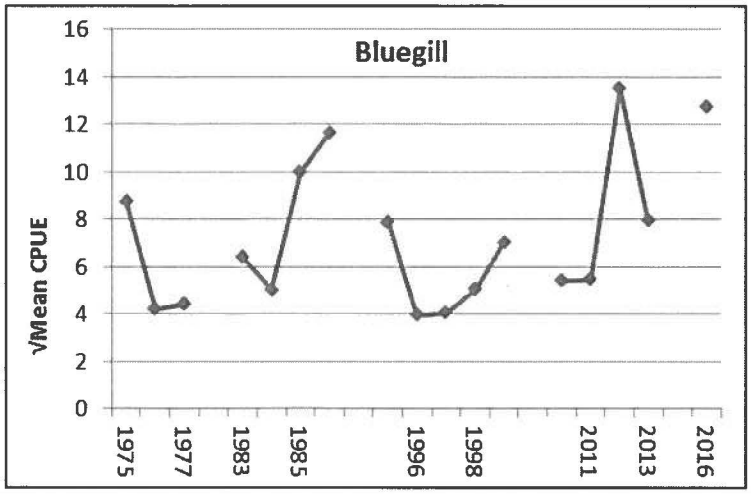


Figure 6-46. Square root transformed mean CPUE(no/0.5hr) for Bluegill collected using a boat electrofisher in Conowingo Pond, June-October 1975-2013 and May-September 2016.

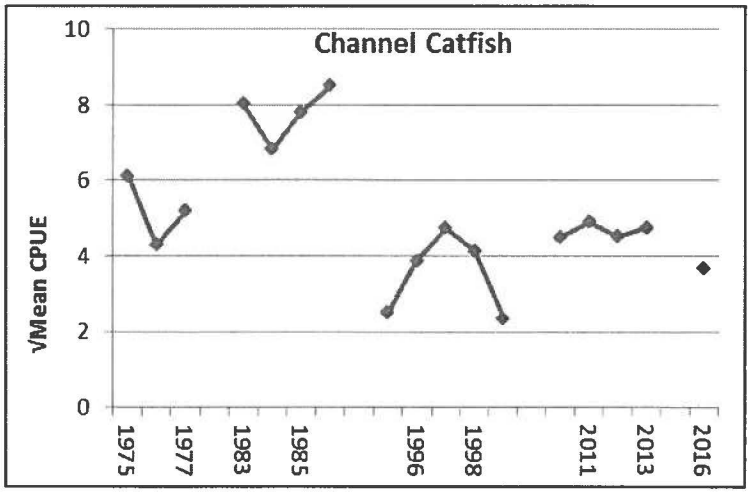


Figure 6-47. Square root transformed mean CPUE(no/0.5hr) for Channel Catfish collected using a boat electrofisher in Conowingo Pond, June-October 1975-2013 and May-September 2016.

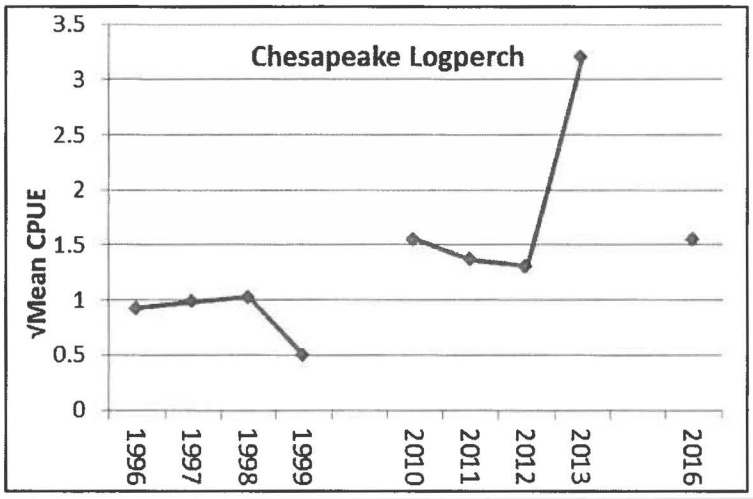


Figure 6-48. Square root transformed mean CPUE(no/0.5hr) for Chesapeake Logperch collected using a boat electrofisher in Conowingo Pond, June-October 1996-2013 and May-September 2016.

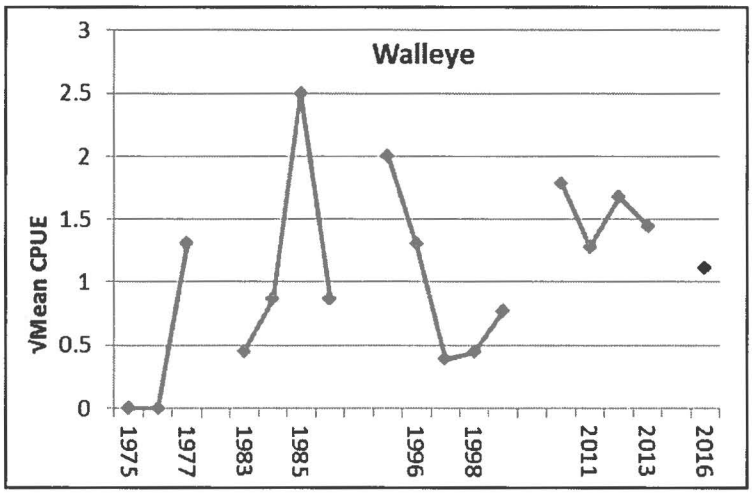


Figure 6-49. Square root transformed mean CPUE(no/0.5hr) for Walleye collected using a boat electrofisher in Conowingo Pond, June-October 1975-2013 and May-September 2016.

Discussion and Conclusions

Temporal differences in CPUE were evident for several species and reflect variations in the fish community associated with year-class strength and changes in species composition. CPUE during 2016 was comparable to pre-EPU study observations and within the range of historic observations for all species except White Crappie. Long-term trends in electrofishing CPUE were observed for Gizzard Shad and White Crappie. No long-term trends in the seine collections were evident for the selected RIS.

Many confounding factors affect fish population dynamics in Conowingo Pond, including changes in water quality, year-to-year differences in river flow, species introductions, and immigration from Conowingo East Fish Lift and emigration through the Holtwood Fish Lift. Fish populations are not static and differences in relative abundance reflect these changes. Many environmental factors including floods, droughts, and water quality changes (e.g. phosphorous loading from upper basin) can affect relative abundance.

Based on the comparison of relative abundance results of this study and the available historic data we can conclude:

- Relative abundance of the RIS was comparable to pre-EPU observations,
- Relative abundance of most RIS in 2016 was within their historic ranges,
- Considerable variation in relative abundance occurred over the available data period,
- Variable year-class strength for some species resulted in a wide range of relative abundance, and
- Changes in fish populations were within normal ranges and the result of naturally variable environmental conditions.

7 Juvenile American Shad Migration

This section of the report addresses PADEP draft NPDES permit comments related to the potential effect of the post-EPU PBAPS thermal discharge on migratory fishes. In particular, PADEP raised a question regarding the potential for PBAPS's thermal plume to block migration of juvenile American Shad in Conowingo Pond.

7.1 Analysis

Under the previously licensed thermal power conditions (prior to EPU) the design plant discharge temperature increase above ambient intake temperature (ΔT) was approximately 22°F without cooling towers in operation. However, during the Pre-EPU Demonstration Study (Normandeau and ERM 2014) temperature monitoring determined that the ΔT was less than 22°F and averaged 19.4°F during July and August; the months with warmest ambient water temperature. The post-EPU temperature monitoring completed in 2016 indicated that the increase in PBAPS discharge temperature did not exceed 3°F which corresponded well with the expected (based on engineering specifications) maximum increase in the ΔT of 3°F. Thus during 2016 monitoring period (May 1 through September 30) the observed maximum post-EPU ΔT was 22.4°F (19.4°F + 3°F). The modelling analyses provided herein use the maximum design ΔT of 25.0°F (22°F + 3°F) which is higher than the observed conditions and provides an additional conservative margin of +2.6°F.

Evidence of absence of impedance to emigration of juvenile American Shad in Conowingo Pond was gathered from two sources: (1) field sampling, and (2) a 3-D time varying hydrodynamic model.

There is no reported reproduction of American Shad in Conowingo Pond. Most juvenile American Shad use Conowingo Pond as an emigration corridor during their seaward journey. These juveniles originate from Pennsylvania Fish and Boat Commission stocking of chemically marked hatchery-reared fry during late May and June upstream of the hydroelectric dams on the Susquehanna River. Historically, three fixed locations had been monitored for juvenile American Shad during the fall months which may be used as indices for the time of entry of the juveniles into Conowingo Pond, residency duration of juveniles within Conowingo Pond, and exit of the juveniles out of Conowingo Pond. The monitoring locations were: sampling at the Holtwood Hydroelectric Dam inner forebay by lift net (entry), PBAPS outer screens (duration of residency), and Conowingo Dam cooling water strainers (exit time). The entry of juvenile American Shad into Conowingo Pond generally occurs in October and November at water temperatures between 50 to 65°F (10.0°C-18.3°C) with peak emigration generally occurring between 50 to 55.4°F (10.0 -13.0°C) coincident with a fall freshet typically in late October to mid-November. Table 7-1 summarizes the number of juvenile American Shad collected at the three monitoring locations between 2005 and 2009.

Historically, water temperatures of 50 to 60° F (10.0-15.6°C), as measured at Holtwood Hydroelectric Dam, occurred 25% of the time in October and 23% in November. At these

ambient water temperatures, with the designed rise in temperature of 25°F (13.9 °C), the temperature of the PBAPS effluent at the point of discharge structure would be 75.0°F (23.9 °C) and 85.0°F (29.5°C), respectively. At an ambient water temperature of 65° F, the water temperature of the discharge at the point of entry into Conowingo Pond is predicted to be 90 °F. Allowing for rapid dissipation via the "jet" type discharge, the actual temperature will be less than 90°F. However, results of the 3-D time varying hydrodynamic model more accurately quantify the size and temperature of the plume because it takes into account the effects of other factors including river flow and operation of the MRPSF.

The emigration period for juvenile American Shad through Conowingo Pond is October and November. The analyses provided herein focus on water temperatures and the configuration of the PBAPS thermal plume during these months. The long-term data set for daily water temperatures and flows at Holtwood Hydroelectric Dam were used to determine near worst case conditions for combined low flows and high temperatures during juvenile American Shad emigration. Two modelling scenarios were selected: ambient temperatures of 65 °F and river flows of 10,000 cfs and ambient temperatures of 55° F and river flows of 15,000 cfs. The joint probability occurrence of these river flows and water temperatures ranged from 1.65 to 14.66% (Table 7-2). We modeled these hydrological conditions and integrated the model results with the reported avoidance temperature of juvenile American Shad to delineate the potential areas of avoidance. For this analysis water temperature greater than 86°F was assumed to be an impedance to juvenile shad emigration. Experimental studies (Moss 1970; Marcy et al.1976) have reported that juvenile American Shad avoid water temperatures above 86°F.

We used a time-varying 3-D hydro-thermal model (Generalized Environmental Modeling System for Surface waters or GEMSS® to identify (a) PBAPS plume size and configuration and (b) areas in Conowingo Pond exceeding 86°F during the migration period in the fall months.

Figure 7-1 and Figure 7-2 show the thermal plume dispersion at river flows of 10,000 cfs and 15,000 cfs with ambient water temperatures of 65 and 55°F, respectively at four depths (surface, 5ft, 10ft, and 15ft). No area above 86.0°F exists during the month of November. In October at ambient water temperature of 65°F only a small narrow area exists at the surface along the western shore. Subsurface temperatures are all less than 86°F. Virtually the entire pond is available for downstream migrating juveniles. These model results suggest an absence of impedance to emigration of juvenile American Shad in Conowingo Pond.

7.2 Summary and Conclusions

A 3-D time varying hydrodynamic model was used to predict the areas in Conowingo Pond during October and November at two hydrological conditions: ambient temperatures of 55° F and 65°F and river flows of 10,000 cfs and 15,000 cfs; the EPU maximum rise in water temperature was assumed to be 25°F with no cooling towers operating. The joint probability occurrences of these hydrological events in October and November ranged from 1.65 to 14.66%. Modeling results indicated that only a very small, narrow area hugging the west shoreline downstream of the PBAPS discharge structure contains surface water temperature > 86°F (assumed an impedance to juvenile shad emigration) at an ambient temperature of 65°F;

at ambient water temperatures of ≤ 61.0 °F no area of 86.0 °F exists. Virtually the entire Conowingo Pond is available for juvenile American Shad emigration. Therefore, there is no potential for thermal blockage. This is supported to a large extent by the collection of emigrating juvenile American Shad at cooling water strainers at Conowingo Dam (7 mi downstream of PBAPS).

Table 7-1. Juvenile American Shad Outmigration Data for Holtwood Lift Net, PBAPS travelling screens, and Conowingo Dam Strainer, September 11 through December 12, 2004 through 2009.

