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[NAI and ERM] Normandeau Associates, Inc. and Environmental Resource Management. 2014. "Final Report for the Thermal Study to Support a 316(a) Demonstration: Peach Bottom Atomic Power Station." Prepared for Exelon Generation. February 2014.

# FINAL REPORT FOR THE THERMAL STUDY TO SUPPORT A §316(a) DEMONSTRATION

# PEACH BOTTOM ATOMIC POWER STATION

Prepared for:

Exelon Generation

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February 2014

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## Executive Summary

Exelon's Peach Bottom Atomic Power Station (PBAPS or Station) is a two-unit, power generating station in York County, Pennsylvania. The Station operates under NPDES Permit No. PA0009733 and a Clean Water Act §316(a) variance for its thermal discharge to Conowingo Pond, an impoundment on the Susquehanna River.

This demonstration supports Exelon's request for a thermal variance and represents the culmination of extensive studies and analyses of Conowingo Pond and the Station's operations. This demonstration shows that the previous thermal variance has assured, and the requested variance will continue to assure, the protection and propagation of a Balanced Indigenous Community (BIC) of aquatic biota in Conowingo Pond, thereby meeting the 316(a) standard for granting a thermal variance.

The biota of Conowingo Pond has been studied for many years, both prior to operation of PBAPS in 1974 and in the subsequent operational period. The most recent prior thermal demonstration study occurred from 1996 to 1999.

This report describes the 4-year thermal study that consisted of fish and benthic macroinvertebrate community sampling and temperature monitoring in Conowingo Pond during periods without cooling towers (in 2010) and when one (2011), two (2012), and three (2013) cooling towers operated. Overall, 224 benthic macroinvertebrate samples were collected at 10 stations. For fish, a total of 673 collections were completed using trawl, seine, and boat electrofisher at 30 stations. Hydrothermal modeling was used to predict thermal plume configurations for Current Licensed Thermal Power (CLTP) and for the increased thermal load that will occur after the pending Extended Power Uprate (EPU). The EPU will increase licensed thermal power and result in a maximum increase in the discharge temperature of 3°F from the existing thermal power level.

**Temperature Monitoring Program**

The objectives of the temperature monitoring program were to:

- Provide water temperatures at each biological sampling station to support the interpretation of biological data,
- Obtain temperature data for a range of environmental conditions, and
- Support the hydrothermal model.

The temperature data under CLTP were used to analyze the changes in the size and configuration of the thermal plume as additional cooling towers were operated. With respect to water temperature reductions from cooling tower operation:

- 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 where reductions were variable and related to ambient temperatures and Susquehanna River flows.

**Biological Survey**

The benthic macroinvertebrate survey determined the influence of the thermal plume on the composition and abundance of the benthic community in shallow-water shoreline habitat. The benthic community was evaluated with a PADEP stream assessment protocol. This protocol was used to compare Index of Biotic Integrity scores for all of the sampling stations, both within and outside of the thermally affected areas.

The macroinvertebrate assessment found that there are temperature-related effects on the benthic community; these effects are limited to a narrow band of shallow-water habitat along the western shoreline for a distance no farther than 0.65 miles downstream of the discharge canal. The temporarily affected area represents approximately 12 acres of the shallow shoreline habitat in Conowingo Pond. Lower IBI scores were only observed during July and August when the thermal plume water temperatures were highest. Improvement in IBI scores occurred in subsequent months indicating re-colonization and recovery of the benthic community.

The spatial and temporal distribution of fish relative to the thermal plume was evaluated by sampling at both thermally and non-thermally influenced locations with three methods of sampling: seining, electrofishing, and bottom trawling. This sampling program was similar to, but more extensive than, the fish community sampling that has been performed periodically in Conowingo Pond for over 40 years.

Fish species distribution and community composition were similar at the non-thermal and thermal stations. No thermally stressed fish were observed. Specific analyses of the fisheries data included evaluation of catch per unit of sampling effort, relation of water temperature to fish occurrence, length-frequency distributions, relative weight, and the occurrence of external anomalies. No substantial differences in these metrics were found between thermally influenced locations and those not influenced by the thermal plume.

The overall conclusions from the fish survey are:

- There is a diverse fish community within Conowingo Pond,
- The fish community has the ability to sustain itself through cyclical seasonal changes,
- Numerous prey species are abundant in the fish community,
- Pollution- or heat-tolerant species do not dominate the fish community,
- No measurable benefit was observed in terms of fish community composition or relative abundance from reduction in temperature resulting from cooling tower operation, and
- A BIC is being sustained in Conowingo Pond.

Based on the evaluation and comparison of relative abundance data from this study and the comparison to the prior fish sampling data in Conowingo Pond, we can conclude:

- There is considerable variation in relative abundance over time,

- Differences in relative abundance during the current study did not appear to be related to differences in water temperature resulting from cooling tower operation,
- Relative abundance of most Representative Important Species in 2010-2013 was within their historic ranges,
- Variable year-class strength for some species resulted in a wide range of relative abundances over time, and
- Changes in fish populations are normal and expected due to naturally variable environmental conditions and historic species introductions.

Operation of variable numbers of cooling towers during the study had no detectable benefit to the integrity of the BIC in Conowingo Pond. Fish and benthic macroinvertebrate community composition and relative abundance were similar among study years. No spatial or temporal patterns were evident in the fish or benthic macroinvertebrate community that can be related to the number of cooling towers that were operating.

This study confirmed the overall conclusion of the most recent prior thermal discharge demonstration study that there is a thriving, balanced fish community in Conowingo Pond under current and previous operating conditions. Similarly, the benthos community, within the constraints of the waterbody, is characteristic of a BIC.

**Hydrothermal and Avoidance Modeling**

The overall objective of hydrothermal modeling was to develop a predictive tool to quantify the horizontal and vertical dimensions of the thermal plume prior to and after Extended Power Uprate (EPU) implementation. Calibration and validation of the model showed that it reproduced the hydrodynamic and thermal structure of the Pond relative to the PBAPS thermal discharge, Muddy Run generation and pumpback, diurnal heating and cooling, and other dynamic input parameters.

The hydrothermal model was coupled to a fish avoidance model that was based on species-specific avoidance temperatures. During the course of the study, the avoidance model was shown to overestimate the areas that fish avoided, that is, individuals of certain RIS were found where measured water temperatures exceeded species-specific avoidance temperatures.

The conclusions from hydrothermal modeling are:

- For the typical summertime condition, areas of fish avoidance would be small, local, and temporary,
- For the extreme summertime condition, there would be sizable avoidance areas 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,
- The avoidance model over predicts avoidance areas because fish were collected in locations where water temperatures exceeded their laboratory-derived avoidance temperatures,

- No habitat critical to the maintenance of the BIC would be avoided within the thermal plume, thus diminished maintenance of RIS would not be expected, and
- Cross-sections of the thermal plume indicate that sufficient areas of the channel will be available at water temperatures less than the avoidance temperatures for the RIS to allow their movement within the Pond.

**Overall Conclusions of the Study**

This demonstration study concludes that under current operation of PBAPS, a BIC exists in Conowingo Pond. This community is characterized by diversity, the capacity to sustain itself through cyclic seasonal changes, and the presence of necessary food chain species; furthermore, the community is not dominated by pollution tolerant species. These characteristics are sufficient for the issuance of a thermal variance as described in USEPA guidance (1977).

There will be a 3°F increase in the discharge temperature after EPU. Based on information from the hydrothermal and avoidance models, as well as biological and temperature data obtained in this study, a BIC will be maintained after the EPU.

The previous 316(a) thermal variance issued in 2000 is appropriate and achieves the goal of protecting and maintaining the BIC. Continuation of the previous thermal variance is appropriate and warranted based on the results of this study. A similar conclusion was reached after the completion of the most recent historic thermal effects study. Consideration should be given to thermal and biological monitoring after the power uprates. Monitoring and evaluation of actual thermal conditions, post-EPU, could be used to determine whether modification from operating under the previous thermal variance is required to maintain a BIC.

# 1 Introduction

Exelon Generation, LLC's (Exelon) Peach Bottom Atomic Power Station's (PBAPS or "the Station") is an electric nuclear 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 (the Pond or Conowingo Reservoir) of the Susquehanna River.

As required by the Permit, Exelon conducted a 316(a) Demonstration study, "Thermal Study", in 2010 – 2013 for these purposes:

1. As a demonstration study of an alternative thermal effluent limitation (as required by Footnote 3 in Part A of the NPDES permit) and alternative thermal effluent limitations under §316(a) of the CWA,
2. To evaluate changes in the thermal plume created by operation of up to three helper cooling towers, and
3. As a predictive study of the changes to the thermal discharge associated with planned power uprates to Units 2 and 3 of the Station, and predicting the effects of operating helper cooling towers.

A work plan (or study plan) for the thermal study was developed through extensive coordination with the Pennsylvania Department of Environmental Protection (PADEP). The study plan is provided in Appendix 11.1. Sufficient agreement between Exelon and the PADEP was reached on the various technical data collection objectives and methods to begin the field study in July 2010 in advance of the January 2011 effective date of the renewed NPDES permit.

The main components of the study include temperature monitoring and modeling and biological sampling of shore zone benthic macroinvertebrates and the resident fish community throughout the Pond. Field data collection was primarily performed in April through October, the main period of fish reproduction and growth as well as highest ambient and discharge water temperatures. The period of warmest water temperatures, July and August, is emphasized in this report due to PADEP's expressed interest in the potential extent of fish exclusion from habitats affected by the thermal plume. Data collection began in July 2010 and was originally planned to extend through a fifth year, 2014, but the field study was curtailed in 2013, with PADEP concurrence, to accommodate application for a revised NPDES permit due to planned implementation of the extended power uprates (EPU) for Units 2 and 3 starting in 2014.

To support a thermal variance the permittee must demonstrate that the otherwise applicable water quality standard for temperature is more stringent than necessary to assure the protection and propagation of the waterbody's balanced indigenous community or BIC (EPA 2008). Maintenance of a BIC of aquatic life in the waterbody receiving the thermal discharge is the major requirement for a power station to receive a thermal discharge variance, according to applicable Section 316(a) technical guidance issued by the US Environmental Protection Agency (USEPA 1977). USEPA guidance describes a BIC as a biotic community that:

- Is typically characterized by diversity,
- Displays the capacity to sustain itself through cyclic seasonal changes,

- Includes the presence of necessary food chain species, and
- Lacks domination by pollution tolerant species.

A BIC may include:

- Historically non-native species introduced through a program of wildlife management. This would include several of the non-native RIS (e.g. Smallmouth Bass, Largemouth Bass, etc.) that are now naturalized and a main component of the Susquehanna River fish community. Importantly, the guidance indicates that a BIC can reflect impoundment or other conditions that are essentially irreversible.
- Species whose presence or abundance results from substantial irreversible environmental modifications unrelated to the thermal discharge.

A BIC will not include:

- Species whose presence or abundance is attributable to the introduction of pollutants that will be eliminated by having all sources comply with the applicable thermal limits.
- Species whose presence or abundance is attributable to alternative effluent limitations imposed pursuant to Section 316(a).

An important component of a 316(a) variance is the ability of the discharger to demonstrate the absence of prior appreciable harm to the BIC from the thermal discharge. Key considerations for evaluating appreciable harm were provided in USEPA's 1975 guidance document (USEPA 1975) and include:

- Substantial increase in abundance or distribution of any nuisance species or heat tolerant community not representative of the highest community development achievable in receiving waters of comparable quality,
- Substantial decrease in formerly indigenous species, other than nuisance species,
- Changes in community structure to resemble a simpler successional stage than is natural for the locality and season in question,
- Unaesthetic appearance, odor or taste of the waters,
- Elimination of an established or potential economic or recreational use of the waters,
- Reduction in completion of life cycles of indigenous species, including migratory species, and
- Substantial reduction in community heterogeneity or trophic structure.

Interim results for the first 3 years of the study; 2010, 2011, and 2012; were reported in Normandeau Associates and ERM (2011, 2012, and 2013a). This final 316(a) thermal variance demonstration report describes the work performed and results for the entire 4-year period of the thermal study. This report presents both retrospective and prospective analyses which show that the thermal variance under which PBAPS operated since 2000 has supported a BIC in Conowingo Pond and the requested thermal variance needed after the power uprates will assure the protection and propagation of a balanced indigenous community (BIC) of aquatic life in the Conowingo Pond, thereby meeting the 316(a) standard for granting of a thermal variance.