Date	Holtwood Lift Net [a]	PBAPS Fall Sampling [b]	Conowingo Dam Strainer Sampling [c]	Date	Holtwood Lift Net [a]	PBAPS Fall Sampling [b]	Conowingo Dam Strainer Sampling [c]
Sept. 11	0	0	0	Nov. 11	0	1	
				Nov. 12	0	1	0
Oct. 12	0	0	0	Nov. 13	0	1	
Oct. 13	0	3	0	Nov. 14	0	0	
Oct. 14	0		0	Nov. 15	0	0	0
Oct. 15	0	0	0	Nov. 16	0	0	
Oct. 16	0			Nov. 17	0	0	
Oct. 17	0			Nov. 18	0	0	
Oct. 18	0	0	0	Nov. 19	0	2	0
Oct. 19	0	1		Nov. 20	0	6	0
Oct. 20	0	2	0	Nov. 21	0	8	
Oct. 21	0	1	5	Nov. 22	0	0	0
Oct. 22	0	0	0	Nov. 23	0	0	
Oct. 23	0	7		Nov. 24	0	1	0
Oct. 24	8	46	5	Nov. 25	0	0	
Oct. 25	2	15	0	Nov. 26	0	1	2
Oct. 26	0	23	4	Nov. 27	0	2	
Oct. 27	0	25		Nov. 28	0	1	0
Oct. 28	181	7	7	Nov. 29	0	0	
Oct. 29	0	1	1	Nov. 30	0	0	
Oct. 30	0	0		Dec. 1	0	1	
Oct. 31	17	20	7	Dec. 2	0	0	
Nov. 1	0	26	0	Dec. 3	0	1	
Nov. 2	0	3	2	Dec. 4	0		0
Nov. 3	0	9		Dec. 5	0	2	0
Nov. 4	0	7		Dec. 6	0	0	
Nov. 5	0	12	0	Dec. 7	0		
Nov. 6	0			Dec. 8	0	11	
Nov. 7	0	8	1	Dec. 9	0		
Nov. 8	0	2	1	Dec. 10		5	
Nov. 9	1	1	1	Dec. 11	0		
Nov. 10	0	1	1	Dec. 12	0		

	Holtwood Lift Net	PBAPS Fall Sampling	Conowingo Dam Strainer Sampling
Overall Total	209	264	37

[a] Am. Shad collected by Lift Net in 2005, 2006, and 2008

[b] Am. Shad collected at PBAPS in 2005, 2006, 2007, 2008, and 2009

[c] Am. Shad collected in Conowingo Strainers in 2005, 2006, 2007, and 2008

Peak outmigration water temperature range: 10.0°C to 13.0°C

Table 7-2. Joint probability occurrence (%) of average daily water temperature and river flows measured at Holtwood Dam in October and November, 1956-2012. October –November are emigration periods of juvenile American Shad in lower Susquehanna River.

River Flow (cfs)	Water Temperature (°F)								
	46-50	51-55	56-60	61-65	66-70	71-75	76-80	>80	Total
	October*								
0-9,999		2.26	7.64	14.66	12.65	5.19	1.10	0.31	43.80
10,000-14,999		1.71	4.58	7.45	2.93	0.92	0.06	0	17.65
15,000-19,999	0.24	1.10	3.85	2.69	1.16	0.49	0.06	0	9.59
20,000-24,999	0.06	1.34	2.50	2.02	0.73	0.18	0	0	6.84
	November*								
0-9,999	3.44	6.93	4.07	1.65	0.45	0	0	0	17.37
10,000-14,999	3.31	5.22	0.83	0.51	0	0	0	0	12.21
15,000-19,999	2.93	2.99	0.57	0.25	0	0	0	0	9.16
20,000-24,999	3.05	1.97	0.89	0.25	0	0	0	0	9.80

**Emigration period for juvenile American Shad in the lower Susquehanna River*

Note: shaded cells referred to in the text

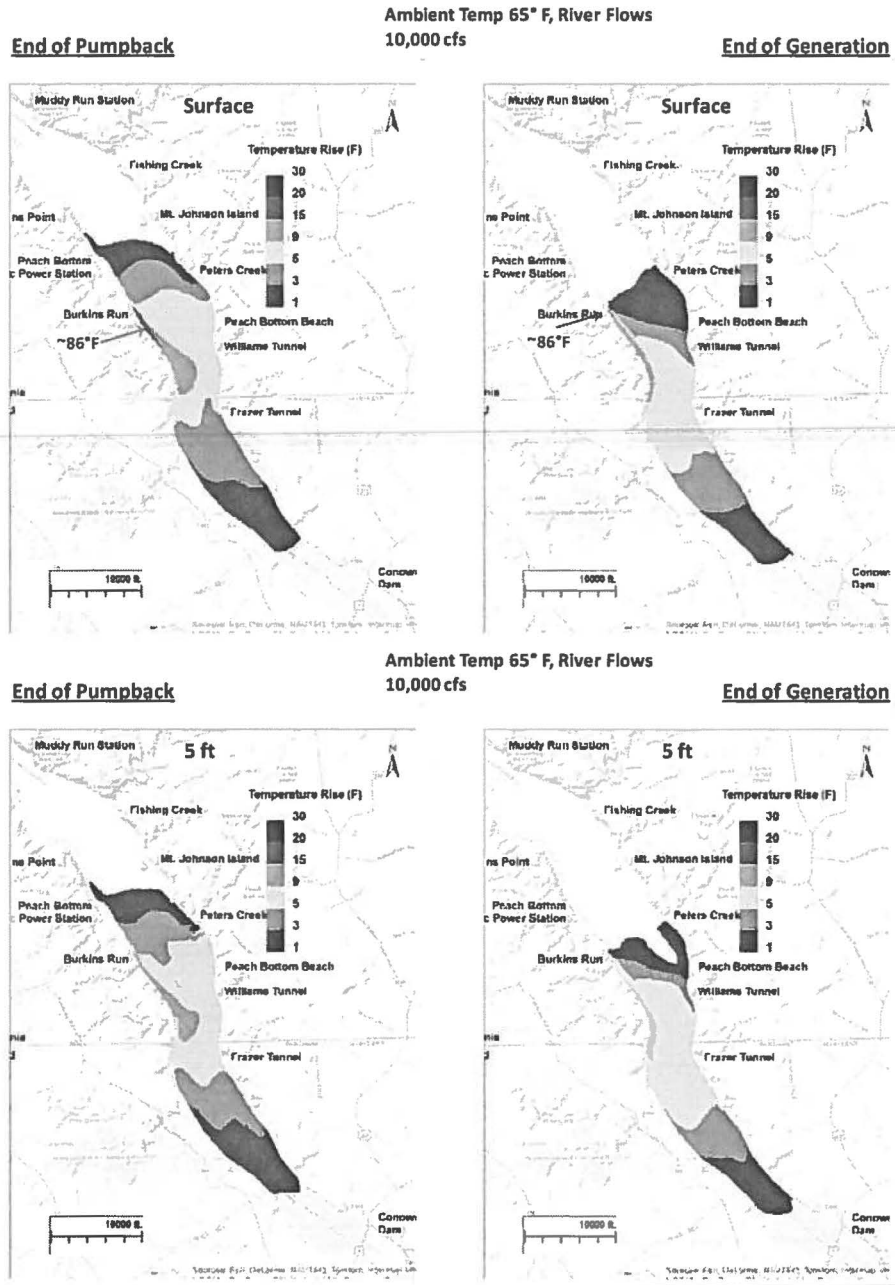
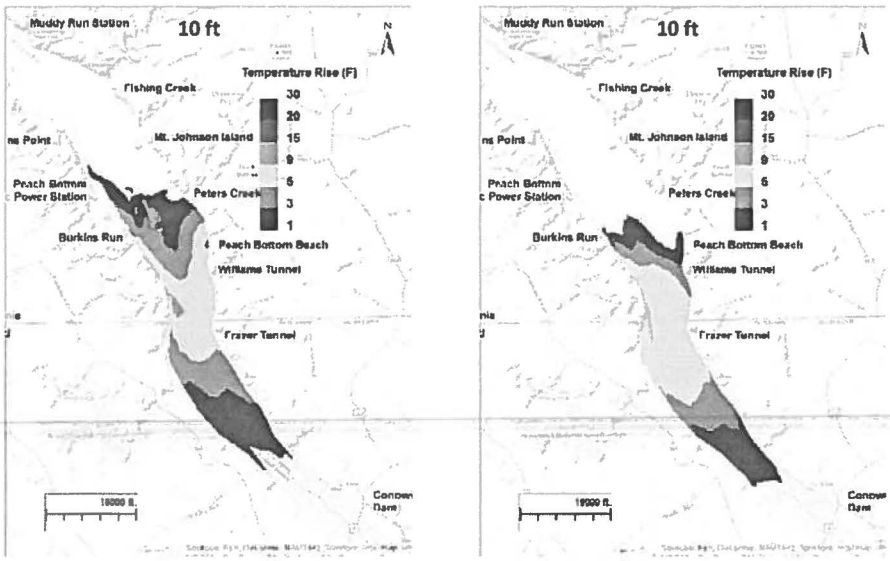


Figure 7-1. Predicted thermal plume at surface, 5ft, 10ft, and 15ft during MRPSF pumping

(left panel) and generation (right panel) at river flow of 10,000 cfs and water temperature 65° F (representing the month of October). MRPSS pumping (28,000 cfs) continuously for 12h followed by generation (28,000 cfs) for 12h. Peach Bottom operating under EPU conditions resulting in temperature rise (color coded) above the ambient temperature of 65° F.

Ambient Temp 65° F, River Flows
10,000 cfs

End of Pumpback **End of Generation**



Ambient Temp 65° F, River Flows
10,000 cfs

End of Pumpback **End of Generation**

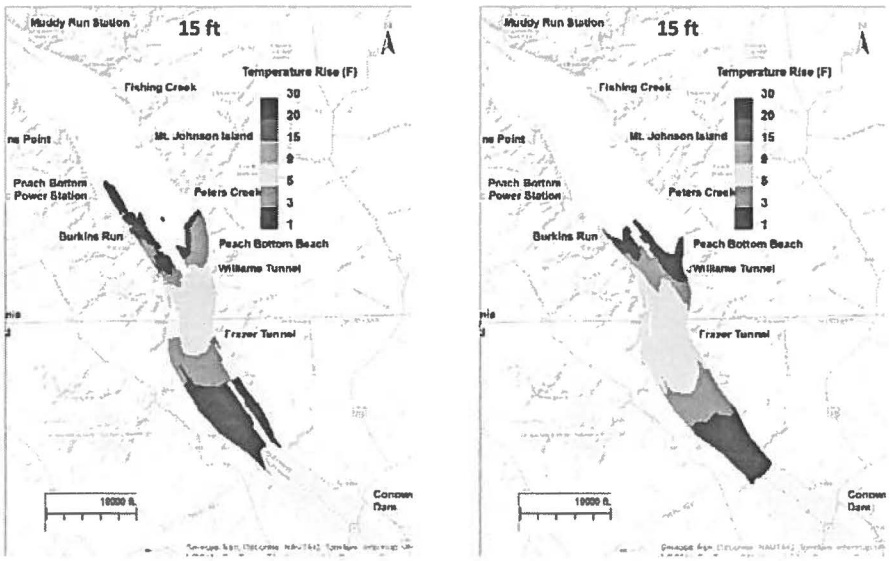


Figure 7-1. Continued.

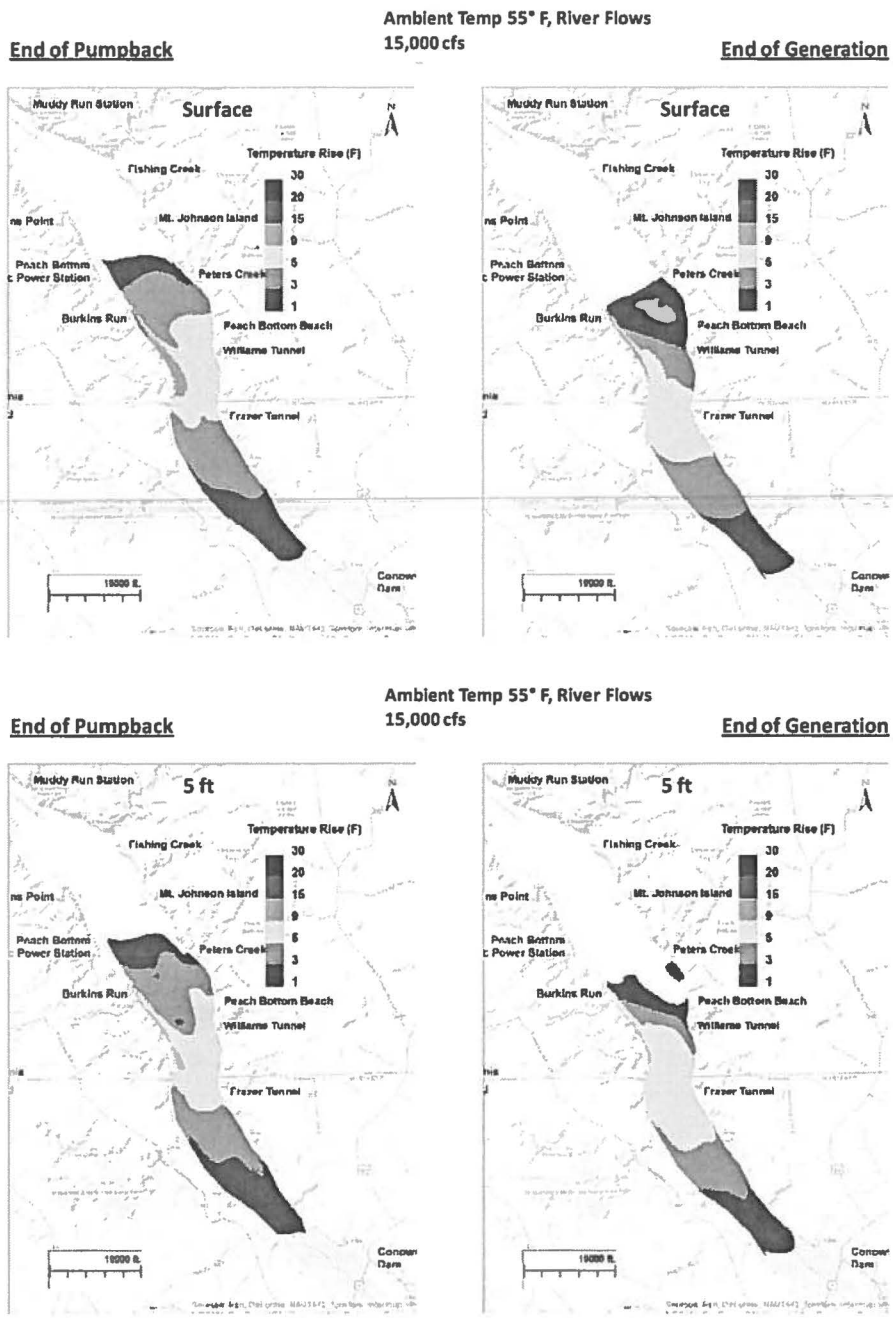
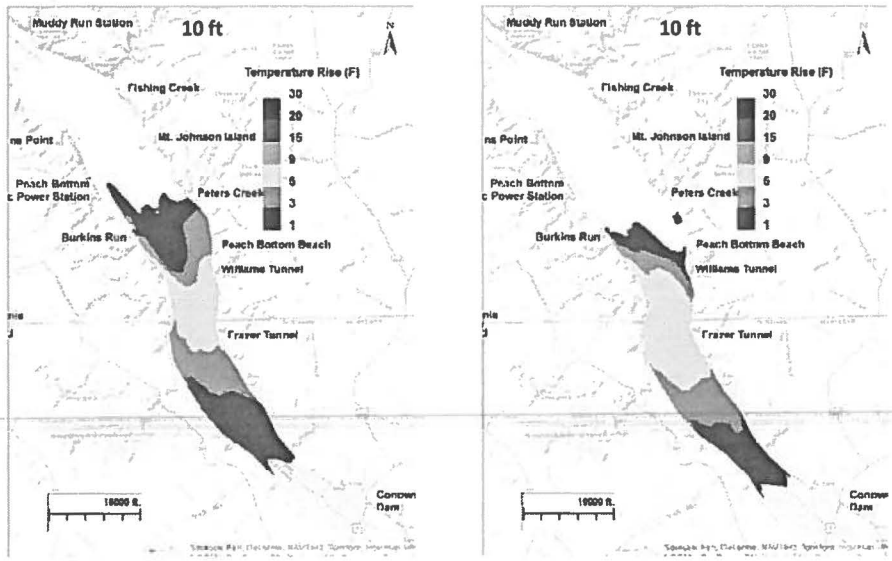


Figure 7-2. Predicted thermal plume at surface, 5ft, 10ft, and 15ft during MRPSF pumping

(left panel) and generation (right panel) at river flow of 15,000 cfs and water temperature 55° F (representing the month of November). MRPSS pumping (28,000 cfs) continuously for 12h followed by generation (28,000 cfs) for 12h. Peach Bottom operating under EPU conditions resulting in temperature rise (color coded) above the ambient temperature of 55°F.

Ambient Temp 55° F, River Flows
15,000 cfs

End of Pumpback **End of Generation**



Ambient Temp 55° F, River Flows
15,000 cfs

End of Pumpback **End of Generation**

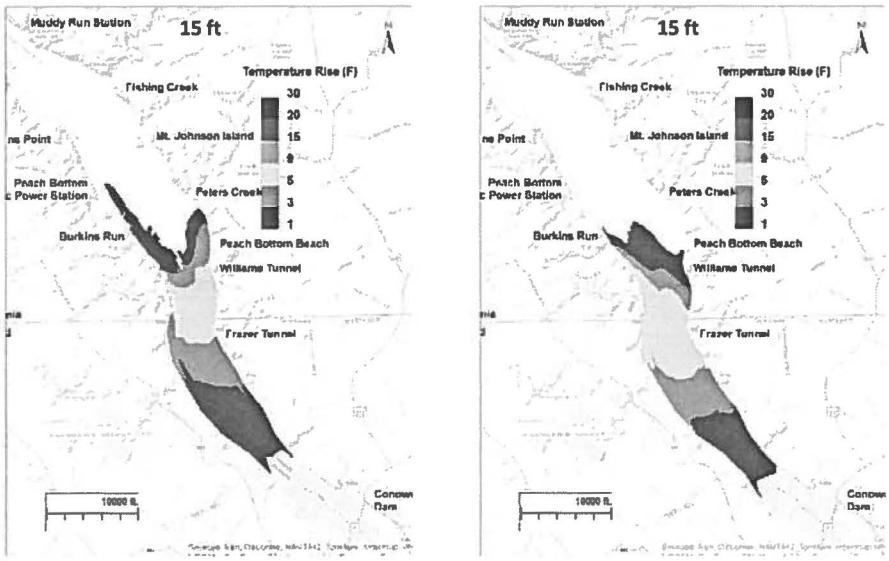


Figure 7-2. Continued

8 Gizzard Shad Seasonal Distribution

This section of the report addresses United States Fish and Wildlife Service (USFWS) comments related to the seasonal distribution of Gizzard Shad in Conowingo Pond relative to the PBAPS thermal plume. The USFWS raised a question about whether the thermal plume may provide a winter refuge for Gizzard Shad which, otherwise, may not survive extreme cold temperatures during the winter. Exelon agreed to provide a compilation of information from previous studies related to Gizzard Shad seasonal distribution in Conowingo Pond relative to the thermal plume. This compilation of data available from previous studies includes information related to winter water temperatures in the pond, Gizzard Shad distribution, and winter survival.

8.1 Analysis

Gizzard shad, native to eastern North America (Jenkins and Burkhead 1993), was inadvertently introduced into Conowingo Creek, a tributary to Conowingo Pond in May 1972 during an American Shad transport from the Conowingo Dam West Fish Lift. Successful reproduction ensued the same year and the species dispersed into the Muddy Run Reservoir and Muddy Run Recreation Lake. A chronology of Gizzard Shad population expansion in Conowingo Pond is provided in Appendix 10.2. Gizzard Shad are present in much of the Pennsylvania portion of the Susquehanna River including some upstream reservoirs (Stauffer et al. 2016) which are most likely subject to extreme winter conditions and do not receive heated effluent from power plants.

Gizzard Shad are reported to become disoriented at cold water temperatures and may suffer high mortality at water temperatures below 3.3 °C (38.0 °F) with mortality being size selective such that larger sized Gizzard Shad have a higher survival than smaller individuals (Bodola 1965; Jester and Jensen 1972; Adams et al. 1985; Fetzer et al. 2011; Michaletz 2010). Natural winter "die offs" of Gizzard Shad, particularly young Gizzard Shad have been reported from water bodies with and without thermal discharge. Depending upon the severity and duration of winters, a natural winter "die off" of Gizzard Shad, particularly young-of-the year, has been reported from water bodies with or without thermal discharges including Conowingo Pond. However, a complete "kill" has not been reported or inferred. Presumably an unknown number of older fish survive over winters as evident by capture of adults the following spring in water bodies unaffected by thermal discharge. Bodola (1965) reported winter "die off" of Gizzard Shad in multiple years from Lake Erie, PA, Jester and Jensen (1972) from Elephant Butte Lake, NM, and Fetzer *et al.* (2011) from Oneida Lake, NY.

In Conowingo Pond, the Gizzard Shad seems to tolerate temperatures < 2.2 °C (< 36.0 °F) and does not appear to need a "thermal refuge" to sustain its population. The average water temperature in December 1972 (first winter month exposure) the year Gizzard Shad were inadvertently introduced into Conowingo Pond (PBAPS was not operating), was 37.8 °F (3.2 °C). In January and February 1973 the average temperatures were 1.9 °C (35.5 °F) and 1.3 °C (34.3 °F), respectively. These temperatures were measured at Holtwood Dam, 7 miles upstream of PBAPS. From a historical perspective, the long term (1956-2007) average incoming water

temperatures (as measured at the upstream Holtwood Dam, 1956-2007) in December, January, and February, respectively are: 3.1 °C (37.6 °F), 1.5 °C (34.7 °F), 1.5 °C (34.7 °F), similar to those experienced in December 1972, and January-February 1973.

The complete shutdown of PBAPS (i.e., no thermal refuge) between 1987 and 1989 did not seem to affect the Gizzard Shad population in Conowingo Pond; the population survived the winters despite the absence of PBAPS thermal discharge. The incoming average water temperatures (°F) in December – February (1987-1989) were:

Month	1987	1988	1989
December	39.3	36.2	33.5
January	34.8	32.5	34.2
February	34.0	33.1	36.3

The tolerance of Gizzard Shad to low water temperatures was also corroborated by recent electrofishing sampling of non-thermally affected areas at Mt. Johnson Island (Station 164) and the East Shore (Station 165) in Conowingo Pond in January 2013. Some 22 Gizzard Shad were collected at Mt. Johnson Island and 21 on the East Shore (water temperature of 2.0 °C or 35.6 °F compared to 20 specimens each collected at the two locations in the thermal discharge (Stations 189 and 190). Therefore, the lower temperature tolerance of Gizzard Shad appears to be < 2.2 °C (< 36.0 °F).

During the fall large numbers of Gizzard Shad have been observed emigrating from Conowingo Pond downstream past Conowingo Dam. The annual migration (fish lift introductions) of Gizzard Shad from the lower Susquehanna River (up to 1 million Gizzard Shad) likely contributes substantially to the total population of this species in the Pond, and these fish do not benefit from overwintering in the Pond within the extent of the PBAPS thermal plume.

8.2 Summary and Conclusions

The Gizzard Shad population expanded rapidly after being inadvertently introduced into Conowingo Creek, a tributary to Conowingo Pond in May 1972. PBAPS was not operating then. The average water temperatures in subsequent January and February 1973 were 1.9 °C (35.5 °F) and 1.3 °C (34.3 °F), respectively. Again, when PBAPS was completely shut down (no thermal discharge) for two years (between 1987 and 1989) the Gizzard Shad population appeared to survive extreme winter conditions (water temperature between 32.5 and 36.3 °F). Gizzard Shad population experienced extreme winter temperatures in subsequent years and colonized other upstream areas. The population is thriving in areas unaffected by thermal discharges in the Susquehanna River and elsewhere. Conowingo Pond is an open system and recruits Gizzard Shad from both downstream and upstream sources. Gizzard shad are distributed throughout Conowingo Pond and each year upwards of 1 million adult Gizzard Shad

are introduced into Conowingo Pond from the Conowingo Dam East Fish Lift. A "thermal refuge" is not necessary for propagation and sustenance of the Gizzard Shad population in Conowingo Pond.

9 Conclusions

9.1.1 Temperature

An important component of the pre-EPU 316(a) Demonstration Study was modeling temperatures and temperature increases for extreme low flow and high temperature conditions using the post-EPU thermal discharge rate. In 2016, Susquehanna River flows and temperatures were very close to the flow and temperature values used to predict worst case biological impacts post-EPU. Because direct measurement was completed of net temperature increases from the EPU and reductions that occur when the cooling towers operate, the summer of 2016 was ideal for verifying the model and observing overall physical and biological impacts.

Model verification was undertaken in two steps, validation of assumptions and comparison of model results to observations. Modeling performed for the pre-EPU 316(a) Demonstration Study, and subsequently used in the biological evaluation, assumed a value of the temperature increase from the intake to the head of canal and a specific level of cooling tower performance. Based on measurements obtained in 2016, these two modeling assumptions were validated. The average temperature increase from the intake to the head of canal was 22.1°F, which was 0.3°F less than the assumed post-EPU condenser temperature rise of 22.4°F. Furthermore, each cooling tower provided about a third more cooling than expected (2.2°F instead of 1.6°F).

Model results showed very good agreement with observations. Agreement was tested by comparing temperature observations against model results at the warmest, most biologically sensitive monitoring stations, as identified in the pre-EPU 316(a) Demonstration Study. The observations were hourly, allowing between 400 and 1700 observations for comparisons to model results. Because the model was run for a single set of extreme Susquehanna River flows and temperatures, it was sufficient for the observations to be bounded by the model's estimate of maximum temperatures. Only 0.05% of observations exceeded this upper bound; which constitutes satisfactory model verification.

9.1.2 Fish and benthic macroinvertebrate communities

Water temperatures observed during 2016 at the biological monitoring locations were comparable to pre-EPU observations with the exception of late August through September period, which was warmer. Dissolved oxygen monitoring was completed within and outside of the PBAPS thermal plume to evaluate DO concentrations that may affect available fish habitat or cause blockage to fish migration past PBAPS. DO concentrations were protective of the aquatic community with sufficiently high DO to maintain fish habitat and allow for migration past PBAPS.