Section 2 of this demonstration report provides information about PBAPS, Conowingo Pond and previous important thermal effects biological studies conducted relative to PBAPS that will be useful for interpreting the results of the current study. The Representative Important Species of fish that are emphasized in the thermal effects evaluations are discussed in Section 4. The three major components of the demonstration study: biological monitoring, temperature modeling, and hydrothermal modeling; are discussed in Sections 3, 5, and 6, respectively. Section 7 provides the prospective biological evaluation of potential thermal effects after implementation of the power uprates. A comprehensive summary of conclusions for both the retrospective and prospective evaluations is presented in Section 8. Additional supporting information is provided in Sections 9 (Glossary) and 10 (Literature Cited) and in the Appendices.

This report and the associated study were designed to determine whether there is a BIC within Conowingo Pond.

# 2 Background

This section provides key information about PBAPS and Conowingo Pond as well as a brief summary of the previous 316(a) variance demonstration and the recent biological studies conducted in the Pond relative to the PBAPS thermal discharge.

## *2.1 The Peach Bottom Atomic Power Station*

PBAPS is in York County, Pennsylvania, on the west shore of Conowingo Pond, the lowermost impoundment on the Susquehanna River (Figure 2-1). The Station is located at approximately river mile (RM) 17, about 3 miles upstream from the Pennsylvania-Maryland border and 7 miles upriver from Conowingo Dam. The Station consists of two boiling water reactors and operates as a base-load facility with both units normally generating at full capacity. Unit 2 began commercial operation in June 1974 and Unit 3 entered commercial service in December 1974. A refueling outage for one of the two units takes place each fall during which one of the units is brought off-line (Unit 2 outages are in even-numbered years, Unit 3 outages are in odd-numbered years). Refueling is preceded by a power coast-down due to nuclear fuel depletion which occurs approximately 6 weeks prior to the start of the refueling outage.

PBAPS withdraws water for condenser cooling and service needs from Conowingo Pond through an outer intake structure, through two 3-acre intake ponds (one pond serving each unit), and then through an inner intake structure. There are six circulating water pumps (three per unit) that supply cooling water to the condensers and six service water pumps (three per unit) that provide water for process and equipment needs. Each circulating water pump has a nominal capacity of 250,000 gallons per minute (gpm), or 557 cubic feet per second (cfs). Each service water pump has a nominal capacity of 14,000 gpm, or 31.2 cfs. In the winter, some heated water is recirculated from the discharge basin through a small gate that connects to the intake pond, which provides freeze protection for the water supply of the cooling water intakes.

The design temperature rise across the condensers is 22°F and across the service water system is 10.7°F. As noted in Section 3.2, the actual temperature rise for the combined condenser and service water flow as observed in this study averaged 19.4°F at the head of the discharge canal during the two warmest months of the year, July and August.

The heated effluent is discharged into a common discharge basin that leads to a 4,700-ft long discharge canal (Figure 2-2) separated from Conowingo Pond by a berm. The canal terminates downstream (south) of PBAPS at a submerged jet discharge structure (Figure 2-3) designed for rapid mixing of the heated effluent into ambient Conowingo Pond water and immediate reduction in temperature.

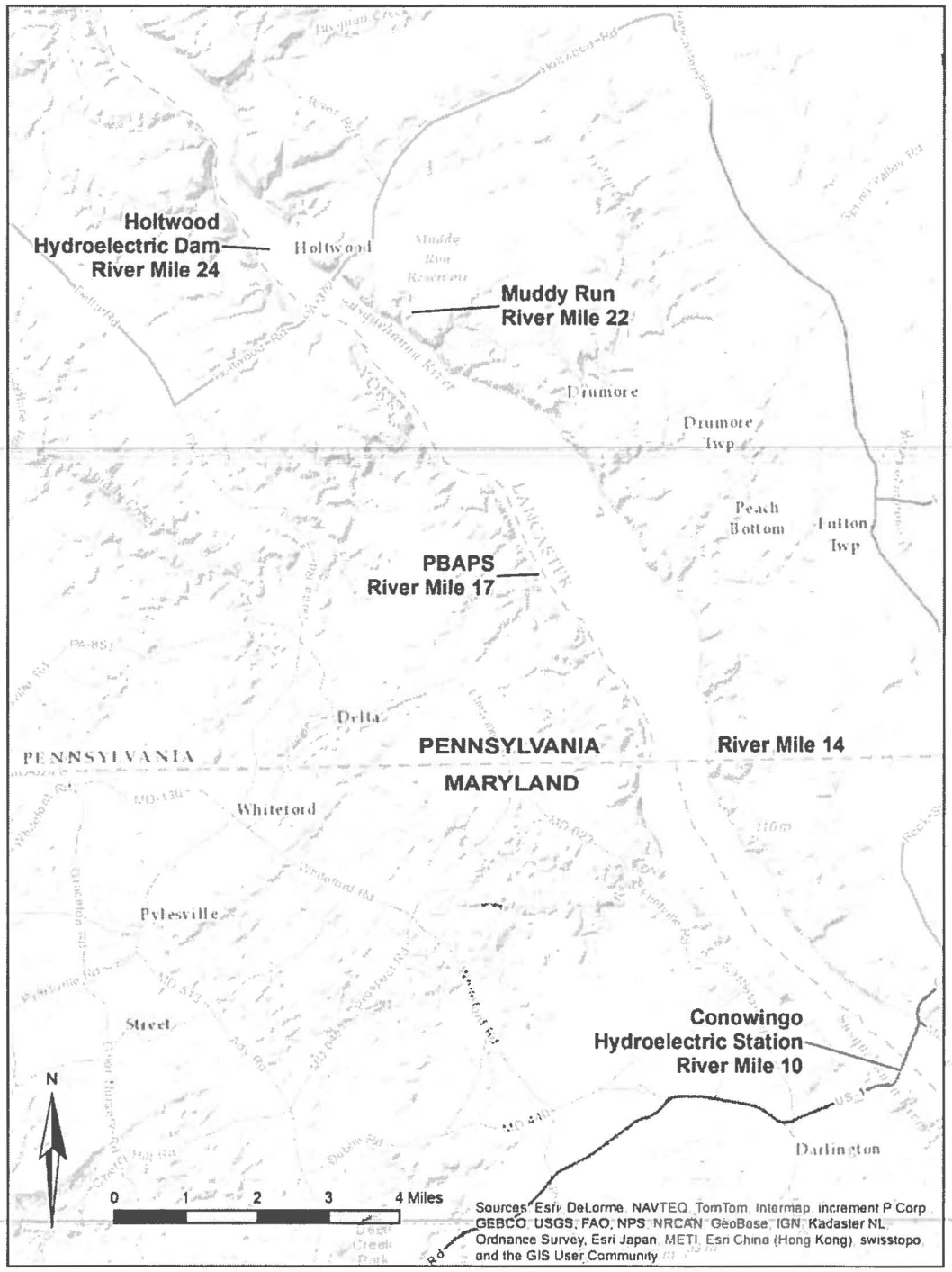



Figure 2-1. Location of Conowingo Pond.

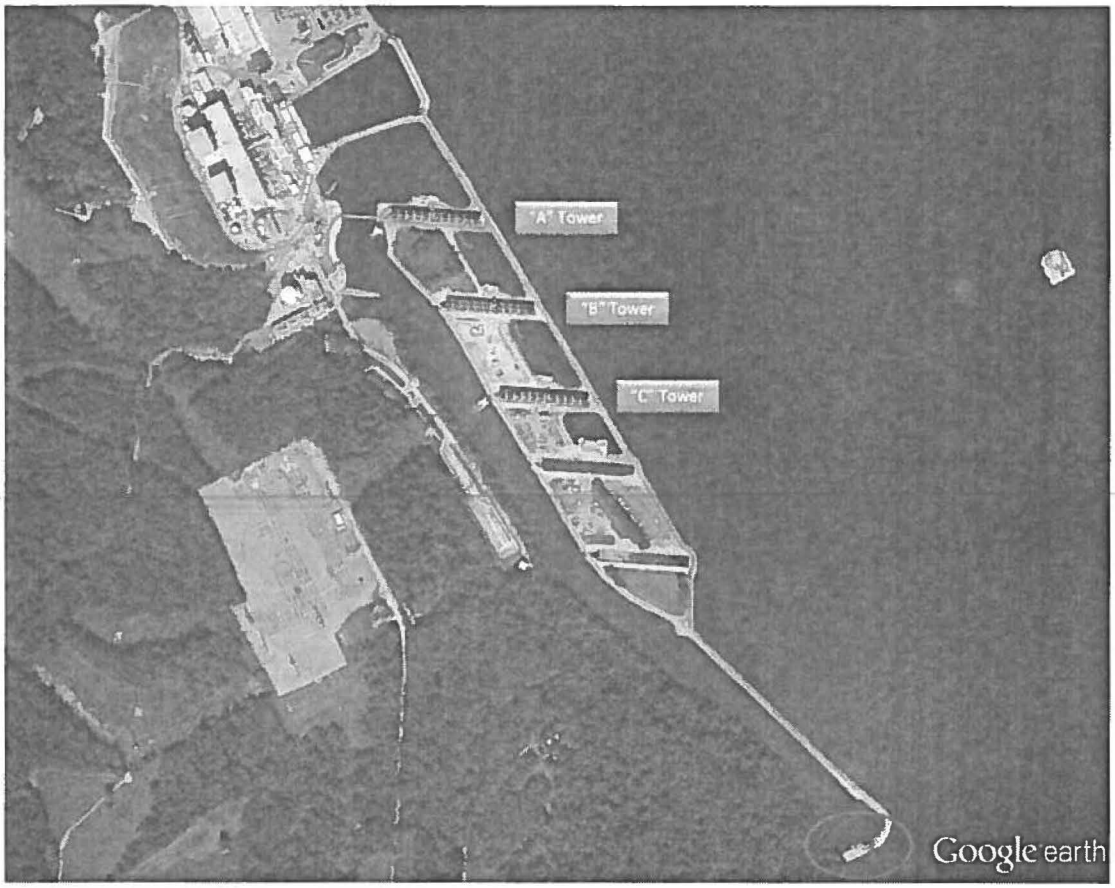



Figure 2-2. PBAPS discharge canal with cooling towers locations and designations (circled area is the end of the discharge canal).

Figure 2-3. PBAPS discharge structure at the end of the canal, looking upstream.

### 2.2 *Source Waterbody Description*

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 (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 has a design storage capacity of 310,000 acre-ft. It is about 14 miles long and averages 1 mile wide. The elevation at normal full Pond is 108.5 ft (Conowingo Datum) and Pond elevation is normally 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.

Since environmental monitoring began in 1966, there has been no substantial thermal stratification in Conowingo Pond. However, during summer, generally at water temperatures exceeding 75°F and Susquehanna River flows less than 12,000 cfs, dissolved oxygen stratification can occur, particularly in deeper areas of the lower third of the Pond. However, this stratification quickly breaks down during periods of heavy rain and high winds (Mathur *et al.* 1988). There is no information showing that the temporary dissolved oxygen stratification is caused or influenced by PBAPS. Whaley (1960) showed that dissolved oxygen stratification

occurred in the Pond prior to operation of PBAPS; a natural phenomenon 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 MRPSF. Conowingo Hydroelectric Station currently has to comply with Federal Energy Regulatory Commission-mandated seasonally adjusted minimum flow requirements.

### *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 demonstration studies prior to the current 316(a) demonstration study were completed from 1996 to 2000. These studies included thermal profiling and extensive fish community monitoring to examine the potential to reduce the number of cooling towers needed to maintain the integrity of a BIC in Conowingo Pond.

Conowingo Pond is a dynamic and complex biological system in which there is an almost continuous movement of fish and water into and out of the Pond. The complexity of the fish community derives from these three sources:

- Seasonal immigration into Conowingo Pond from below Conowingo Dam via the East Fish Lift and from above Conowingo Pond through Holtwood Dam,
- Emigration out of Conowingo Pond via Conowingo Dam and the Holtwood Fish Lift, and
- Exchange of organisms between Conowingo Pond and MRPSF.

Except for the known number of fish that are transported through the fishways at Conowingo and Holtwood, it is difficult to quantify the recruitment into and losses out of Conowingo Pond. Extensive sampling throughout Conowingo Pond since the mid-1960s provides substantial historical information concerning the biota (PECO 1975, 1976; Normandeau Associates 1997-2000a).

Water quality standards applicable to Conowingo Pond aquatic life are designated for the protection of warm water fishes and migratory fishes per 25 Pa. Code 93.3. Since 1966, approximately 60 species have been captured in the Pond and the tributary streams. The Comely Shiner, Spotfin Shiner, Bluegill, Green Sunfish, Bluntnose Minnow, and Spottail Shiner are the common forage species. The Channel Catfish is one of the most numerous large-bodied fishes and a target species for some anglers. The Flathead Catfish, a predatory species, was introduced into Conowingo Pond in 2000 and has become widely distributed in the Pond and is sought after by anglers. White Crappie, once abundant through the early 1980's, is now

uncommon due to introduction of Gizzard Shad. The common game fishes are the Smallmouth Bass, Largemouth Bass, and, to a lesser extent, Walleye. The RIS members of the fish community are discussed in Section 4.

The distribution of the fish community is not uniform in the Pond. Some species, such as Largemouth Bass, are more common in the lower part of the Pond whereas Smallmouth Bass, Walleye, and Bluntnose Minnow are more common in the upper reaches of the Pond. The Gizzard Shad population, inadvertently introduced in 1972 from below Conowingo Dam, has exploded and this species competes for food with other fishes in the Pond. Large fluctuations in abundance of the common species between sampled locations and years have been well documented (Robbins and Mathur 1976; Normandeau Associates 2000a).

### *2.4 Summary of Previous 316(a) Demonstration and Important Biological Studies*

The original 316(a) Demonstration Report, *Materials Prepared for the Environmental Protection Agency, 316(a) Demonstration for PBAPS Units No. 2 & 3 on Conowingo Pond* (PECO 1975) was submitted to the Pennsylvania Department of Environmental Resources (PADER), now PADEP, and the USEPA in July 1975. This report was submitted by Philadelphia Electric Company, which later changed its name to PECO Energy Company, and subsequently became an Exelon company in 2000. The original 316(a) demonstration sought thermal effluent limitations that were less stringent than would be produced by a closed cycle-cooling system, but yet sufficient to ensure the protection and propagation of a BIC of shellfishes, fishes, and wildlife in and on Conowingo Pond.

The limitations were based on a design consisting of an open-cycle cooling system that used three mechanical draft "helper" cooling towers, cooling 58 percent of the flow that was mixed with the remaining 42 percent of the flow prior to being discharged, via the submerged jet discharge, to the Pond.

In February 1976, the USEPA requested that ecological data in the July 1975 submittal be integrated with predicted isotherms to illustrate the impact of the thermal discharge on biological communities. It was also requested that tables and graphs be used to present the effects of the predicted isotherms on the various life history stages and parameters in the representative important species (RIS) of biota selected by the USEPA for use in the 316(a) demonstration (Elder *et al.* 1973). Subsequent to the original 316(a) demonstration, evaluation of the potential biological impacts of the thermal discharge focused solely on the fish community because RIS of fish were judged to be representative of the BIC of aquatic biota.

In June 1976, PECO submitted a supplementary report to the agencies documenting the results of this analysis (PECO 1976). This document, entitled *Supplementary Materials Prepared for the Environmental Protection Agency, 316(a) Demonstration for PBAPS Units No. 2 & 3 on Conowingo Pond*, also stated that the Company agreed to new requirements that included the use of two additional helper towers. The five towers would be operated in a phased manner, from zero to all five towers in operation.

In 1977, the agencies approved the phased operation of the cooling towers (zero to five) based on evaluation of ambient water temperature, fish tolerances to sudden change in temperature, and cooling efficiency of the towers (PECO 1977).

From 1996 through 1999, PECO performed a 4-year fishery and habitat avoidance study with zero to two towers in operation to further evaluate the necessity of cooling the heated discharge (Normandeau Associates 1997, 1998, 1999, 2000a, and 2000b). The results of the study indicated that the operation of cooling towers was only needed during certain infrequent concurrent low flow and high water temperature conditions. The regulators (PADEP, Pennsylvania Fish and Boat Commission and Maryland Department of Natural Resources) concurred and the PBAPS heated effluent was thereafter discharged into the Pond without auxiliary cooling. A condition was imposed that required auxiliary cooling with one to two towers under extreme low flow – high water temperature conditions if the fish community showed signs of thermal stress.

To assess thermal-related fish stress and determine if any cooling towers should be operated, the agencies required that a boat-based fish surveillance program be implemented when Susquehanna River flow was less than 3,000 cfs at the Marietta USGS gage and incoming ambient water temperatures at Holtwood Dam were greater than 85°F. Of particular interest was potential stress to the large number of fish (often more than 700,000) introduced annually into Conowingo Pond via the Conowingo East Fish Lift since 1997.

PBAPS operated in this manner, without the need to operate cooling towers at any time or without evidence of fish stress, until 2011 when, during the course of the current 316(a) demonstration study, the PADEP required the use of one or more cooling towers from June 15 through September 15 in 2011 (one cooling tower), 2012 (two cooling towers), and 2013 (three cooling towers).

As noted in the following section, no migratory fish, such as American Shad (*Alosa sapidissima*) or American Eel (*Anguilla rostrata*), are included as RIS for this demonstration and, therefore, are not evaluated in this report with regard to interaction with the thermal plume from PBAPS. However, upstream and downstream passage of American Shad and American Eel were evaluated considering interaction of MRPSF operations and the PBAPS thermal plume at current licensed thermal load by Normandeau Associates and Gomez and Sullivan (2012) and at the greater predicted thermal load post-EPU by Normandeau Associates and ERM (2013b). Both evaluations found that, among a host of factors, spikes in natural river flows causing spillage >25,000 cubic feet per second at Holtwood Dam with high turbulence, velocities, and turbidity together with inefficient passage at the existing fish passage facilities pose greater impedance to American Shad migration and restoration than operation of either PBAPS or MRPSF individually or together. Radio tagging studies of American Shad showed no evidence of adverse effects of the thermal plume on upstream or downstream migration. Both prior studies indicate that there is no thermal blockage to migratory fishes in Conowingo Pond.

# 3 Temperature Monitoring Program

The four objectives of the temperature monitoring program were to

- Measure temperatures at the biological sampling stations;
- Provide a temperature dataset for a range of Susquehanna River flows;
- Provide a temperature dataset for a range of Holtwood, Muddy Run, PBAPS, and Conowingo operations; and
- Support calibration and validation of the predictive hydrothermal model.

Data from the monitoring program were also used to determine the effectiveness of cooling towers on reducing temperatures in the discharge canal and downstream of the discharge canal.

This section of the report describes the temperature monitoring system and presents an analysis of the in-canal cooling tower performance as well as a data-based assessment of the towers' effectiveness in reducing temperatures downstream of the discharge canal. Section 6.3 discusses the use of the data to support the model calibration and validation and Section 6.4 describes use of the data for the biological assessment.

As used in this report, a monitor is a single temperature recording instrument, sometimes referred to as a thermistor. A station consists of one or more monitors on a mooring at a specific location. A transect refers to line of stations across or down Conowingo Pond. One set of monitors recorded temperatures of the cooling water system, including cooling tower cold and hot water side temperatures. A second set of monitors recorded temperatures in Conowingo Pond at transects used in previous studies (the "historical transects") and one new transect, and at seining and electrofishing stations.

Thirty-five stations were fitted with one or more monitors. For deep water stations, monitors were placed in a surface-to-bottom configuration, with the number of monitors and their vertical spacing dependent on the water depth at that location. The locations of all stations were logged with a Global Positioning System (GPS) at the time of deployment.

Temperature data for the transect, seining, and electrofishing stations were collected using Onset HOBO® Pro v2 Water Temperature Data Loggers. These instruments are accurate to 0.36°F in the range 32 to 122°F, can resolve temperatures to 0.04°F at 77°F, and have a 5-minute response time. Each monitor recorded temperature every 15 minutes. Data from each instrument were downloaded at approximately 4-week intervals. Cooling water station data were collected by a separate set of monitors.

Temperature data were recovered for

- June 29 to November 29, 2010;
- April 1 to December 8, 2011;
- March 21 to November 14, 2012; and
- March 22 to November 18, 2013.

The monitoring program collected 1.15 million data points in 2010, 1.94 million in 2011, 2.08 million in 2012, and 2.04 million in 2013. In 2011 the passage of Tropical Storm Lee resulted in the temporary loss of several thermistors, which were subsequently replaced.

### *3.1 Station Descriptions*

Thermal monitors were placed along historical Transects 100, 200, 300, 400 and at a single location mid-channel near Hopkins Cove (Station 611), for a total of 20 stations. An additional transect was established immediately offshore of the intake (Transect 150) and consisted of three stations. Locations are shown in Figure 3-1. Transects are defined as a series of cross-Pond stations, e.g., Transect 100 includes Stations 101, 102 and 103; Transect 200 includes 201, 202, 203, 204 and 205. Stations along transect 400 were re-located, as requested by DEP, to coincide with historical locations. For most stations, temperatures were measured near-surface (i.e., within 1 ft of the surface), at 5-ft and 10-ft depths, and near-bottom (within approximately 1 ft of the bottom). At the two deeper stations (Stations 402 and 611) temperatures were measured near-surface, at 10-ft and 20-ft depths, and near-bottom.

In addition to the array of monitors shown in Figure 3-1, monitors were installed at eleven seining and electrofishing stations to characterize the temperature history of the biological sampling stations. The seining stations are shown in Figure 3-2 and the electrofishing stations are shown in Figure 3-3. A total of seven monitors were deployed at the seining stations in 2010 (increased to nine in 2011 with the addition of Stations 216 and 217) and at two of the electrofishing Stations (189 and 190). For these stations, the thermal monitors were placed on the bottom in shallow shoreline locations that were less than 5 ft deep.

Additional temperature monitors were deployed to record temperatures from the intake through the end of the discharge canal. Four stations were established to monitor temperatures at the outer and inner intake structures, at the head of the discharge canal, at the exit from the discharge canal and at the inlet and outlet for each operating cooling tower. Figure 3-4 shows the locations of the cooling water stations.

Data collected at cooling water stations allowed calculation of temperature changes

- from the intake to the discharge at the head of the canal,
- through each operating cooling tower, and
- from the intake to the end of the discharge canal.

Data from these monitors were compared to data from the Conowingo Pond monitors downstream of the discharge to assess the effectiveness of the towers in reducing temperatures downstream of the discharge.

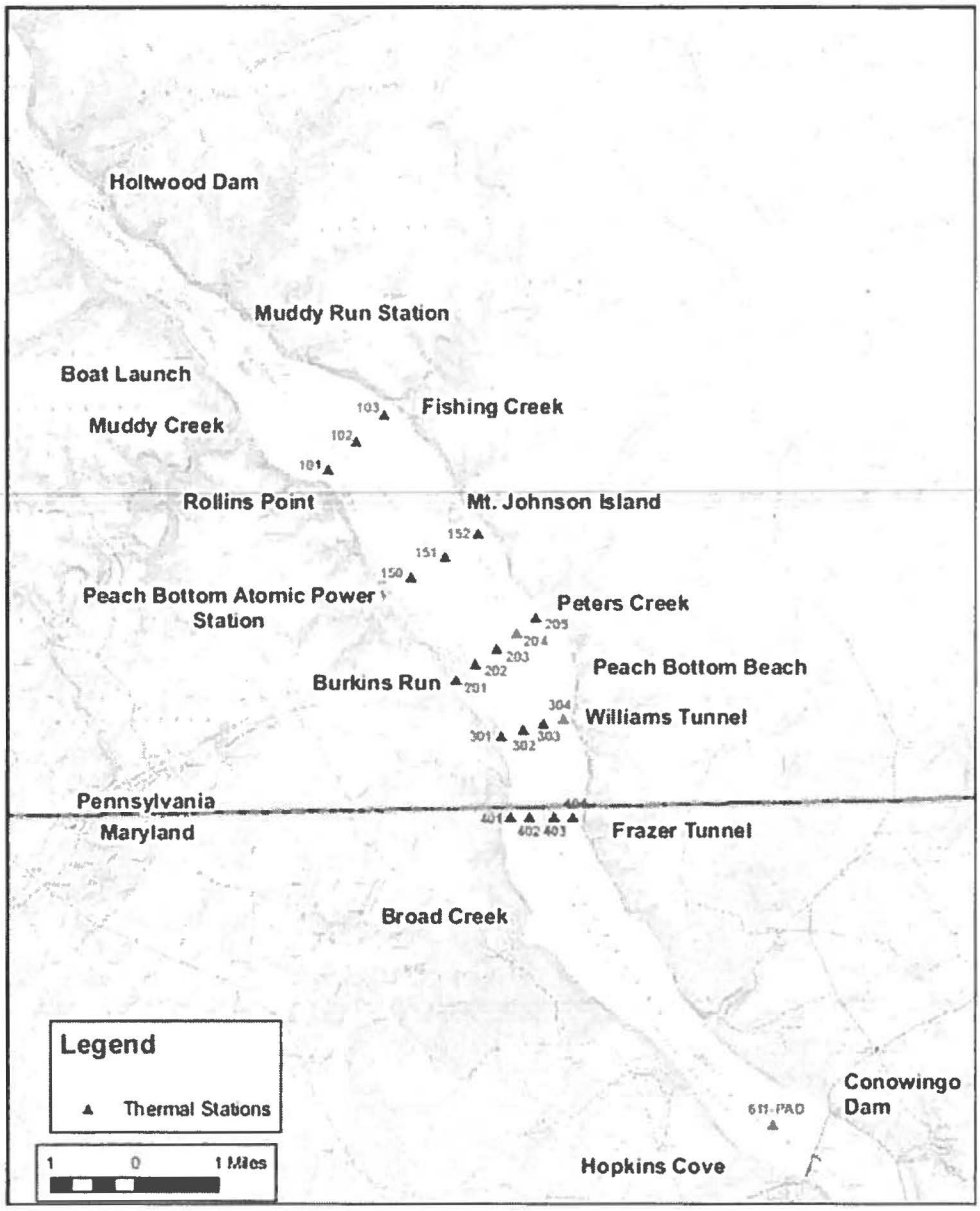



Figure 3-1. Transect locations and designations.