Surveys of the benthic macroinvertebrate community indicated similar species composition to pre-EPU monitoring; the community was characterized by tolerant taxa, in particular, Oligochaeta, Chironomidae, *Gammarus*, Gastropods, and *Corbicula* which were abundant at most stations. IBI scores and metrics indicated that the benthic community was similar to pre-

EPU observations for most months of monitoring. IBI scores and metrics were higher in July and August at the nearfield stations (214 and 215) during the post-EPU monitoring. In contrast, post-EPU scores were lower at Stations 214 and 215 in September due to lower flows and higher ambient temperatures during this month. The areas with measurable effects from the thermal plume were along the west shoreline at Stations 214 and 215 as was the case during pre-EPU monitoring.

A diverse warmwater fish community represented by 34 species was observed during the 2016 monitoring. Fish composition and relative abundance was similar between the thermal and non-thermal stations. Observations of the fish community as characterized by the selected metrics indicated similar composition to the pre-EPU period. Avoidance of the highest water temperature was observed at the nearfield electrofishing station (161) from July through September. The pattern of avoidance was comparable to pre-EPU observations with the exception of September where avoidance was not observed during pre-EPU monitoring. The avoidance and measurable reduction in the fish diversity was observed along the west shoreline and was limited to periods with high water temperatures and low flows. Avoidance was not observed at the seine stations (214 and 215) that experience the highest water temperatures. Observations of fish health (external anomalies) and fish condition (relative weight) indicated minimal differences between the thermally influenced and non-thermal locations. Fish health and condition were comparable to the Pre-EPU Demonstration Study with no measurable influence from the EPU identified. The length-frequency distribution of the representative important species was comparable to Pre-EPU observations and relative abundance of most RIS was within their historic ranges.

9.1.3 Overall

Post-EPU monitoring occurred during a period of low Susquehanna River flows coincident with high water temperatures. These conditions provided an ideal opportunity to evaluate the impact of the EPU on Conowingo Pond during extreme conditions. The monitoring results showed that cooling tower operation effectively mitigates the additional heat discharge by the EPU. This conclusion is based on the fact that observed water temperatures at the nearfield stations in 2016 for extreme low flow and water high temperature conditions were less than the modeled temperatures presented in the pre-EPU 316(a) Demonstration Study.

The measurable spatial and temporal effects of the PBAPS thermal plume on the biota of Conowingo Pond were similar to those observed during the pre-EPU monitoring. Temporal patterns of fish avoidance and decline in benthos diversity were apparent, related to high water temperatures and were also similar to those observed during the pre-EPU monitoring.

Periods of high temperatures occurred from July through September with measurable effects on the fish community as observed at Station 161 similar to pre-EPU results. The measurable loss in benthic community diversity was most evident during September at Stations 214 and 215 due to higher temperatures and lower flows during this month. The stations with measurable impacts are the same areas of the Pond where similar observations were made during pre-EPU

monitoring. These impacts are along the west shore at stations within approximately 0.6 mile of the PBAPS discharge canal.

Both the fish and benthic macroinvertebrate community composition and relative abundance were similar to pre-EPU monitoring. Indices used to describe the community structure of the biological community indicated that thermally influenced and non-thermally influenced stations were similar during pre-EPU and post-EPU monitoring. Overall, a balanced indigenous community exists in Conowingo Pond with the EPU.

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11 Appendices

11.1 PBAPS Post-EPU Study Plan

11.2 Chronology of Gizzard Shad Population Expansion

APPENDIX 11.1

STUDY PLAN

STUDY PLAN FOR POST-EPU THERMAL AND BIOLOGICAL MONITORING

PEACH BOTTOM ATOMIC POWER STATION

Prepared for:

Exelon Generation

Prepared by: Normandeau Associates, Inc. and ERM, Inc.

Revision 3, April 2016

Introduction

This study plan outlines the details for performing biological and thermal monitoring following Extended Power Uprates (EPU) for Peach Bottom Atomic Power Station (PBAPS) Unit Nos. 2 and 3. This biological and thermal study supports the monitoring requirements of fish and macroinvertebrate communities set forth in Part C of PBAPS's NPDES Permit No. PA0009733. Section 1 of this study plan addresses the biological and thermal monitoring discussed above. Section 2 of this study plan addresses a review of potential impacts to American Shad migration as a result of the EPUs for PBAPS Unit Nos. 2 and 3. This review of American Shad migration is being performed based on PADEP's disposition of NPDES permit comments during the review period of the draft NPDES Permit. Section 3 of this study plan addresses USFWS comments related to distribution of Gizzard Shad in Conowingo Pond relative to PBAPS's thermal plume.

Section 1

Thermal Plume Monitoring

Objective: Monitor water temperatures in Conowingo Pond to compare to 2010-2013 NPDES thermal study results regarding the characteristics of the plume after implementation of the EPU.

Monitoring Period: May 1 through September 30, 2016.

Monitoring Locations: Thermal monitoring locations will include: cooling water intake outer screen structure; head of discharge canal; end of discharge canal; and at Transects 200, 300 and 400 in Conowingo Pond, specifically stations 201, 203, 205, 301 303, 401 and 403 (Figure 1). At the Transect stations, the temperature monitors will be installed at the surface (at approximately 1 foot depth) and at approximately 10 feet depth below surface, and bottom at each station. At the other referenced monitoring locations a single monitor will be installed at approximately mid-depth to characterize water temperature. In addition, temperature monitors will be installed at the biological collection locations, specifically stations 221, 208, 214, 215, 189, 190, 216, and 217 (Figure 2). At the biological stations, a single temperature monitor will be installed on the bottom. Table 1 provides a summary of the proposed temperature monitoring locations and monitor depths.

Table 1. Water temperature monitor location and monitor depth.

Monitor Location	Monitor Depth			
	Water Surface	10ft Below Surface	Mid-Depth	Bottom
Intake Screen			X	
Head of Canal			X	
End of Canal			X	
201, 203, 205, 301, 303, 401, 403	X	X		X
221, 208, 214, 215, 189, 190, 216, 217				X

Monitoring Method: Water temperatures will be recorded hourly using temperature data loggers that are accurate to approximately 0.36 °F in the range of 32 to 122 °F.

Deliverables: A spreadsheet providing raw water temperature data will be created along with a list of collected daily average, minimum and maximum temperatures. Temperature reporting will include tables or figures that provide the duration and frequency of high temperatures. Temperature changes due to cooling tower operations will be recorded and evaluated. A comparison of daily average, minimum, and maximum temperatures during the transition period (i.e., turning on a cooling tower) to values obtained from the thermal model will be prepared. The comparison will consider that the forcing conditions (meteorology, river flows and plant operations) during 2016 will be different than the ones used in the thermal model. Analysis to compare the post-EPU temperatures with the predictive model will be completed to verify the model.

This monitoring plan includes a sufficient number of monitoring stations and frequency of data collection such that the temporary loss of data from one or more thermistors will not interfere with the proposed analysis. Furthermore, because data will be recovered approximately monthly, gaps due to malfunctioning or displaced thermistors will not exceed one month. Any loss of data will be noted in the report.

Dissolved Oxygen Monitoring

Objective: Monitor dissolved oxygen in Conowingo Pond in shallow shoreline areas along west shoreline downstream of the PBAPS discharge canal. In particular,

monitoring will focus on periods of low-flow and high water temperature which could result in low dissolved oxygen concentrations.

Monitoring Period: June 1 through September 30, 2016.

Monitoring Locations: Dissolved oxygen monitoring will be completed at biological stations 208, 215 and 189. A single monitoring device will be installed toward the bottom of the water column at each location. Monitors will be installed in water with depth less than 10 ft.

Monitoring Method: Dissolved oxygen concentrations will be recorded hourly using a Hydrolab water quality multiprobe or equivalent data logger.

Deliverables: A spreadsheet providing raw dissolved oxygen data will be created along with a list of collected daily average, minimum, and maximum dissolved oxygen concentrations.

Biological Monitoring

Objective: Monitor biological community in Conowingo Pond to determine characteristics of the fish and benthic macroinvertebrate communities after implementation of the EPU. Collection locations for fish and benthic macroinvertebrates are provided in Figure 3.

Monitoring Period: May 1 through September 30, 2016

Sampling Procedure: Fish sampling will generally employ the same field sampling protocols that were used during the 2010 through 2013 studies (Normandeau and ERM 2014). Collected fish will be identified to species (or genus for those too small to identify to species in the field), counted, measured, and examined for disease, external parasites, lesions, tumors (DELTs) and anomalies. Fish DELTs and anomalies will be recorded using the acronyms provided in PADEP Field Data Sheet for Tissue Sampling (Attachment 1). Live fish will be released back to the Pond except for those retained to confirm identifications or retained as voucher or reference specimens. Large numbers of collected fishes will be subsampled (maximum of 50 specimens per species) for individual length measurement.

Seine

A seine measuring 10 ft by 4 ft with ¼-inch mesh will be used once monthly at each station. Most sites able to be sampled effectively with this gear are small beaches less than 100 ft long. To standardize results for each site, five hauls will be conducted at each sampling station. This sampling with fine mesh seines is intended to capture the young of many species and those fishes having a relatively small size as adults that frequent shallow, shore zone habitat.

Data recorded at each station for each collection will include weather, date, time, Secchi disc transparency, air and surface water temperatures, dissolved oxygen, and estimated water depth.

Electrofishing

Fish will be collected at night using boat electrofishing equipment employing pulsed direct current to minimize fish injury. The boat-mounted shocker will be maneuvered slowly through the stations as close to shore as practicable. Each sample will consist of approximately 30 minutes of shocking. Stunned fish will be netted and placed in an on-board live well for subsequent processing except for large specimens (e.g., common carp and quillback) which will not be brought on-board, but will be counted and recorded. Boat electrofishing will collect larger fish that frequent the shallow, shore zone habitats that are not effectively sampled with seines.

Data recorded at each station for each collection will include weather, date, time, air and surface water temperatures, dissolved oxygen, specific conductance, and estimated water depth.

Benthic Macroinvertebrates

Collections will occur within littoral benthic habitats and samples processed following the PADEP Multi-habitat Stream Assessment Protocol (PADEP 2008). A habitat assessment will be completed during each benthic macroinvertebrate collection following PADEP habitat assessment protocol (PADEP 2013).

Monitoring Locations:

Electrofishing:

Upstream of thermal plume: 187 and 165
Downstream of thermal plume: 161, 189, 190, and 217

Seining:

Upstream of thermal plume: 220, 221, and 208
Downstream of thermal plume: 214 and 215

Benthic Macroinvertebrates:

Upstream of thermal plume: 208, 220, and 221
Downstream of thermal plume: 189, 214, 215, and 216

Figure 3 provides a spatial representation of the monitoring locations.

Monitoring Interval: Perform monthly fish and benthic macroinvertebrate collections at each station.

References

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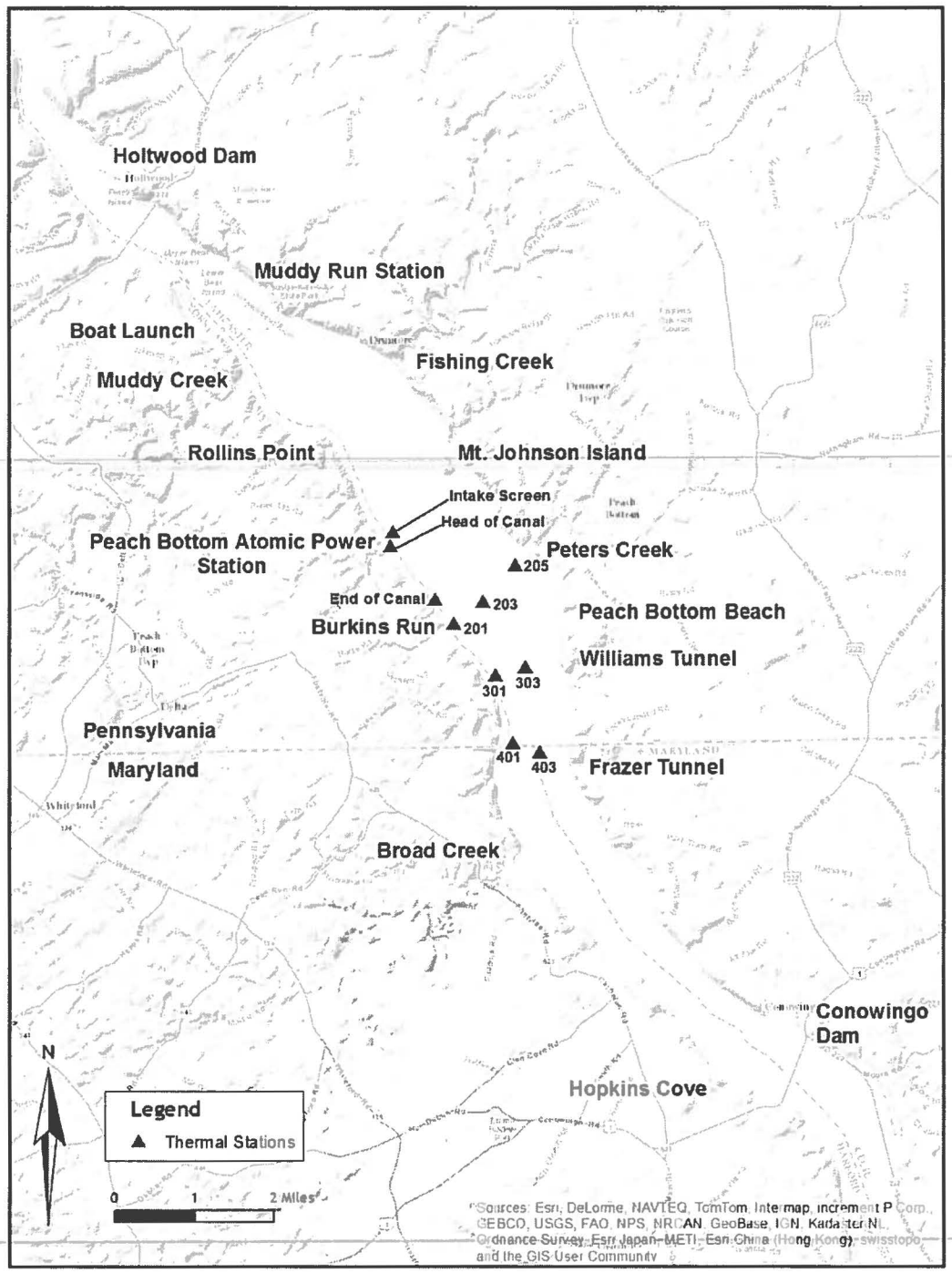


Figure 1. Proposed temperature monitoring transects and locations in Conowingo Pond.

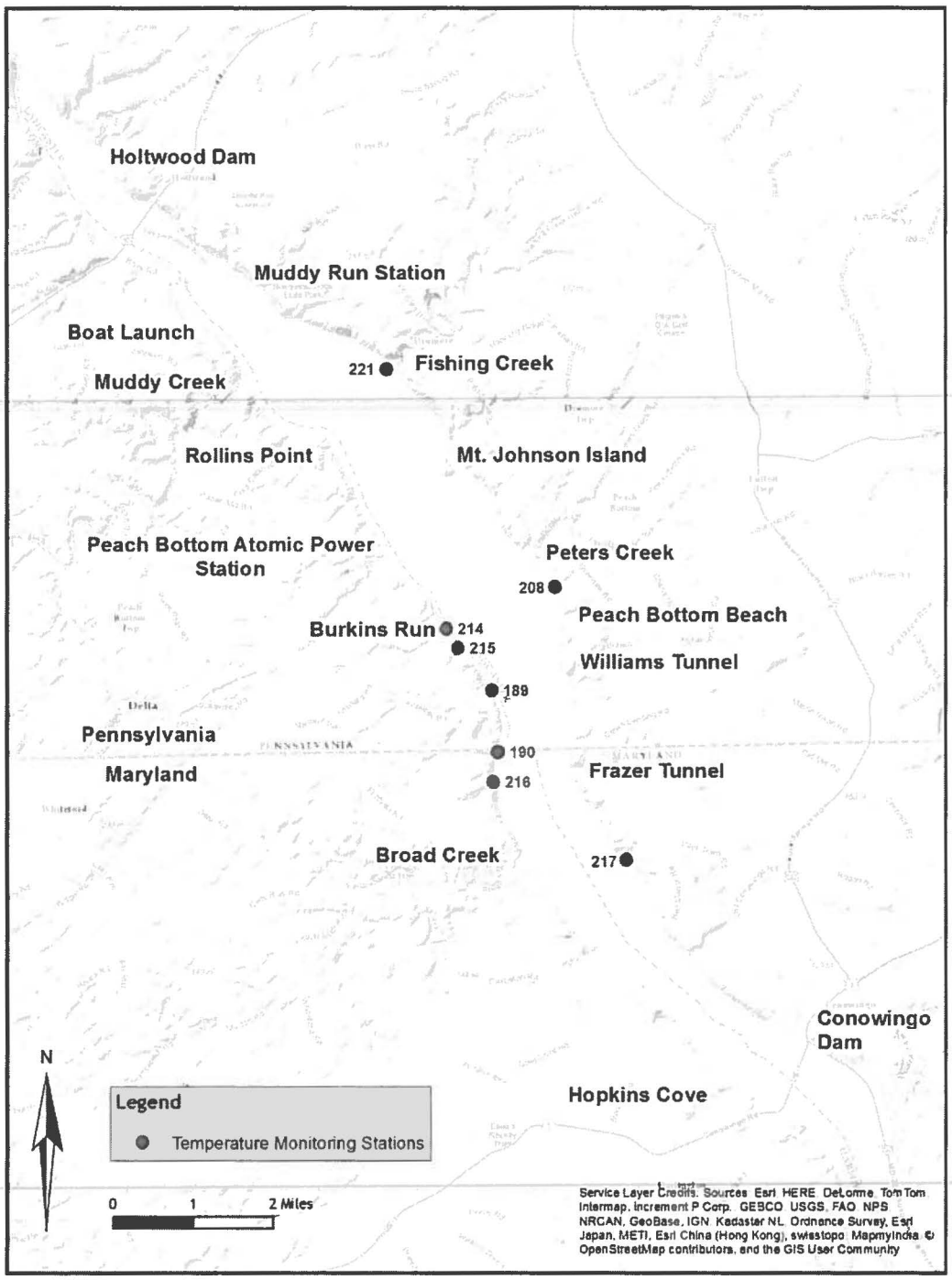


Figure 2. Proposed temperature monitoring locations that coincide with biological collection locations in Conowingo Pond.

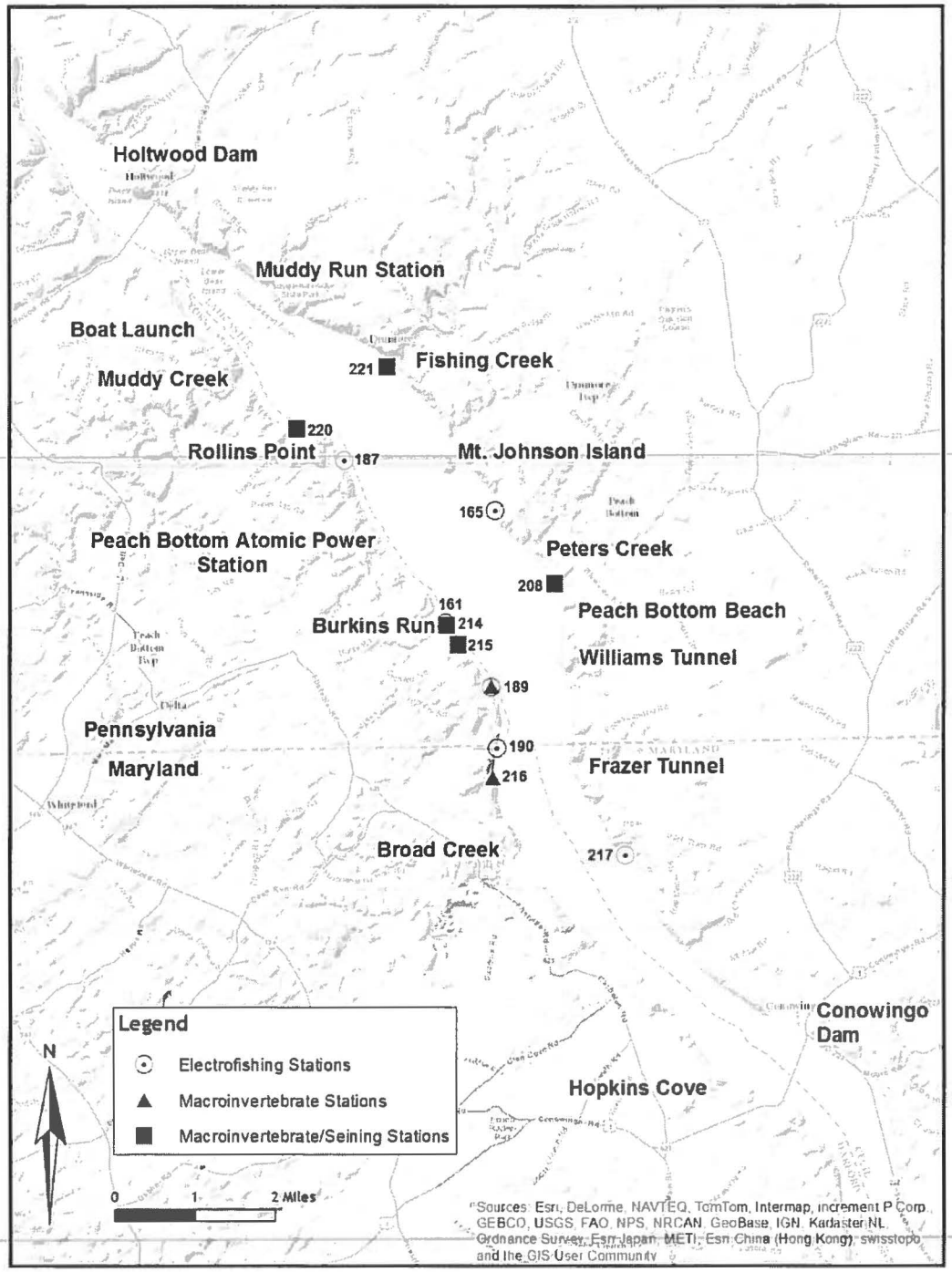


Figure 3. Proposed biological collection locations in Conowingo Pond.

Section 2

American Shad Study

Objective: To address draft NPDES permit comments related to the potential effect of the PBAPS thermal discharge on American Shad during post-EPU conditions on Unit Nos. 2 and 3.

Exelon Deliverable: A desktop study that will use existing information and current scientific understanding of American Shad in Conowingo Pond to address the draft NPDES permit comments. This will be accomplished through use of the existing hydrothermal model and existing model outputs that characterize the thermal plume for several low-flow and high water temperature scenarios. The existing model output for these scenarios will then be evaluated to determine the potential for PBAPS's thermal plume to block migration of American Shad in the Conowingo Pond.

Section 3

Gizzard Shad Seasonal Distribution

Objective: To address USFWS April 2016 comments related to seasonal distribution of Gizzard Shad in Conowingo Pond relative to the PBAPS thermal plume.

Exelon Deliverable: Provide a compilation of information related to Gizzard Shad seasonal distribution in Conowingo Pond relative to the PBAPS thermal plume. This information will be obtained from existing reports, primarily the Final Report for the Thermal Study to Support a 316 (a) Demonstration at Peach Bottom Atomic Power Station, March 2013.

Deliverables: After completion of monitoring a report will be submitted to PADEP. This report will include all three sections of the Study Plan. Section 1 will include data tables, analysis of the data, and comparison with pre-EPU biological and thermal monitoring data. The report will be submitted to PADEP for review by February 3, 2017. This monitoring plan includes a sufficient number of monitoring stations and frequency of data collection such that a minor interruption of data collection due to weather or other impacts will not interfere with proposed analysis.

Raw data files for biological monitoring will be submitted to PADEP in a database format such that for each observation a single independent row of biological data is provided and non-biological data is linked to the biological data through a common identifier.

ATTACHMENT 1

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF WATER STANDARDS AND FACILITY REGULATION

GENERAL INSTRUCTIONS FOR FIELD DATA SHEET TISSUE SAMPLING

STATION NUMBER: Enter WQN Station Number, WQF Station Number or Survey Station Number as appropriate. Leave blank if none of these apply.

NOTE: If WQN Number is entered, then Waterbody Name, Location, County and Municipality can be left blank.

DATE, COLLECTOR, AGENCY and COLLECTOR NUMBER: Must be completed.

NEW STATIONS: If a WQF station number has not previously been assigned, Quad. Name, Quad. Number, either Lat/Long or inches-N/inches-W and RMI (to nearest 0.1 mile) must be entered (for STORET input).

TISSUE TYPE: Standard samples are:

1. Skin-on, scaled fillets for gamefish, panfish and rough fish.
2. Skinless fillets for catfish and bullheads.

SAMPLE: A normal sample is a composite of 10 fillets from 5 fish. For large fish, 5 fillets can be used.

75 PERCENT RULE: The individual fish in each composite should be as close to the same size as possible. A general guideline is that the length of the smallest individual in the composite should be no less than 75 percent of the length of the largest individual.

Fish Health:					
Black grub	**Bg**	Trematode	**Tr**	Frayed fins	**Ff**
Deformities	**De**	Tumor	**Tu**	Eroded fins	**Ef**
Eroded skin	**Es**	White cysts	**Wc**	Eroded gills	**Eg**
Fungal infection	**Fi**	Emaciated	**Em**	Frayed gills	**Fg**
Leeches	**Le**	Cloudy eye	**Ce**	Clubbed gills	**Cg**
Melanistic area	**Ma**	Exophthalmic eye	**Ee**	Spotted Gills	**Sg**
Open sore	**Os**	Hemorrhagic eye	**He**	Cyst on gills	**Cg**
Raised red sore	**Rr**	Missing eye	**Me**		
Life History:					
Gravid	**G**	Post spawn	**Ps**	Milting male	**Mm**

ATTACHMENT 1

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF WATER STANDARDS AND FACILITY REGULATION

FIELD DATA SHEET TISSUE SAMPLING

Station # _____ Waterbody _____ Date & Time _____

Location _____

_____

County _____ Municipality _____

Collector _____ Agency _____ Coll.# _____

COMPLETE FOR NEW STATIONS

Quad. Name _____ Quad.# _____

Lat. (inches N) _____ Long. (inches W) _____ RMI _____

Method:
- ☐ Electrofishing
- ☐ Rotenone
- ☐ Seine
- ☐ Angling
- ☐ Gill Net
- ☐ Other (specify)

Tissue Type:
- ☐ Whole Fish
- ☐ Skin-on Fillet – Scaled
- ☐ Skinless Fillet
- ☐ Skin-on Fillet – Not Scaled
- ☐ Other (specify):

SPECIES	TL (inches)	WT (lbs. oz.)	Fish Health & Life History*
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

*Use Fish Health & Life History Codes (if needed)

Comments: (water/weather conditions, man-hours expended, problems, etc.)