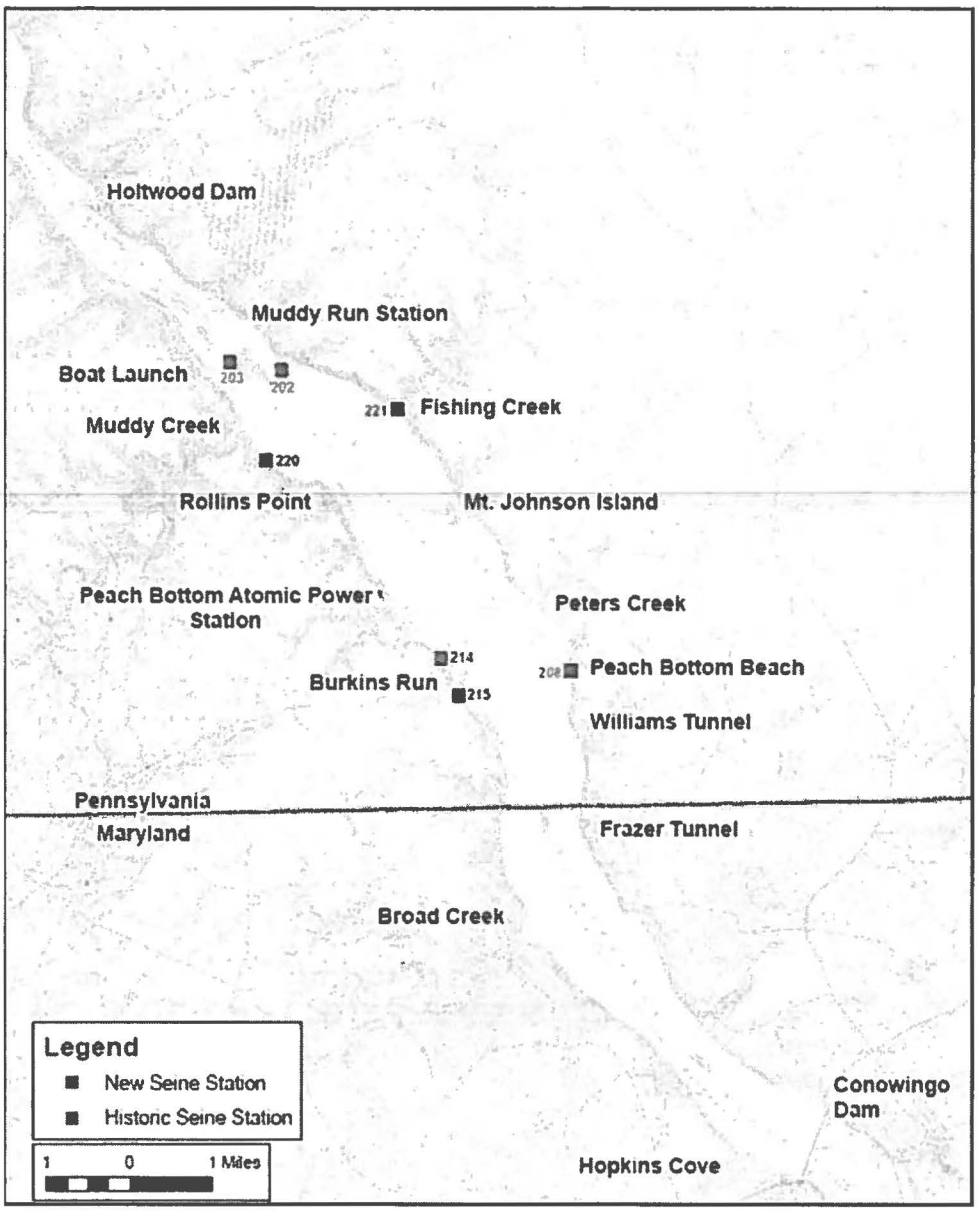



Figure 3-2. Seining station locations and designations.

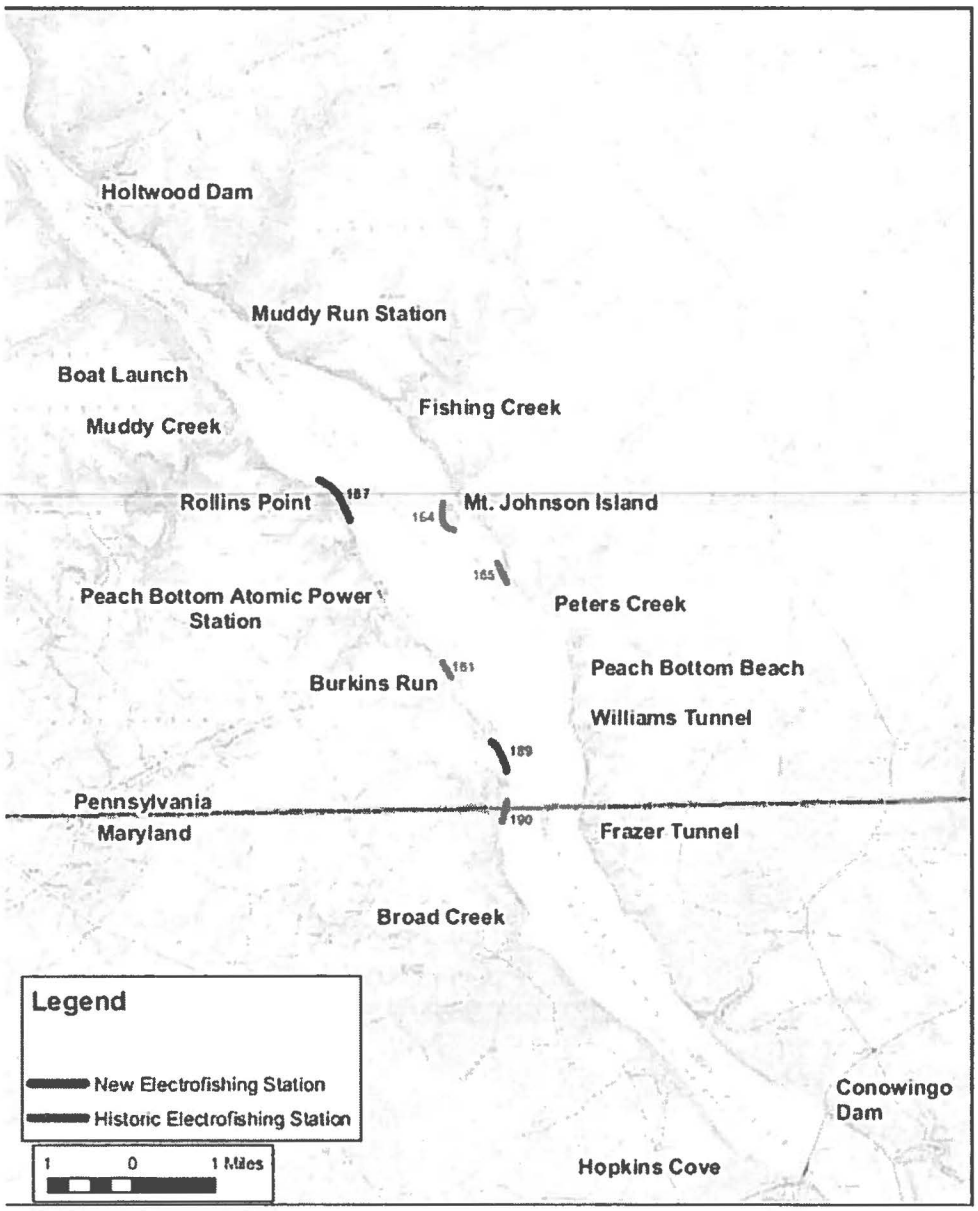



Figure 3-3. Electrofishing station locations and designations.

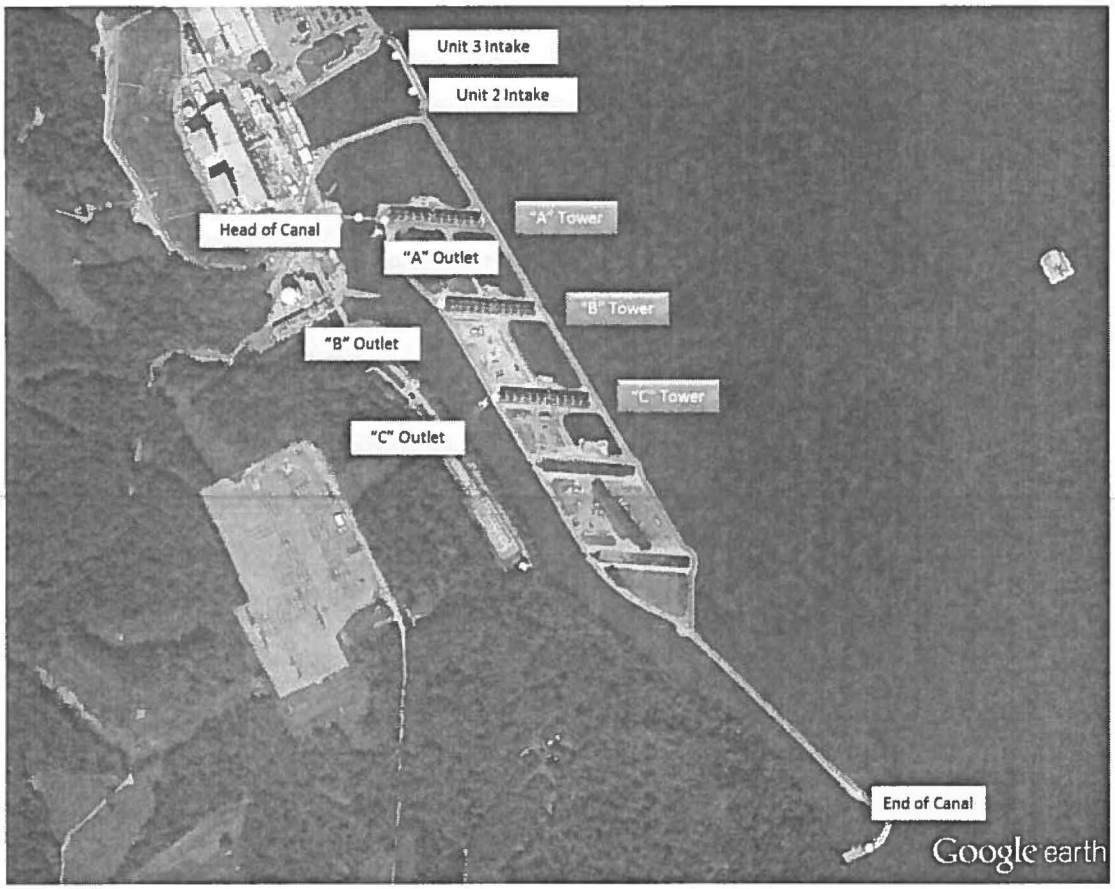



Figure 3-4. PBAPS cooling water system station locations and designations.

### *3.2 Conditions during the Study Years*

The behavior of the thermal plume is determined primarily by the PBAPS discharge rate and temperature rise and the Susquehanna River flow rate. Muddy Run pumpback and generation flows and upstream temperatures (an indication of natural heating and cooling due to surface heat exchange) are also important factors, although their effects are primarily in the far-field. Variations in these forcing functions over the study years are described below.

With the exception of end-of-the summer refueling outages, PBAPS operations were steady for all four study years with a discharge rate of 3,529 cfs (the sum of condenser cooling and service water flows). Unit 2 was shut down for refueling on September 12, 2010 and again on September 9, 2012. Unit 3 was shut down for refueling on September 11, 2011 and on September 9, 2013. Outages last approximately 6 weeks and are preceded by a power coast down which decreases power output and reduces circulating water temperature rises.

To characterize Susquehanna River temperatures during the study period, monthly average PBAPS intake temperatures 2010 through 2013 were compared with long-term records at the PBAPS intake and at Holtwood Dam. Both these records are important. The longer Holtwood Dam record was used to generate the joint flow-temperature distribution discussed in Section

6.6. The shorter PBAPS intake temperature record better represents temperatures in the lower portion of Conowingo Pond.

Temperatures during the study years can be characterized by examining Figure 3-5 which shows the PBAPS monthly-average intake temperatures for the study years as well as period-of-record values. The period-of-record averages are based on hourly temperatures measured at the Unit 2 and Unit 3 intakes for 1999 through October 2013 (a 15-year record). The figure shows a typical northern hemisphere seasonal cycle with the highest temperatures in July and August and a rapid drop-off in September and October.

Table 3-1 shows these same temperatures ranked relative to the period-of-record temperatures. The months of July and August of 2010 and 2012 stand out as the warmest of the study period and also warm relative to period-of-record averages. August 2013 was notable for low temperatures.

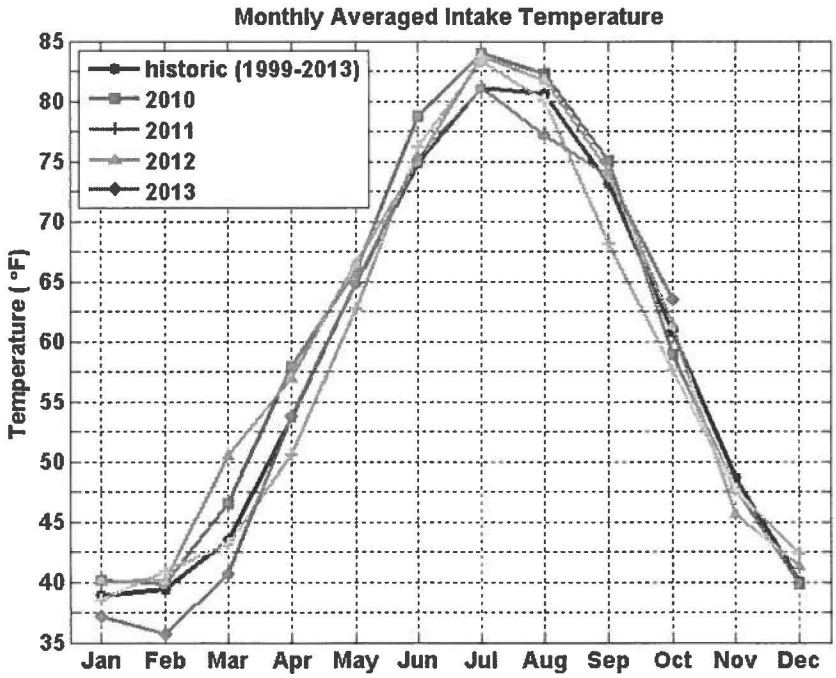



Figure 3-5. Annual temperature cycle for 2010-2013 and historic (1999-2013) average.

Table 3-1. Ranked summer PBAPS intake temperatures. Shaded temperatures exceed period-of-record averages.

| June | Temp, F | July | Temp, F | August | Temp, F | September | Temp, F |
|---|---|---|---|---|---|---|---|
| 2010 | 78.8 | 2010 | 84.0 | 2010 | 82.3 | 2010 | 75.1 |
| 2011 | 76.2 | 2012 | 83.8 | 2012 | 81.8 | 2012 | 74.2 |
| 2013 | 75.1 | 2011 | 83.3 | PBAPS intake, 1999-2013 | 80.6 | 2013 | 73.8 |
| 2012 | 75.0 | 2013 | 81.2 | Holtwood, 1967-2012 | 80.2 | Holtwood, 1967-2011 | 73.6 |
| PBAPS intake, 1999-2013 | 74.8 | PBAPS intake, 1999-2013 | 81.1 | 2011 | 80.1 | PBAPS intake, 1999-2013 | 73.1 |
| Holtwood, 1967-2012 | 74.7 | Holtwood, 1967-2012 | 80.6 | 2013 | 77.2 | 2011 | 68.1 |

Monthly average Susquehanna River flows were calculated from data available at Holtwood Dam from October 1967 through September 2012 (a 45-year record). The Holtwood Dam flow records were provided by PPL and consist of the sum of flows for the Susquehanna River (at Marietta), Conestoga Creek, and Pequea Creek. These records are continuous from 1967 onwards; prior to 1967 there are long periods without data. To characterize flows in the study years, monthly average flows for April through October in each of the study years were compared to 1967-2012 monthly averages (Table 3-2). Each of these years show typical spring high flows followed by decreased summer flow and a return to higher flows in the fall. Superimposed on this pattern are large rainfall events, especially in the Spring of 2011, May of 2012, and the Fall of 2011 when Tropical Storm Lee caused flooding in September. Flows peaked at 632,400 cfs at Holtwood on September 9, 2011 during Tropical Storm Lee.

Monthly flows 2010 through 2013 were both above and below the period-of-record averages with below average flows for most of the summer months in 2010 and 2012. August and September 2010 and July 2012 each had average flows less than 10,000 cfs.

Table 3-2. Monthly average Susquehanna River flow at Holtwood (cfs). Shaded flows are less than 1967-2013 averages.

| Month | 1967-2013 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|
| April | 78,600 | 46,385 | 149,867 | 23,704 | 53,462 |
| May | 48,500 | 34,392 | 110,399 | 52,547 | 29,717 |
| June | 28,900 | 17,508 | 35,079 | 29,693 | 31,949 |
| July | 16,200 | 10,060 | 13,202 | 8,730 | 37,117 |
| August | 12,700 | 8,808 | 17,797 | 10,275 | 15,692 |
| September | 15,800 | 6,142 | 141,479 | 11,222 | 12,266 |
| October | 18,800 | 40,228 | 80,023 | 18,378 | 18,853 |

Overall, the study years covered a representative range of flow and temperature conditions relative to period-of-record values. The summers of 2010 and 2012 represent especially warm temperatures combined with low flows and are ideal periods to collect and analyze data to perform the present study.

### *3.3 Cooling Tower Performance*

A key feature of the Study Plan was the sequential operation of an increasing number of cooling towers from June 15 to September 15 each year. Exelon added one cooling tower each year as the study proceeded:

- 2010 – no towers;
- 2011 – one tower (primarily Cooling Tower B, but Cooling Tower A when needed);
- 2012 – two towers (Cooling Towers A and C); and,
- 2013 – three towers (Cooling Towers A, B, and C).

The primary heat loss process in a cooling tower is evaporative cooling (approximately 75% of the total heat loss). The remainder of the heat loss is dependent on the temperature of the water supplied to the cooling tower. Cooling tower performance is quoted in terms of an approach temperature, i.e., how closely the cold side temperature "approaches" the ambient wet bulb temperature. The approach temperature conveniently summarizes all heat transfer processes.

Figure 3-6 shows measurements obtained in 2010 when no towers were operating. The shortened period of temperature measurement was the result of later-than-planned installation of monitors. The figure shows temperatures measured at the intake, head, and end of the discharge canal. The difference between the head of the canal and intake temperature is the temperature rise through the plant, an average of 19.2°F for 2010. Water passing through the canal is cooled, on average, by 0.2°F through surface heat loss to the atmosphere for a net change from the intake to the end of the canal of 19.0°F. Note that Unit 2 was shut down for about 6 weeks for refueling on September 12, 2010

Cooling Tower B was put into operation on June 13, 2011. Figure 3-7 shows the temperatures at the three stations for June 15 through September 15 of that year. The average temperature rise through PBAPS was 19.3°F for this period; the operation of Cooling Tower B resulted in net

cooling in the canal of 1.9°F and a net change from the intake to the end of the canal of 17.4°F. Unit 3 was shut down for refueling on September 11, 2011.

Figure 3-8 shows temperature measurements for 2012 when two cooling towers operated. The average temperature rise through PBAPS was 19.0°F. Individual cooling tower performance in 2012 was consistent with the performance recorded in 2011. Net cooling in the canal was 3.8°F, attributable to 0.2°F cooling in the canal and approximately 1.8°F for each tower. The net change from the intake to the end of the canal was 15.2°F. Unit 2 was refueled with the outage starting on September 9, 2012.

Figure 3-9 shows temperature measurements for 2013 when three cooling towers operated. The average temperature rise through PBAPS was 18.9°F. Net cooling in the canal was 5.0°F, attributable to 0.2°F cooling in the canal and approximately 1.6°F for each of the three towers. The net change from the intake to the end of the canal was 13.9°F. Unit 3 was refueled beginning September 9, 2013.

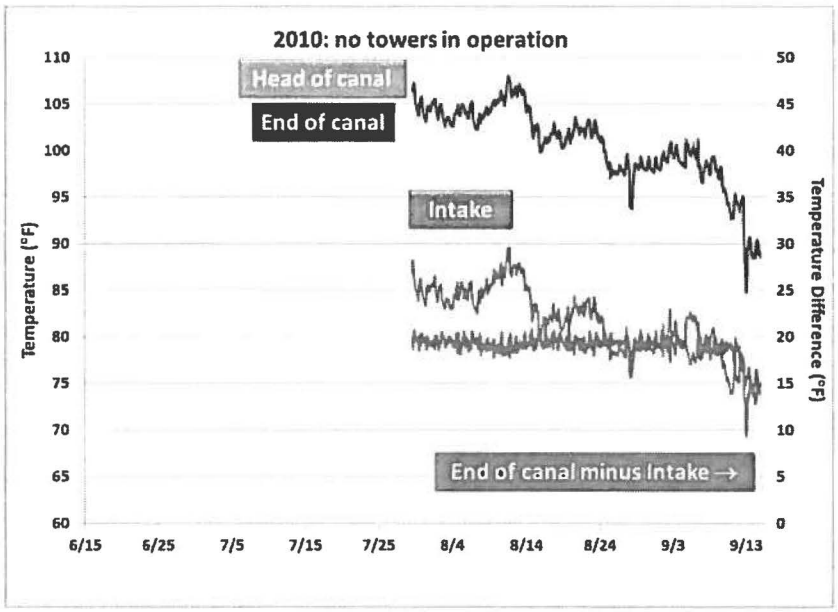



Figure 3-6. Cooling water station data, 2010.

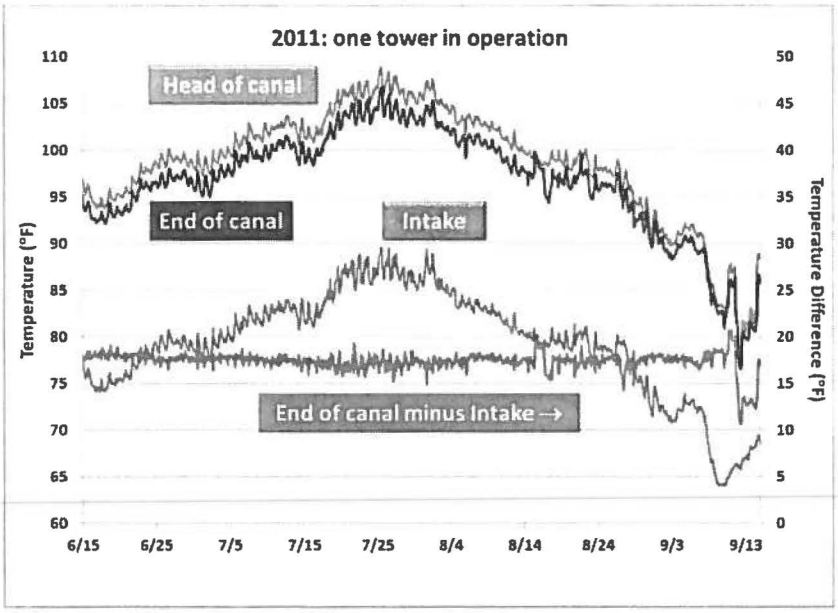



Figure 3-7. Cooling water station data, 2011.