_____

_____

_____

_____

_____

APPENDIX 11.2

CHRONOLOGY OF GIZZARD SHAD POPULATION EXPANSION

Chronology of Gizzard Shad Population Expansion

Gizzard shad, native to eastern North America, was inadvertently introduced (100+ specimens) into Conowingo Creek, a tributary to Conowingo Pond, in May 1972 during an American Shad transport from the Conowingo Dam West Fish Lift. The introduction of Gizzard Shad and its subsequent population explosion in Conowingo Pond occurred prior to the operation of Peach Bottom Atomic Power Station (PBAPS) Unit 2 in July 1974 and Unit 3 in December 1974. At present, Gizzard Shad has successfully colonized new habitats in the Susquehanna River (upstream of York Haven Dam) with or without a thermal plume.

The spawning success of Gizzard Shad in 1972 was demonstrated by capture of its larvae the same year (Figure 1). Prior to 1972, no larval Gizzard Shad were collected but beginning in 1972 catch of larval Gizzard Shad became routine with high densities thereafter. Although the Tropical Storm Agnes in June 1972 had a catastrophic effect on most of the fish community of Conowingo Pond, Gizzard Shad appeared to be quite resilient with continued expansion.

Trawl samples (Figure 2) in Conowingo Pond demonstrated a similar pattern indicating that the Gizzard Shad population was successfully established in the Pond in a relatively short time and became self-sustaining.

Although the Muddy Run Reservoir is not affected by thermal discharge Gizzard Shad successfully colonized this additional habitat since 1972. Block net samples in the Muddy Run Reservoir coves (Figure 3) show Gizzard Shad population continued to grow since 1972. Subsequently, a population developed rapidly and spread to the nearby Muddy Run Recreation Lake (unaffected by thermal discharge). This population experiences same extreme winter temperatures as the population in Conowingo Pond. A large number of young Gizzard Shad is observed emigrating from Muddy Run Reservoir in the fall which may contribute to the Conowingo Pond population.

Gizzard Shad population in Conowingo Pond as noted elsewhere seems resilient despite severe winters, extreme hydrological/meteorological events (e.g., hurricanes, storms, etc.) with only a small start-up (100+ fish) population needed for its explosive population growth.

Installation of fishways, first at Conowingo (1972, and 1991; Figure 4 and 5) then later at Holtwood and Safe Harbor in 1997, and at York Haven in 2000; Figure 6) at all the dams on the Susquehanna River in combination with its presence over 200 miles of the Susquehanna River (unaffected by thermal discharges) including the Muddy Run Reservoir assures a consistent supply of Gizzard Shad spawning stock for upstream and downstream dispersal (Figures 4-6); the system is basically open. Presently, fishes can and do volitionally move upstream to areas above York Haven Hydroelectric Dam (RM 56).

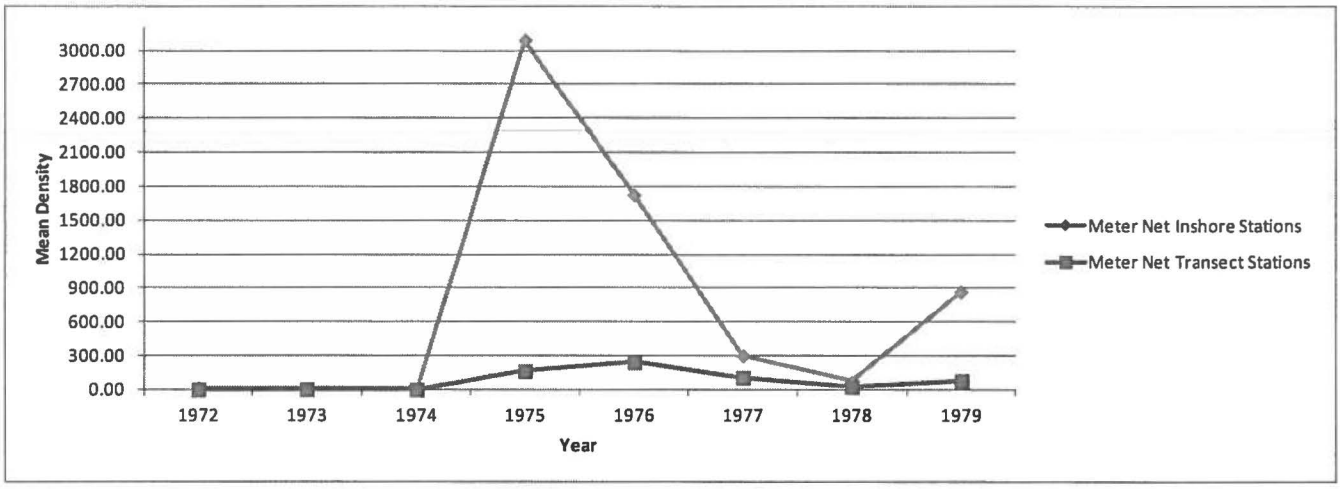


Figure 1. Reproductive success of Gizzard Shad indexed by catch of larval gizzard shad (number of larvae ≤ 25 mm per 1000 m^3) at inshore stations (creeks and coves) and in the main Conowingo Pond (Transect stations), 1972-1979. Densities of larval Gizzard Shad in 1972-1974 at inshore stations < 13.5 per 1000 m^3 could not be shown on the same vertical scale. Data source: RMC-Ecological Division (1979).

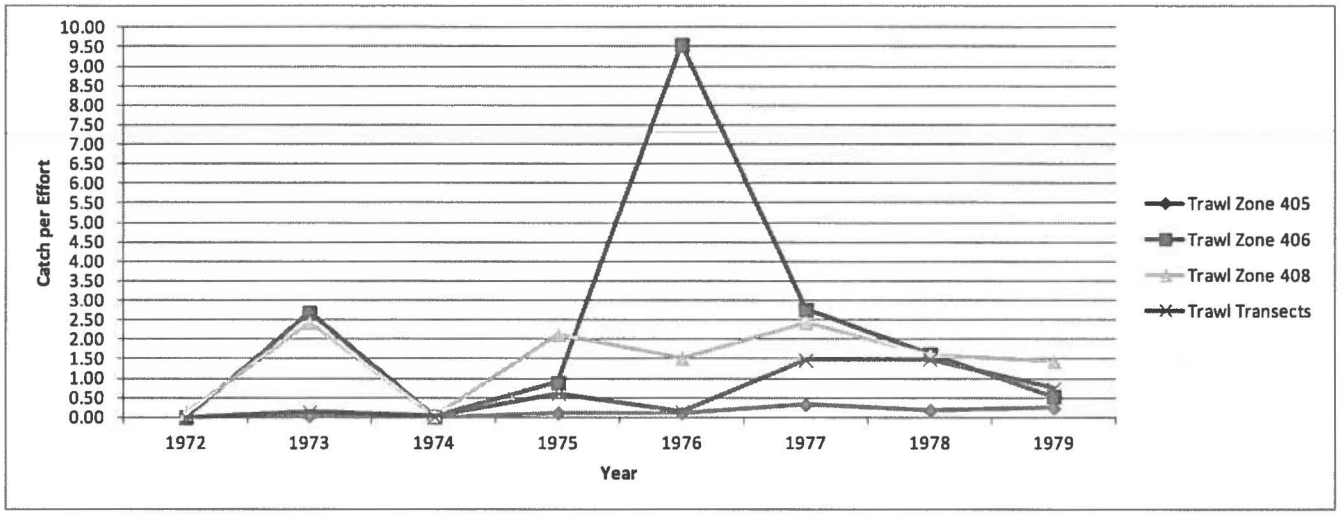
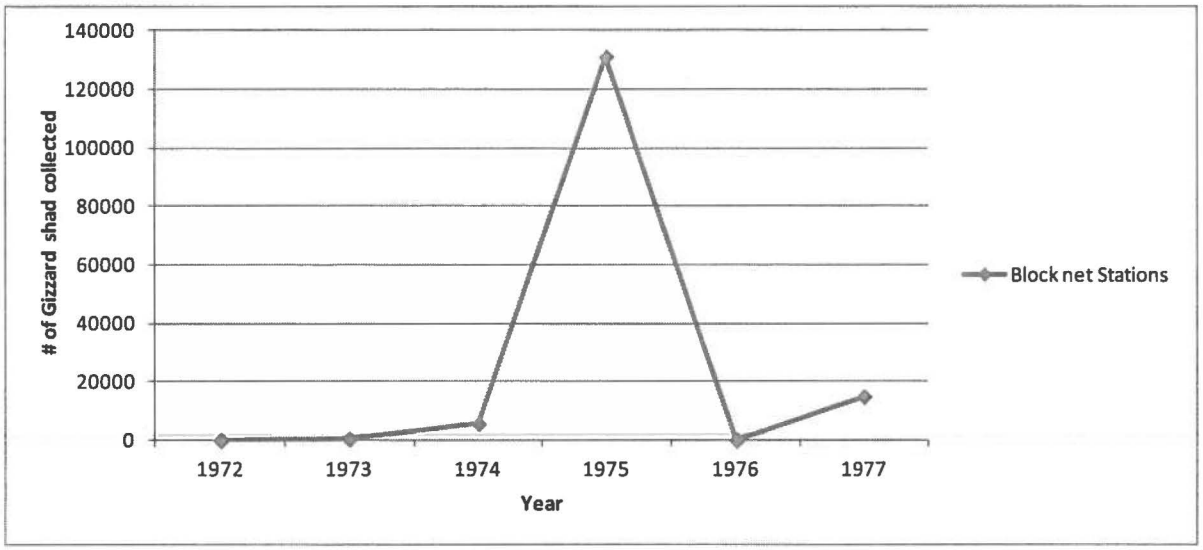


Figure 2. **Catch per effort (number per 10 min trawl haul) of Gizzard Shad in Conowingo Pond, 1972-1979.**

A



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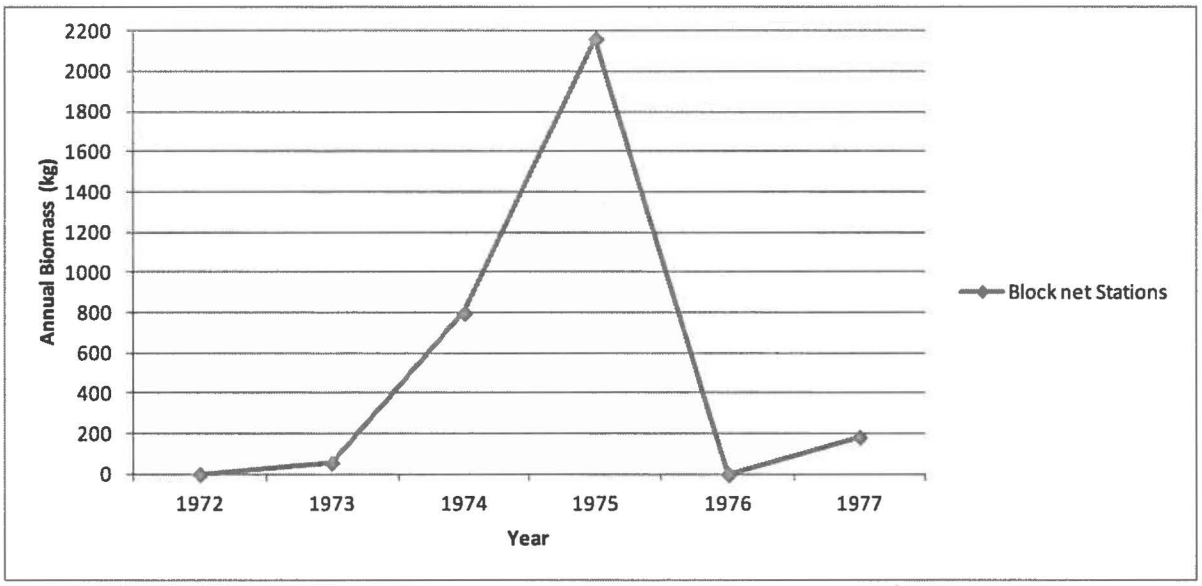

Figure 3. **Number (A) and biomass (kg per ha, B) of Gizzard Shad collected by block net in the Muddy Run Reservoir, 1972-1978. Source: RMC-Ecological Division (1979).**

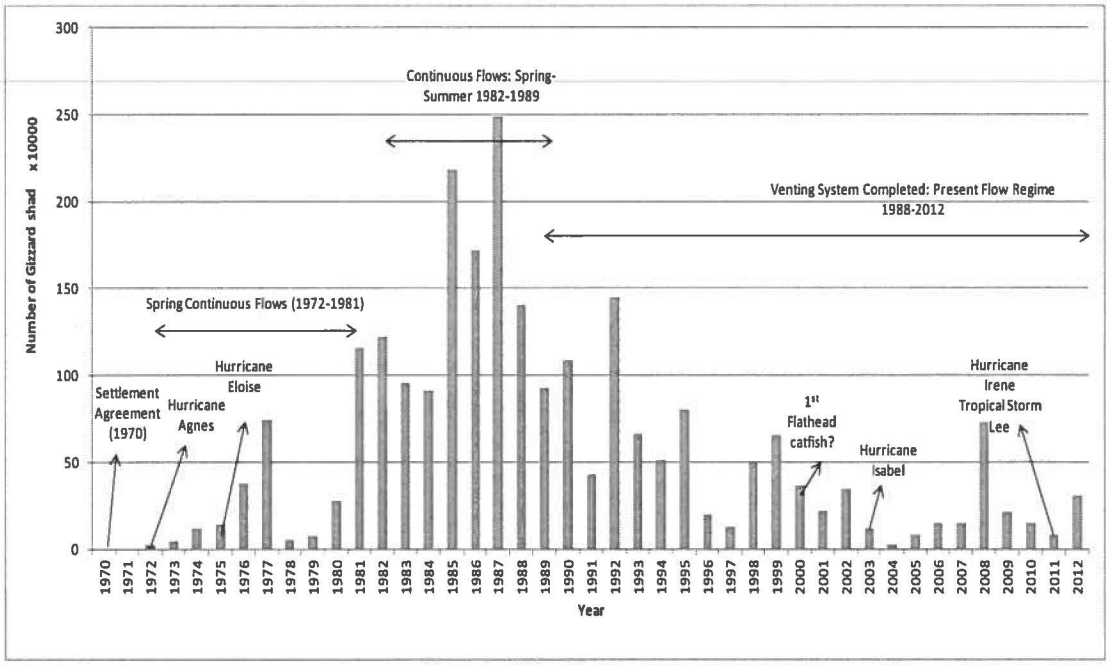

Figure 4. Passage counts of Gizzard Shad at the Conowingo West Fish Lift (1972-2012).