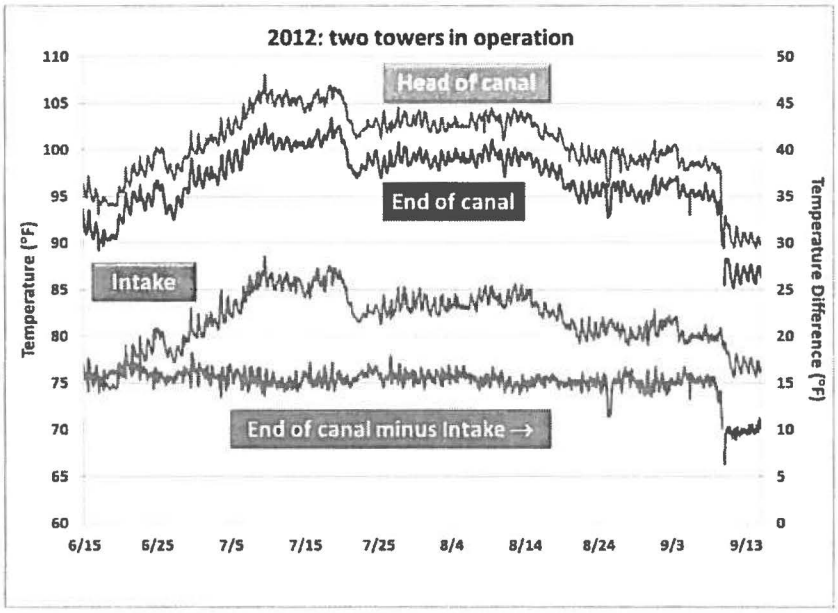



Figure 3-8. Cooling water station data, 2012.

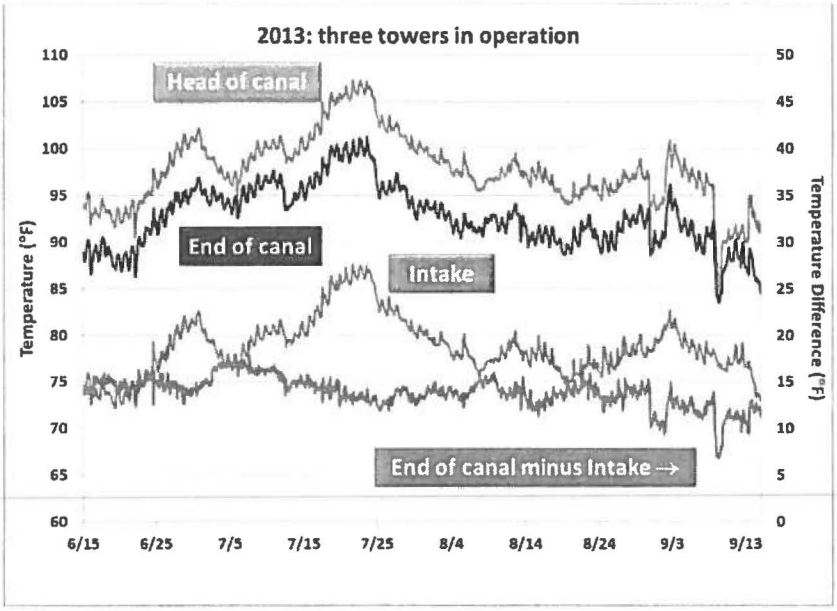



Figure 3-9. Cooling water station data, 2013.

The preceding graphical summaries of temperatures through the cooling water system show all data available for the June 15 to September 15 period. The analysis that follows here and in the next section examines the incremental cooling in Conowingo Pond due to the operation of an additional cooling tower both within the discharge canal and downstream in Conowingo Pond. This analysis uses data that begins July 1 rather than June 15 because, as noted earlier, the 2010 data begins later in the summer and although each year is different with respect to flows, temperatures and meteorological conditions, using consistent dates provides some commonality of conditions.

The temperature reductions in the discharge canal are summarized in Table 3-3 for the common data period (July 1 to September 15). The table shows that canal temperatures decrease as each tower is added. The incremental change in temperature can be calculated by taking the differences in temperature reduction and by recognizing the 0.2°F cooling that occurs in the canal. The table shows that temperature reductions at the end of the canal average 1.6°F when each additional cooling tower is operated.

Table 3-3. Summary of temperatures and temperature reductions in the discharge canal; averages for June 15 to September 15 data, when available.

| | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|
| | No towers | One tower | Two towers | Three towers |
| Head of Canal (°F) | 100.4 | 98.8 | 101.1 | 98.0 |
| End of Canal (°F) | 100.2 | 96.8 | 97.2 | 93.0 |
| Overall temperature reduction (°F) | 0.2 | 2.0 | 3.9 | 5.0 |
| Temperature reduction due to cooling tower(s) (°F) | 0.0 | 1.8 | 3.7 | 4.8 |
| | | First Tower | Second Tower | Third Tower |
| Average temperature reduction per cooling tower (°F) | 0.0 | 1.8 | 1.9 | 1.6 |

### *3.4 Effectiveness of Cooling Towers in Reducing Downstream Temperatures*

The analysis of cooling tower operations can be extended to a set of stations downstream of the discharge structure where thermal effects on aquatic resources, if any, could occur. An overview of the behavior of the thermal plume is helpful in understanding the results of this analysis.

The discharge structure releases heated water at 5 to 8 feet per second through fixed subsurface openings (Figure 2-3). The cooling water that emerges from the discharge structure is warmer than the adjacent waters of Conowingo Pond and therefore tends to rise to the surface. The cooling water is also moving substantially faster than the adjacent waters. Higher relative velocity promotes mixing with cooler water while buoyancy tends to restrict mixing. Mixing occurs when parcels of adjacent, cooler water are entrained into the plume. Entrainment is greatest when plume and ambient velocities are most different. However, the entrainment process reduces the temperature of the plume and its velocity to the point that entrainment ceases when the plume is no longer moving faster than adjacent waters.

Entrainment cannot occur along the western edge of the plume inasmuch as the supply of cool, ambient water is limited by the plume's close proximity to the shoreline. The presence of the shoreline also explains another feature of the PBAPS thermal plume; high Susquehanna River flows tend to bend the plume along the shoreline and reduce mixing because of a reduced velocity difference.

The point at which entrainment ceases is the end of the near-field region. The near-field plume can be distinguished in the field by pronounced velocity and temperature differences. In fact, the near-field is defined as the region where plume dimensions are controlled by the velocity induced by the discharge structure. The surface area of the near-field region is relatively small and although some heat is transferred to the atmosphere in this region, the majority of the heat transfer takes place over large distances in the far-field region.

In the far-field region, the plume is no longer clearly recognizable by a core of elevated temperature and high velocity. Its trajectory is controlled by ambient velocities rather than the velocities induced by the design of the discharge structure. Turbulent mixing has ceased and the mixing that does occur is due to processes common to unheated waterbodies: wind and

wave action, daytime heating and nighttime cooling as well as high flow events such as floods. However, most of the heat added by PBAPS is transferred to the atmosphere in the far-field where small temperature increases above equilibrium temperature act over very large areas.

The following analysis will show the amount of cooling directly attributable to the operation of the cooling towers. Cooling is readily measured at stations in the near-field. Far-field temperatures are also reduced by the operation of the cooling towers; however, these are more apparent when modeled than observed, as will be shown in Section 7.1.

The downstream reductions in temperature relative to the Head of the Canal Station are shown in Table 3-4. These reductions in temperature are the result of a combination (1) heat transfer to the atmosphere in the canal and cooling towers; (2) entrainment of ambient water into the thermal plume in the near-field; and, (3) heat transfer to the atmosphere over large areas in the far-field. In general, all stations show reductions in temperature as the number of operating cooling towers increases.

The relationship between incremental temperature reductions (Table 3-5) and the number of towers operating is not entirely linear and becomes less so farther downstream from the discharge canal. For example, at Station 215, the data indicate that the addition of a single tower can decrease temperatures by 1.3°F, 0.3°F, or 0.9°F. Farther downstream (e.g., Stations 189 and 401) the increment was negative, meaning an <u>increase</u> in temperature when another tower was added. The variations in temperature reductions are a consequence of changing Susquehanna River flows – high flows tend to push the thermal plume towards the western shoreline while promoting mixing with ambient water. The variations in temperature reductions are also a function of day-to-day weather which affects both cooling tower performance and cooling at the water surface.

The downstream stations shown in Table 3-4 and Table 3-5 can be more systematically studied by separating them into shoreline, nearshore and cross-river transects as shown in Figure 3-10. Table 3-6 shows cooling tower effectiveness along the shallow shoreline stations downstream of the discharge canal. This table shows that there are clear temperature reductions down to and some distance beyond Station 215. Downstream of Station 215, there are temperature increases when additional towers operate. Increases are likely due to variations in conditions from the 2010 base year, especially the fact that Stations 189 and 190 are not always in the plume. Station 190 is located around a bend in Conowingo Pond, and away from the downstream-directed plume trajectory.

For the nearshore stations which measure deeper, offshore water that aligns more with the plume (Table 3-7), there is definite temperature reduction with the addition of towers to Station 301. However, the reductions are a surface phenomenon, as shown in Table 3-8, which shows both reductions and increases in the lower part of the water column. The cross-river transect only shows consistent temperature reductions to Station 301 (Table 3-9).

Table 3-4. Downstream surface temperature reductions from the Head of Canal (°F); averages for June 15 to September 15 data, when available.

| Station | Distance (miles) | Temperature Reduction (°F) | | | | Primary temperature reduction process |
|---|---|---|---|---|---|---|
| | | No towers | One tower | Two towers | Three towers | |
| | | 2010 | 2011 | 2012 | 2013 | |
| Head of Canal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | Cooling towers (when operating) |
| End of Canal | 0.9 | 0.2 | 2.0 | 3.9 | 5.0 | |
| 214 | 1.2 | 6.7 | 8.3 | 8.8 | 10.0 | Entrainment |
| 201 | 1.3 | 11.7 | 12.4 | 13.9 | 14.6 | |
| 215 | 1.5 | 8.4 | 9.7 | 10.0 | 10.9 | |
| 301 | 2.1 | 9.6 | 9.8 | 11.9 | 12.5 | Heat transfer to the atmosphere |
| 189 | 2.2 | 13.0 | 13.1 | 13.0 | 13.9 | |
| 401 | 2.9 | 13.8 | 14.5 | 15.4 | 15.2 | |
| 611 | 7.8 | 13.8 | 13.8 | 15.0 | 15.3 | |

Table 3-5. Incremental surface temperature reductions as towers are added (°F); averages for June 15 to September 15 data, when available.

| | Distance (miles) | **Incremental** Temperature Reduction (°F) | | |
|---|---|---|---|---|
| | | First Tower | Second Tower | Third Tower |
| Head of Canal | 0.0 | - | - | - |
| End of Canal | 0.9 | 1.8 | 1.9 | 1.2 |
| 214 | 1.2 | 1.6 | 0.5 | 1.2 |
| 201 | 1.3 | 0.7 | 1.5 | 0.7 |
| 215 | 1.5 | 1.3 | 0.3 | 0.9 |
| 301 | 2.1 | 0.2 | 2.1 | 0.6 |
| 189 | 2.2 | 0.2 | -0.2 | 1.0 |
| 401 | 2.9 | 0.7 | 0.9 | -0.2 |
| 611 | 7.8 | 0.0 | 1.2 | 0.4 |

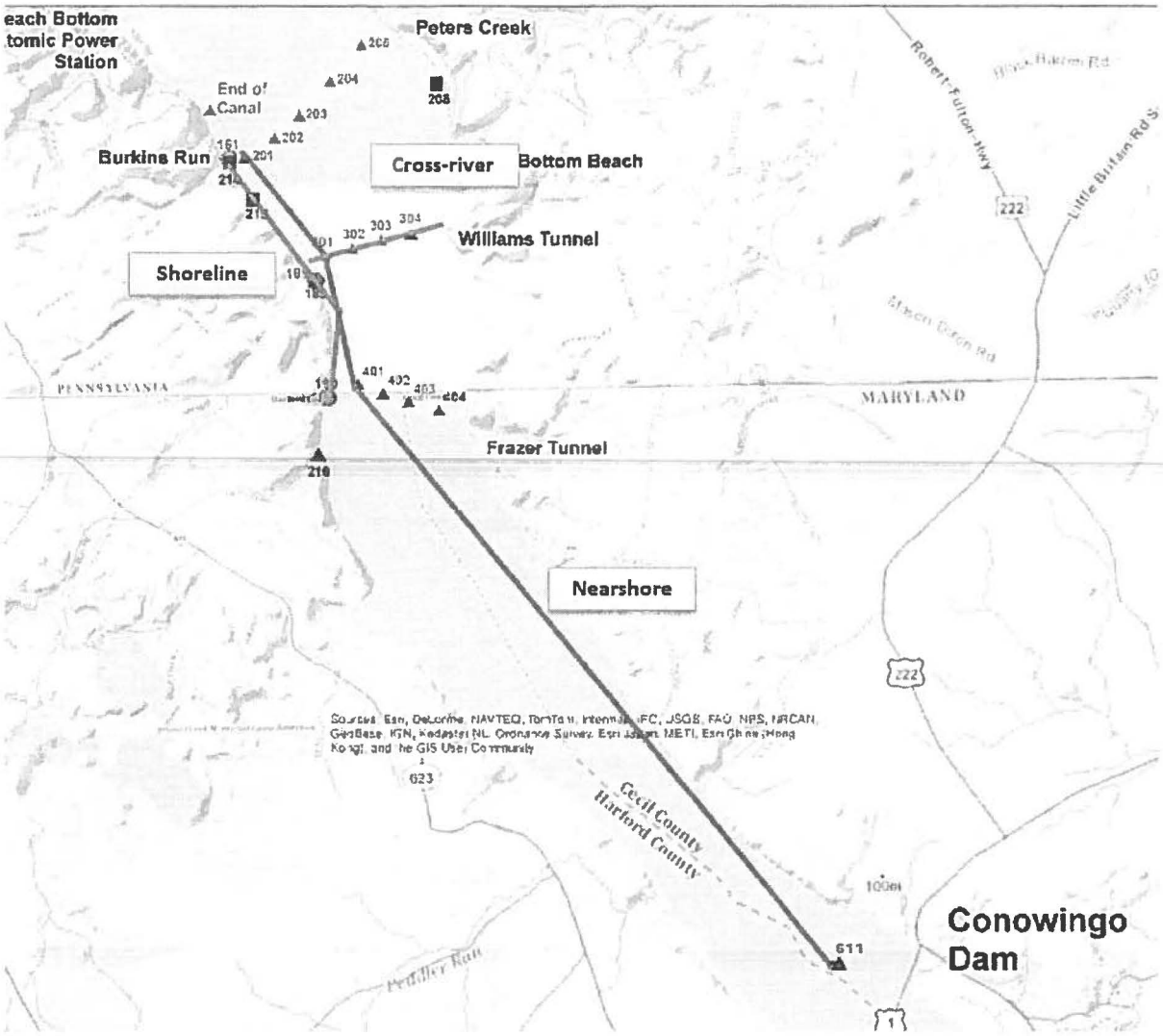



Figure 3-10. Transects and stations used in the cooling tower analysis.

Table 3-6. Incremental temperature reductions at shoreline stations; averages for June 15 to September 15 data, when available.

| | | Incremental Temperature Reduction (°F) | | | |
|---|---|---|---|---|---|
| Station | Distance (mi) | First Tower | Second Tower | Third Tower | All Towers |
| End of Canal | 0.00 | 1.8 | 1.9 | 1.2 | 4.9 |
| 214 | 0.37 | 1.6 | 0.5 | 1.2 | 3.3 |
| 215 | 0.65 | 1.3 | 0.3 | 0.9 | 2.5 |
| 189 | 1.32 | 0.2 | -0.2 | 1.0 | 1.0 |
| 190 | 2.05 | 0.2 | -1.0 | 1.2 | 0.4 |

Table 3-7. Incremental temperature reductions at nearshore stations – surface; averages for June 15 to September 15 data, when available.

| | | Incremental Temperature Reduction (°F) | | | |
|---|---|---|---|---|---|
| Station | Distance (mi) | First Tower | Second Tower | Third Tower | All Towers |
| End of Canal | 0.00 | 1.8 | 1.9 | 1.2 | 4.9 |
| 201 | 0.39 | 0.7 | 1.5 | 0.7 | 2.9 |
| 301 | 1.22 | 0.2 | 2.1 | 0.6 | 2.9 |
| 401 | 2.05 | 0.7 | 0.9 | -0.2 | 1.4 |
| 611 | 6.95 | 0.0 | 1.2 | 0.4 | 1.6 |

Table 3-8. Incremental temperature reductions at nearshore stations – bottom; averages for June 15 to September 15 data, when available.

| | | Incremental Temperature Reduction (°F) | | | |
|---|---|---|---|---|---|
| Station | Distance (mi) | First Tower | Second Tower | Third Tower | All Towers |
| End of Canal | 0.00 | 1.8 | 1.9 | 1.2 | 4.9 |
| 201 | 0.39 | -0.3 | 1.0 | 0.0 | 0.8 |
| 301 | 1.22 | -0.3 | 1.1 | 0.1 | 0.9 |
| 401 | 2.05 | -1.3 | 1.0 | 0.9 | 0.5 |
| 611 | 6.95 | -1.5 | 2.5 | 1.1 | 2.1 |

Table 3-9. Incremental temperature reductions at cross-river stations – surface ; averages for June 15 to September 15 data, when available.

| | | Incremental Temperature Reduction (°F) | | | |
|---|---|---|---|---|---|
| Station | Distance (mi) | First Tower | Second Tower | Third Tower | All Towers |
| End of Canal | 0.00 | 1.8 | 1.9 | 1.2 | 4.9 |
| 301 | 1.22 | 0.2 | 2.1 | 0.6 | 2.9 |
| 302 | 1.31 | 1.3 | 0.9 | 1.6 | 3.8 |
| 303 | 1.42 | -0.2 | 0.8 | 1.5 | 2.1 |
| 304 | 1.56 | 1.8 | 0.7 | 1.4 | 3.9 |

### *3.5 Conclusions*

Each of the four objectives of the temperature monitoring program was met:

- Temperatures were recorded at the biological sampling stations and subsequently used to interpret biological data;
- Temperatures throughout the Pond were measured over a representative range of Susquehanna River flows and temperatures, including periods of very low flows and high temperatures;
- Temperature data were obtained for typical operations at Holtwood, Muddy Run, PBAPS, and Conowingo operations; and
- Temperature data were used for hydrothermal model calibration and validation.

Analysis of the temperature data showed that:

- 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 where reductions were variable and related to ambient temperatures and Susquehanna River flows.

# 4 Representative Important Species (RIS)

Eleven fish species are designated as RIS for this demonstration as agreed upon with PADEP and in accordance with the study plan (Normandeau Associates *et al.* 2010). Nine of the species were evaluated as RIS in previous thermal effects demonstrations for PBAPS and were retained for this demonstration as agreed upon with PADEP. Most continue to be 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. Two new fishes, Chesapeake Logperch and White Sucker, were added as RIS for this Demonstration at the request of PADEP. Although no federally-listed threatened or endangered species are present in Conowingo Pond, the Chesapeake Logperch was added because it was a candidate species in Pennsylvania at the start of the study. Subsequently, in December 2012, it was listed as threatened by Pennsylvania. The White Sucker is included because it is more thermally sensitive than many of the other RIS. No migratory fish are included as RIS. The eleven RIS are:

- Bluegill (*Lepomis macrochirus*)
- Bluntnose Minnow (*Pimephales notatus*)
- Channel Catfish (*Ictalurus punctatus*)
- Gizzard Shad (*Dorosoma cepedianum*)
- Largemouth Bass (*Micropterus salmoides*)
- Logperch (*Percina caprodes*) renamed Chesapeake Logperch (*P. bimaculata*)
- Smallmouth Bass (*Micropterus dolomieu*)
- Spotfin Shiner (*Cyprinella spiloptera*)
- Walleye (*Sander vitreus*)
- White Crappie (*Pomoxis annularis*)
- White Sucker (*Catostomus commersonii*)

This section provides basic life history and habitat preference information for each of the RIS.

## *4.1 Bluegill*

Bluegill is a numerically abundant, recreationally important panfish that is widely distributed in shallow and deep habitats in Conowingo Pond. The species is prey for top carnivore species such as Largemouth Bass, Smallmouth Bass, Flathead Catfish, and Walleye.

Bluegill is most abundant along shoreline areas in lentic and lentic type environments such as ponds, lakes, reservoirs, and large, low velocity streams (Whitmore *et al.* 1960). In riverine habitats, Bluegill is mostly restricted to areas of low velocity (Hubbs and Lagler 1958). Adults prefer current velocities <0.3 ft/sec, but will tolerate up to 1.5 ft/sec (Hardin and Bovee 1978). In riverine environments, nest sites are selected for low flow velocity. Optimal lacustrine habitat is characterized by fertile lakes, ponds, and reservoirs with extensive littoral areas (Emig 1966; Scott and Crossman 1973). However, deeper areas are also required for overwintering and retreat from the summer heat (Scott and Crossman 1973). Cover in both lacustrine and riverine habitats in the form of submerged vegetation or logs and brush is utilized by the species, especially juveniles and small adults (Moyle and Nichols 1973; Scott and Crossman 1973).

Nests are usually found in quiet, shallow 3.3-9.8 ft water (Swingle and Smith 1943). Although spawning can occur over almost any substrate, fine gravel or sand is preferred (Stevenson *et al.* 1969; Pflieger 1975).

### *4.2 Bluntnose Minnow*

Bluntnose Minnow is a numerically important prey species and together with Comely Shiner (*Notropis amoenus*), Spottail Shiner (*Notropis hudsonius*) and Spotfin Shiner represents an important forage base for the larger carnivorous fishes. The Bluntnose Minnow occupies a broad range of habitats including lakes, ponds, rivers, and streams. They prefer shallow areas of clear water with sand and gravel bottoms, but they are also found over mud and silt and/or aquatic vegetation. The Bluntnose Minnow exhibits great habitat plasticity (Jenkins and Burkhead 1993).

The spawning of Bluntnose Minnow typically occurs between late May and September. Spawning takes place in pool shallows beneath stones or debris. When natural cavities are lacking, sometimes the male burrows through the silt to create a space beneath an object. The eggs are usually deposited in the cavities in a single layer, rarely in clumps (Jenkins and Burkhead 1993). Females of this genus are fractional spawners, i.e., they discharge eggs more than once during a spawning period (Gale 1983). Males defend the nest.

### *4.3 Channel Catfish*

Channel Catfish is abundant and widely distributed in Conowingo Pond and is important to anglers. It is most numerous in bottom trawl samples but is also among the most numerous species taken by electrofishing.

Optimum riverine habitat for Channel Catfish is characterized by warm temperatures (Andrews *et al.* 1972) and a diversity of velocities, depths, and structural features that provide cover and food (Bailey and Harrison 1948). Optimum lacustrine habitat is characterized by large surface area, warm temperatures, high productivity, low to moderate turbidity, and abundant cover (Davis 1959; Pflieger 1975).

Fry, juvenile, and adult Channel Catfish concentrate in the warmest sections of rivers and reservoirs (Ziebell 1973; Stauffer *et al.* 1975; McCall 1977). They strongly seek cover. Debris, logs, cavities, boulders, and cut banks in lakes and in low velocity (0.5 ft/sec) areas of deep pools and backwaters of rivers will provide cover for Channel Catfish (Bailey and Harrison 1948). Cover consisting of boulders and debris in deep water is important as overwintering habitat (Miller 1966; Jester 1971; Cross and Collins 1975). Deep pools and littoral areas (> 16 ft deep) with > 40% suitable cover are assumed to be optimum.

Channel Catfish usually spawn in secluded semi-darkened nests adjacent to large rocks, log jams, in holes, and in other types of cavities (Harlan *et al.* 1987).

### *4.4 Gizzard Shad*

Gizzard Shad is the most abundant fish in Conowingo Pond and the young are important prey species. It was inadvertently introduced into (approximately 100 individuals) Conowingo Pond in 1972 (two years prior to PBAPS start-up) during American Shad trial transports. Hundreds of

thousands of Gizzard Shad are transported into Conowingo Pond each spring via the East Fish Lift at Conowingo Dam. This species is often the most abundant species in trawl and electrofishing samples. It uses other upstream fishways as well and has become well established throughout the lower Susquehanna River.