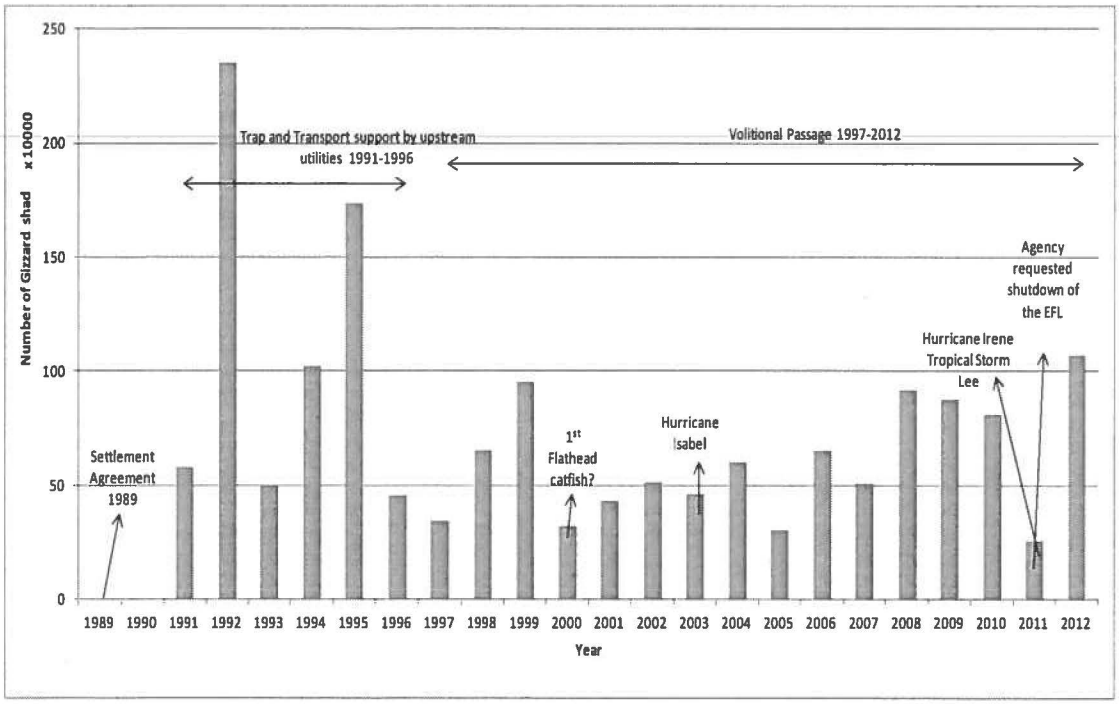

Figure 5. Passage counts of Gizzard Shad at the Conowingo East Fish Lift (1991-2012).

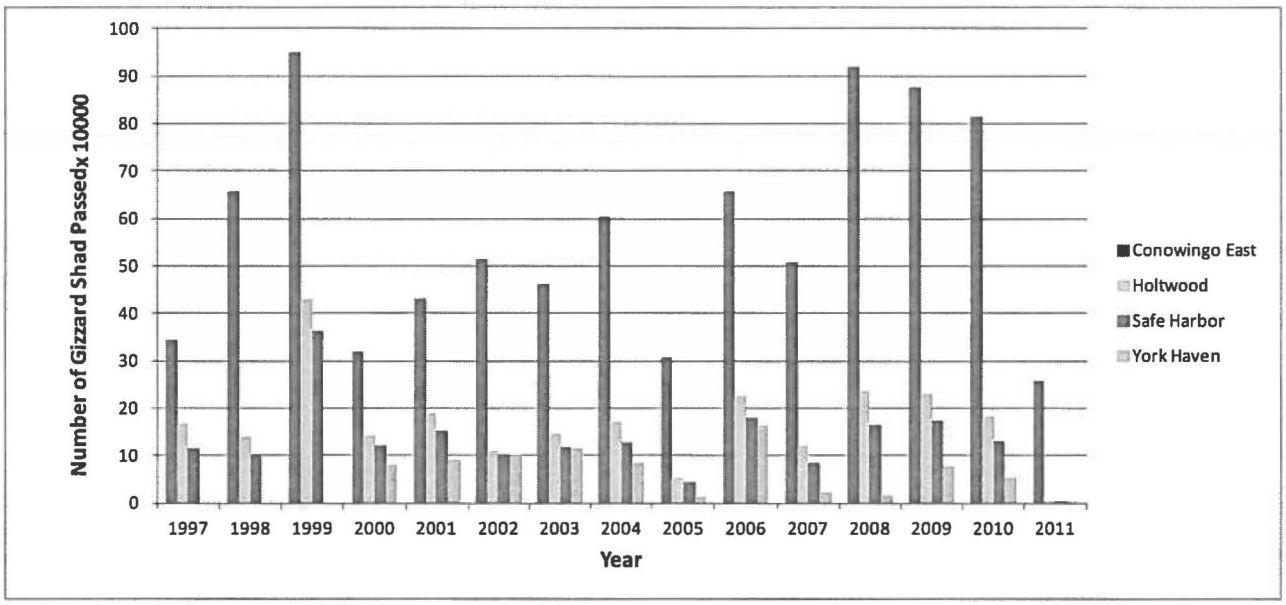

Figure 6. **Passage counts of Gizzard Shad at the four fishways showing rapid colonization of upstream areas, 1997-2011. Voluntary passage at Conowingo EFL, Holtwood and Safe Harbor commenced in 1997; and York Haven in 2000.**

The following sources/reports were reviewed to prepare the response and conclusions that a "thermal refuge" is not necessary for propagation and sustenance of Gizzard Shad and the population is thriving in areas unaffected by thermal discharges.

- Pre-operational report (1966-1973) and the initial 316(a) report (1977) describing the baseline water quality, benthic and zooplankton, fish composition, ecology, distribution, and abundance of fishes in the Pond and surrounding waters. The 316(a) report and a supplement compared the pre-operational and post-operational data on the studied parameters and provided thermal tolerances (temperature preference, avoidance, heat and cold shock) of approximately 27 species.
- Semi-annual post-operational reports (prepared as part of PBAPS as part of U.S. Nuclear Regulatory Commission Technical Specifications requirements relative to the operation of the station. These reports compared changes, if any, in the above mentioned parameters.
- Annual reports prepared relative to the operation of the Three Mile Island Nuclear Station (approximately 49 miles upstream of PBAPS) during forced shutdown, and subsequent start-up. These reports show presence of Gizzard Shad in the 1990s before the fishways were installed at Holtwood, Safe Harbor dams (1997) or York Haven Dam (2000).
- Sampling in Conowingo Pond relative to operation of Peach Bottom Atomic Power Station: (1) meter net samples (1969-1977) to signify spawning success, time, temperature, and areas, and (2) trawling (1967-1980, 1996-1999), seining, trap netting, electroshocking to indicate survival and successful establishment of Gizzard Shad population in the Pond and exposures to a wide array of environmental changes, and (3) responses to natural catastrophic events such as Tropical Storm Agnes in 1972 and Hurricane Eloise in 1975.
- Sampling in Muddy Run Pumped Storage Reservoir (1970-1977) as part of licensing of the Muddy Run Pumped Storage Station: block net sampling and meter net sampling (1970-1977) to demonstrate successful establishment of Gizzard Shad population in 1972 and the potential for recruitment to Conowingo Pond, particularly during voluntary fall emigration;
- Annual Conowingo West Lift Fish (1972-present) and East Fish Lift (1991-present) operation reports. These reports provide (1) fish passage counts, (2) temporal changes in relative abundance and expansion of Gizzard Shad population before (1972-1996) and after (1997-present) voluntary passage at the EFL along with events deemed notable since 1972, (3) annual recruitment of Gizzard Shad into Conowingo Pond, and (3) potential factors contributing to the species expansion;
- Holtwood, Safe Harbor Fish Lift Counts (1997-present), and York Haven Fish Ladder (2000-present) provide an estimate of the number of Gizzard Shad that may continue upstream migration into non-thermally affected areas with potential for downstream recruitment; and range expansion.

ENCLOSURE 13

13_PADEP_2011_NONEXELON.pdf

[PADEP] Pennsylvania Department of Environmental Protection. 2011. "Letter to Peach Bottom Atomic Power Station (J. Brozonis) regarding NPDES Permit PA0009733 Entrainment Characterization Study Work Plan." May 5, 2011.

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11-54

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION
WATER MANAGEMENT PROGRAM

NON-EXELON

MAY 5 2011

Mr. Joseph Brozonis
Sr. Environmental Chemist
Peach Bottom Atomic Power Station
1848 Lay Road
Delta, PA 17314

Re: Peach Bottom Atomic Power Station
NPDES Permit PA 0009733
Entrainment Characterization Study Work Plan

Dear Mr. Brozonis,

The Department of Environmental Protection (DEP) has reviewed the "Work Plan for an Entrainment Characterization Study" for the Peach Bottom Atomic Power Station dated February 25, 2011.

The work plan is consistent with the NPDES permit requirements relating to the entrainment characterization study in Part C. Therefore, DEP has no additional comments and the work plan is approved. As stated in the work plan, the sampling is scheduled to commence during the week of March 4, 2012.

Please contact Heidi Biggs at hbiggs@state.pa.us or 717-772-5656 if you have any questions or comments.

Sincerely,

Lee A. McDonnell, P.E.
Program Manager
Water Management Program

cc: Scott Sklenar - Exelon Nuclear
Paul Harmon - Normandeau Associates, Inc.

ENCLOSURE 14

14_PADEP_2014b_NONEXELON.pdf

[PADEP] Pennsylvania Department of Environmental Protection. 2014b. "Letter to Exelon Generation Company, LLC (P. Navin) regarding "401 Water Quality Certification Peach Bottom Atomic Power Station Extended Power Uprate," DEP File No. EA 67-024, NRC Docket No. NRC-2013-0232, York and Lancaster County. July 23, 2014.

CCN 14-54

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION
WATERWAYS & WETLANDS PROGRAM

July 23, 2014

NON-EXELON

Mr. Patrick D. Navin
Exelon Generation Company, LLC
Peach Bottom Atomic Power Station
1848 Lay Road
Delta, PA 17314-9032

RE: 401 Water Quality Certification
Peach Bottom Atomic Power Station-Extended Power Uprate
DEP File No. EA 67-024
NRC Docket No. NRC-2013-0232
York and Lancaster County

Dear Mr. Navin:

This is in reference to your request for Water Quality Certification under Section 401 of the Federal Clean Water Act, submitted to our office on November 21, 2013. The request relates to the Exelon Generation Co., LLC-Peach Bottom Atomic Power Station-Extended Power Uprate (PBAPS) project that will take place at the Peach Bottom Atomic Power Station in York County, in the Commonwealth of Pennsylvania.

The Department of Environmental Protection (DEP) has reviewed your request for 401 Water Quality Certification and hereby grants the 401 Water Quality Certification for the Peach Bottom Atomic Power Station-Extended Power Uprate project. The approved certification is attached.

Any person aggrieved by this action may appeal, pursuant to Section 4 of the Environmental Hearing Board Act, 35 P.S. Section 7514, and the Administrative Agency Law, 2 Pa. C.S. Chapter 5A, to the Environmental Hearing Board, Second Floor, Rachel Carson State Office Building, 400 Market Street, PO Box 8457, Harrisburg, PA 17105-8457, 717.787.3483. TDD users may contact the Board through the Pennsylvania Relay Service, 800.654.5984. Appeals must be filed with the Environmental Hearing Board within 30 days of receipt of written notice of this action unless the appropriate statute provides a different time period. Copies of the appeal form and the Board's rules of practice and procedure may be obtained from the Board. The appeal form and the Board's rules of practice and procedure are also available in braille or on audiotape from the Secretary to the Board at 717.787.3483. This paragraph does not, in and of itself, create any right of appeal beyond that permitted by applicable statutes and decisional law.

IF YOU WANT TO CHALLENGE THIS ACTION, YOUR APPEAL MUST REACH THE BOARD WITHIN 30 DAYS. YOU DO NOT NEED A LAWYER TO FILE AN APPEAL WITH THE BOARD.

IMPORTANT LEGAL RIGHTS ARE AT STAKE, HOWEVER, SO YOU SHOULD SHOW THIS DOCUMENT TO A LAWYER AT ONCE. IF YOU CANNOT AFFORD A LAWYER, YOU MAY QUALIFY FOR FREE PRO BONO REPRESENTATION. CALL THE SECRETARY TO THE BOARD (717.787.3483) FOR MORE INFORMATION.

If you have any questions, please contact me at 717.705.4799, or by email at scwilliams@pa.gov.

Sincerely,

Scott R. Williamson
Program Manager
Waterways & Wetlands Program

Enclosure

cc: Ms. Cindy Bladey, Chief, Rules, Announcements, and Directives Branch, U.S. Nuclear Regulatory Commission
Ms. Maria Bebenek, DEP South-central Region Clean Water Program Manager
Mr. Rich Janati, DEP Radiation Protection
Mr. Andrew Shiels, Deputy Director for Field Operations, PA Fish and Boat Commission
Mr. Andrew Dehoff, Executive Director, Susquehanna River Basin Commission
Ms. Patricia Strong, US Army Corps of Engineers, Baltimore District
Mr. Rick Ennis, Project Manager, U.S. Nuclear Regulatory Commission (by email)
Lancaster County Conservation District
York County Conservation District

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION
WATERWAYS & WETLANDS PROGRAM

July 23, 2014

Ms. Cindy Bladey, Chief, Rules, Announcements, and Directives Branch (RADB)
Office of Administration
Mail Stop: 3WFN, 06-44M
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Re: 401 Water Quality Certification
Exelon Generation Co.-Peach Bottom Atomic Power Station
DEP File No. EA 67-024
NRC Docket No. NRC-2013-0232

Dear Ms. Bladey:

Enclosed is the NRC Docket No. NRC-2013-0232, Section 401 Water Quality Certification for the Exelon Generation Co.- Peach Bottom Atomic Power Station-Extended Power Uprate project.

Any person aggrieved by this action may appeal, pursuant to Section 4 of the Environmental Hearing Board Act, 35 P.S. Section 7514, and the Administrative Agency Law, 2 Pa. C.S. Chapter 5A, to the Environmental Hearing Board, Second Floor, Rachel Carson State Office Building, 400 Market Street, PO Box 8457, Harrisburg, PA 17105-8457, 717.787.3483. TDD users may contact the Board through the Pennsylvania Relay Service, 800.654.5984. Appeals must be filed with the Environmental Hearing Board within 30 days of receipt of written notice of this action unless the appropriate statute provides a different time period. Copies of the appeal form and the Board's rules of practice and procedure may be obtained from the Board. The appeal form and the Board's rules of practice and procedure are also available in braille or on audiotape from the Secretary to the Board at 717.787.3483. This paragraph does not, in and of itself, create any right of appeal beyond that permitted by applicable statutes and decisional law.

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If you have any questions, please contact me at 717.705.4799, or by email at scwilliams@pa.gov.

Sincerely,

Scott R. Williamson
Program Manager
Waterways & Wetlands Program

Enclosure

cc: Mr. Patrick D. Navin, Exelon Generation Co.
Ms. Maria Bebenek, DEP South-central Region Clean Water Program Manager
Mr. Rich Janati, DEP Radiation Protection
Mr. Andrew Shiels, Deputy Director for Field Operations, PA Fish and Boat Commission
Mr. Andrew Dehoff, Executive Director, Susquehanna River Basin Commission
Ms. Patricia Strong, US Army Corps of Engineers, Baltimore District
Mr. Rick Ennis, Project Manager, U.S. Nuclear Regulatory Commission (by email)

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION

WATER QUALITY CERTIFICATION
PEACH BOTTOM ATOMIC POWER STATION
EXTENDED POWER UPRATE PROJECT
AND RELATED MITIGATION

DEP File No. EA 67-024
NRC Docket ID- NRC-2013-0232

EXELON GENERATION COMPANY, LLC
Mr. Patrick D. Navin
Peach Bottom Atomic Power Station
1848 Lay Road
Delta, PA 17314-9032

York and Lancaster Counties
U.S. Army Corps Of Engineers, Baltimore District

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Water Quality Certification under Section 401 of the Federal Clean Water Act
for the Extended Power Uprate
for Exelon Generation Company, LLC - Peach Bottom Atomic Power Station
PA DEP File No. EA 67-024

Peach Bottom Atomic Power Station (PBAPS) is an existing nuclear-fueled boiling water reactor electric power generating facility located along the Susquehanna River in Peach Bottom Township, York County and Fulton and Drumore Townships, Lancaster County. PBAPS is owned by Exelon Generation Company, LLC (Exelon) (a wholly-owned subsidiary of Exelon Corporation) and PSEG Nuclear, LLC. The facility is operated by Exelon. Exelon has submitted a License Amendment Request (LAR) to the US Nuclear Regulatory Commission (NRC) for a proposed Extended Power Uprate (EPU) for units 2 and 3. The proposed EPU would allow the units to change from the currently licensed 3514 megawatts-thermal (MWt) to nominally 3951 MWt per unit.

Impacts to aquatic resources associated with continued operation of the facility and the EPU include water withdrawal from the Conowingo Pond of the Susquehanna River, consumptive use, and the thermal impacts of the heated water discharges back to the Conowingo Pond. Water will continue to be withdrawn at a maximum rate of 2,363.620 million gallons per day (MGD). Water intake will continue to have impingement and entrainment effects on the migratory and resident fish as well as other aquatic species. Consumptive water use at the facility is a maximum of 49.000 MGD. Discharge temperatures include a projected change in the temperature increase at a maximum from existing 22°F increase to a 25°F increase due to the EPU.

Exelon will mitigate the impacts of impingement and entrainment by providing one hundred thousand dollars ($100,000.00) per year for habitat/sediment improvement projects in Lancaster and York Counties. This will include stream improvement projects, agricultural pasture and barnyard best management practices, and small dam removal projects. Consumptive use impacts will be mitigated by adherence to the Susquehanna River Basin Commission (SRBC) consumptive use authorization. Thermal impacts will be mitigated by adherence to the National Pollution Discharge Elimination System (NPDES) permit. Such payments hereunder shall be made for the duration of the operation of PBAPS as an electric generation facility.

On July 23, 2014 the Commonwealth of Pennsylvania (Commonwealth) Department of Environmental Protection (Department, DEP or PADEP), issued Section 401 Water Quality Certification to Exelon for the PBAPS EPU project. The PADEP certifies that the construction, operation and maintenance of the EPU complies with the applicable provisions of sections 301—303, 306, 307 and 316 of the Federal Clean Water Act (33 U.S.C.A. §§ 1311—1313, 1316, 1317 and 1326) and appropriate requirements of state law. The Department further certifies that the construction, operation and maintenance of the EPU complies with Commonwealth applicable

water quality standards and that the construction, operation and maintenance of the EPU does not violate applicable Commonwealth water quality standards provided that the construction, operation and maintenance of the EPU complies with the conditions of this certification, including the criteria and conditions of the following conditions and permits:

1. Discharge Permit – PBAPS shall obtain and comply with a PADEP National Pollutant Discharge Elimination System (NPDES) permit for the discharge of pollutants pursuant to Pennsylvania's Clean Streams Law (35 P.S. §§ 691.1 – 691.1001) and all applicable implementing regulations (25 Pa. Code Chapter 92a).

2. Erosion and Sediment Control Permit - PBAPS shall obtain and comply with a PADEP's NPDES Permit for Stormwater Discharges Associated with Construction Activity pursuant to Pennsylvania's Clean Streams Law and Storm Water Management Act (32 P.S. §§ 680.1-680.17) and all applicable implementing regulations (25 Pa. Code Chapter 102) for any earth disturbance activities that require said permit.

3. Water Obstruction and Encroachment Permits - PBAPS shall obtain and comply with a PADEP Chapter 105 Water Obstruction and Encroachment Permit or Dam Permit for the construction, operation and maintenance of all dams, water obstructions or encroachments associated with the project pursuant to Pennsylvania's Clean Streams Law (35 P.S. §§ 691.1 – 691.1001), Dam Safety and Encroachments Act (32 P.S. §§ 673.1-693.27), and Flood Plain Management Act (32 P.S. §§ 679.101-679.601.) and all applicable implementing regulations (25 Pa. Code Chapter 105).

4. Susquehanna River Basis Commission – PBAPS shall implement the Consumptive Water Use Mitigation Plan as approved and conditioned by the Susquehanna River Basin Commission including any future amendments to that plan.

5. Habitat Improvement Projects –

    a. Commencing on the first March 1 after completion of the EPU of Unit 2, and by March 1 of each year thereafter, PBAPS shall provide a total ONE HUNDRED THOUSAND DOLLARS ($100,000.00) annually in compensatory mitigation to the Pennsylvania Fish and Boat Commission (PFBC), or to such other conservation district, resource agency or 501(c)(3) organization as directed by the PADEP, for the implementation of habitat/sediment improvement projects. This will include stream improvement projects, agricultural pasture and barnyard best management practices, and small dam removal projects.
    b. This annual compensatory mitigation shall be by corporate check, or the like, made payable to the PFBC in the amount of ONE HUNDRED THOUSAND DOLLARS ($100,000.00) for habitat/sediment

improvement projects in Lancaster or York Counties or to such other entities as the PADEP shall direct. PBAPS and PADEP shall receive from PFBC an annual accounting of projects implemented and fund expenditures. The funds shall be deposited by the PFBC into a special non-lapsing interest bearing account established and to be used only for the HIP Projects required by this Water Quality Certification ("PBAPS HIP Funds"). Such payments shall be made for the duration of the operation of PBAPS as an electric generation facility, unless otherwise modified and approved in writing by PADEP in accordance with paragraph 5.d., below.

c. PADEP shall ensure that each project proposed by the PFBC shall be submitted to the DEP South-central Regional Office Waterways and Wetlands Program Manager, or the successor position, for approval. No single project shall receive more than $75,000.00 in compensatory mitigation funding from the PBAPS HIP Fund. Funding priority shall be given for projects that include stream forested buffers of at least 50 feet in width and wetland creation projects. Project funding shall not include any indirect administrative costs and, except where specifically authorized by the DEP, shall not include direct administrative costs. In no case shall direct administrative costs be greater than 10% of the project funding. At PBAPS's option, and subject to land owner approval, for each project signage shall be displayed acknowledging PBAPS's funding of the habitat improvement.

d. Exelon may request that the PADEP revise the compensatory mitigation in response to actions or activities by Exelon that reduce the degree of impingement and/or entrainment at the PBAPS.

6. Water Quality Monitoring - PADEP retains the right to specify additional studies or monitoring to ensure that the receiving water quality is not adversely impacted by any operational and construction process that may be employed by PBAPS

7. Operation – For the EPU under this certification, PBAPS shall at all times properly operate and maintain the PBAPS facilities and systems of treatment and control (and related appurtenances) which are installed to achieve compliance with the terms and conditions of this Certification and all required permits. Proper operation and maintenance includes adequate laboratory controls, appropriate quality assurance procedures, and the operation of backup or auxiliary facilities or similar systems installed by PBAPS.

8. Inspection - The PBAPS, including all relevant records, are subject to inspection at reasonable hours and intervals by an authorized representative of PADEP to determine compliance with this Certification, including all required permits, appropriate requirements of state law and Pennsylvania's Water Quality Standards. A copy of this Certification shall be available for inspection by the PADEP during such inspections of the Projects.

9. Transfer of Projects – If the owners of PBAPS intend to transfer any legal or equitable interest in the PBAPS, they shall serve a copy of this Certification upon the prospective transferee of the legal and equitable interest at least thirty (30) days prior to the contemplated transfer and shall simultaneously inform the PADEP Regional Office of such intent. Notice to PADEP shall include a transfer agreement signed by the existing and new owner containing a specific date for transfer of Certification responsibility, coverage, and liability between them.

10. Correspondence - All correspondence with and submittals to PADEP concerning this Certification shall be addressed to:

Department of Environmental Protection
South-central Regional Office
Waterways and Wetlands Program Manager
909 Elmerton Avenue
Harrisburg, PA 17110-8200

7. Reservation of Rights – PADEP may suspend or revoke this Certification if it determines that PBAPS has not complied with the terms and conditions of this Certification. PADEP may require additional measures to achieve compliance with applicable law, subject to PBAPS's applicable procedural and substantive rights.

8. Other Laws - Nothing in this Certification shall be construed to preclude the institution of any legal action or relieve PBAPS from any responsibilities, liabilities, or penalties established pursuant to any applicable federal or state law or regulation.

9. Severability - The provisions of this Certification are severable and should any provision of this Certification be declared invalid or unenforceable, the remainder of the Certification shall not be affected thereby.

7/23/14

Scott Williamson — Date
Program Manager
Waterways and Wetlands Program