The Gizzard Shad is common in lakes, oxbows, impoundments, sloughs and large rivers with low gradients (Etnier and Starnes 1993), but reaches greatest abundance in waters where fertility and productivity are high (Robison and Buchanan 1988). Gizzard Shad avoid high gradient streams and rivers in the mountains and rivers without large, permanent pools, but can tolerate moderately turbid and, occasionally, even brackish or salt waters (Trautman 1981; Robison and Buchanan 1988).

The Gizzard Shad prefers living in open water, at or near the surface (Becker 1983; Harlan *et al.* 1987). The young may select for areas of aquatic vegetation (Hubbs and Lagler 1943). If the oxygen supply is adequate, the species may descend to depths as great as 108 feet, as in Norris Reservoir, Tenn. (Dendy 1945). In the Coosa River, Alabama, Gizzard Shad were found in deep (greater than 25 feet) as well as shallow water (Scott 1951).

Typically found traveling in schools, juveniles are non-visual planktivores, most commonly utilizing zooplankton and phytoplankton in the diet. Adults are primarily bottom filter-feeding detritivores; eating large quantities of organisms attached to underwater surfaces, especially from littoral areas. Gizzard Shad also feed on phytoplankton in open water (Sublette *et al.* 1990).

Gizzard Shad spawn in spring and early summer, usually in shallow water when water temperatures reach 50°F to 70°F (Williamson and Nelson 1985). Spawning usually occurs at near surface depths (1.0 to 5.2 ft), but sometimes as deep as 49 ft, and sometimes over vegetation or debris (Jones *et al.* 1978, Miller 1960, Wang and Kernehan 1979). Spawning groups swim near the surface and roll about as a mass, ejecting eggs and sperm (Miller 1960). Eggs are demersal and, after slowly sinking, adhere to algae, rocks, and other objects (Miller 1960). Young-of-the-year Gizzard Shad travel in compact schools soon after hatching, but by fall most of the schools disperse and few form the following spring, at least in Norris Reservoir; schooling largely ceases by the time the shad are a year old (Dendy 1946).

### *4.5 Largemouth Bass*

Largemouth Bass is greatly valued by anglers and is found more abundantly in the southern half of Conowingo Pond as compared to the Smallmouth Bass which is more numerous in the northern half. Lacustrine environments are the preferred habitat of Largemouth Bass (Emig 1966; Scott and Crossman 1973). Optimal riverine habitat for Largemouth Bass is characterized by large slow moving rivers or pools of streams with soft bottoms, some aquatic vegetation, and relatively clear water (Trautman 1981; Larimore and Smith 1963; Scott and Crossman 1973). Deacon (1961) reported that Largemouth Bass abundance increased in rivers during dry years when the flow was reduced and the water pooled. Thus, it is assumed that a river with a high percent (~ 60%) of pool and backwater area is optimal. Largemouth Bass has considerable

tolerance to high water temperatures as demonstrated by its widespread distribution in the southern United States.

Much like Bluegill and Smallmouth Bass, males prepare a nest over clean hard substrates, spawn singly with one or more females in the nest, and then drive away all other fishes and other large invaders. A gravel substrate is preferred for spawning (Robinson 1961; Mraz 1964), but Largemouth Bass will nest on a wide variety of other substrates, including vegetation, roots, sand, mud, and cobble (Harlan *et al.*1987; Mraz *et al.* 1961). Nests are constructed by the male at water depths averaging 1 to 3 ft, with depths ranging from about 0.5 to 25 ft (Allan and Romero 1975). The adhesive eggs in the nests are aerated by swimming motions of the male, and the eggs and young are guarded against predators.

### *4.6 Chesapeake Logperch*

Chesapeake Logperch is a small to medium size fish (length up to 7 in) in the perch family. The Chesapeake Logperch was recently removed from taxonomic synonymy with the widely distributed Logperch (*Percina caprodes*) and recognized as a distinct and valid species with limited distribution restricted to the Chesapeake Bay watershed (Near 2008). Little is known about this species and its habitats, but it occurs primarily in larger waterways and lowermost sections of tributaries. Chesapeake Logperch occurs in the lower Susquehanna River primarily in tributaries to the Conowingo Pond and below Conowingo Dam and occurs sporadically in Conowingo Pond.

Logperch inhabit mud-bottomed, sandy, gravelly and rocky areas in big lakes. They can be found living over those bottom types in large rivers. They tend to stay offshore in water deeper than three or four feet, and have been captured at depths of more than 130 feet in Lake Erie. Logperch tolerate a wide variety of habitats. During its spawning runs, the Logperch swims from the larger waterway in which it makes its usual home into smaller tributary streams, where for a short time the fish is abundant (Etnier and Starnes 1993).

Logperch relate intimately to bottom substrate. At night Logperch seek cover and become quiescent (Emery 1973). Trautman (1981) reported that during sunny days they hide under rocks or bury in sand with only the eyes exposed. Logperch feed benthically and may overturn stones by using their snouts to uncover food items (Jenkins and Burkhead 1993).

### *4.7 Smallmouth Bass*

Smallmouth Bass is highly valued by anglers but, like other game fishes that are present in the fish community in Conowingo Pond, it occurs in relatively low numbers. While commonly considered a cool water species, Smallmouth Bass has considerable tolerance to high water temperatures, as demonstrated by its widespread distribution in the southern United States and tolerance to high water temperatures as reported by Wrenn (1980), Mathur *et al.* (1983) and others.

Smallmouth Bass prefer large, clear lakes and clean streams with abundant cover. It is an important sport fish in the Susquehanna River, particularly in the riverine reaches and larger tributaries. Smallmouth Bass is usually more numerous in the upstream reaches of reservoirs, as is the case in Conowingo Pond.

Smallmouth Bass spawn on rocky lake shoals, river shallows, or backwaters or move into creeks or tributaries to spawn (Harlan *et al.* 1987, Coble 1975, Clancey 1980). Smallmouth Bass spawned in warm sloughs or backwater areas bordering the Columbia River (Montgomery *et al.* 1980). The species requires a clean stone, rock, or gravel substrate for spawning (Robbins and MacCrimmon 1974). Studies show that the habitat condition during spawning is the most important factor for year class strength in Smallmouth Bass (Clancey 1980).

Smallmouth Bass exhibits strong, cover-seeking behavior and prefer protection from light in all life stages (Coble 1975; Miller 1975). Deep, dark quiet water is used for cover (Coble 1975), but bass use all forms of submerged cover, such as boulders, rocks, stumps, root-masses, trees, and crevices, without apparent preference for any one type (Hubert and Lackey 1980).

In lakes and reservoirs, adults most often use cooler areas, such as drop-offs, that are away from vegetation and in water <39 ft deep (Scott and Crossman 1973; Coble 1975). In a Tennessee River reservoir, adults were frequently in water >33 ft deep during the summer (Hubert and Lackey 1980).

Nests are usually constructed in water from 1 to 3 ft deep (Coble 1975), but may be built in water up to 23 ft deep (Mraz 1964; Robbins and MacCrimmon 1974). Nests are commonly in gravel or broken rock (Latta 1963; Mraz 1964); near boulders, logs, or other cover (Scott and Crossman 1973); in shallows or backwaters of streams (Clancey 1980); or in protected bays or shoals in lakes (Robbins and MacCrimmon 1974). Nests are also made over bedrock, rootlets in silt, or sand, but these substrates are less commonly used (Cleary 1956; Latta 1963; Scott and Crossman 1973). Nests are usually in areas of quiet water (Pflieger 1975) or very slow current (Robbins and MacCrimmon 1974).

### *4.8 Spotfin Shiner*

Spotfin Shiner, a small-bodied minnow like the Bluntnose Minnow and Comely Shiner, is a numerically important member of the fish community throughout Conowingo Pond and serves as an important prey item for top carnivore fishes. It is a warm water species and is most characteristic of medium to large streams and rivers (Jenkins and Burkhead 1993). It is found over mud, sand and gravel (Becker 1983). In Conowingo Pond, Spotfin Shiner was found mostly in shallow nearshore habitats sampled by seine and electrofishing and not in the more open-water and bottom habitats sampled by bottom trawl.

The Spotfin Shiner is an active mid-depth feeder on drift and to a lesser degree on bottom organisms (Jenkins and Burkhead 1993).

Spotfin Shiner is a scatter spawner and typically spawns in shallow runs or riffles, either on unmodified gravel substrate or over minnow nests, sucker redds, or nests of other species or on the underside of submerged logs and roots (Pflieger 1975, R. J. Miller 1964). Spawning sites are chosen over irregular surfaces so the eggs can be deposited into small crevices where they are safe through incubation.

### *4.9 Walleye*

Walleye is of interest to anglers in Conowingo Pond but, like Smallmouth Bass and Largemouth Bass, has never been numerically important in the sampling programs for PBAPS. Walleye tolerate a wide variety of environmental conditions but are reported to be most abundant in large-to-medium lakes and riverine systems characterized by cool temperatures, shallow to moderate depths, moderate turbidities, extensive littoral areas, extensive areas of clean rocky substrate, and mesotrophic conditions (McMahon and Nelson 1984).

Adult Walleye generally are found under cover in moderately shallow (< 50 ft) waters during the day and move inshore at night to feed (Johnson and Hale 1977; Ryder 1977). Adults often are found in areas with slight currents (Ryder 1977), except during the winter when they tend to avoid turbulent areas (Colby *et al.* 1979).

Habitat requirements for juvenile Walleye seem to be similar to those of adults (Colby *et al.* 1979). The critical velocity for juveniles with a fork length of 7.9 in is 2 ft/sec (Jones *et al.* 1974).

Preferred spawning habitats are shallow shoreline areas, shoals, riffles, and dam faces with rocky substrate and good water circulation from wave action or currents (Johnson 1961; Colby *et al.* 1979).

### *4.10 White Crappie*

White Crappie had historically been an abundant and recreationally important panfish in Conowingo Pond but, following introduction in the 1970's of Gizzard Shad with which it competes for planktonic food when young, is no longer numerically important in the fish community. It occupies both pelagic and shoreline habitats. White Crappie can be abundant as pelagic schools in turbid reservoirs. Spawning occurred in shallow water (< 10 ft) in association with submerged aquatic vegetation and gravel/stone substrates (Cooper 1983). White Crappie are most numerous in base-level, low gradient rivers (Trautman 1981; Smith and Powell 1971).

### *4.11 White Sucker*

The monitoring data show that White Sucker is not numerically important in Conowingo Pond, but it is one of the most thermally sensitive species in the fish community. White Sucker is more numerous in small rivers and streams rather than major rivers and is also found in warm and shallow lakes and tributary rivers of larger lakes. In many North American lakes and reservoirs, each year in early spring large numbers of White Sucker migrate up tributary streams to spawn. White Sucker also is very tolerant of pollution, turbidity, and low oxygen levels.

White Sucker feeds primarily upon the bottom (except for a short period of life during which they feed upon plankton near the surface), consuming midge larvae and small crustaceans, aquatic insects and other arthropods, snails, clams, fish eggs, and detritus (Jenkins and Burkhead 1993).

Stream populations of White Sucker reach maximum abundance in low to moderate gradient streams (Stewart 1926). Larger White Sucker (>6 in TL) primarily inhabit pools (Propst 1982) and are common in areas of slow to moderate velocity (approximately 1.3 ft/sec), although

smaller individuals (<6 in TL) occur in a greater variety of habitats than adults (Scherer 1965, Pflieger 1975, Propst 1982).

# 5 Biological Monitoring and Assessment

## *5.1 Introduction*

This section describes the benthic macroinvertebrate and fisheries components of the thermal effects study as well as the temperature monitoring at the biological stations. As described in the Study Plan, the primary objectives of the biological monitoring component of the study are to:

- Document the spatial and temporal distribution of fishes within the thermal plume and relative to areas of the Pond outside of the thermal plume;
- Document the relative abundance of fishes within the thermal plume and relative to areas of the Pond outside of the thermal plume;
- Determine the relative condition of fishes within the thermal plume and relative to areas of the Pond outside of the thermal plume;
- Document the spatial and temporal distribution of benthic macroinvertebrates within the thermal plume and relative to areas of the Pond outside of the thermal plume; and
- Document the relative abundance of benthic macroinvertebrates within the thermal plume and relative to areas of the Pond outside of the thermal plume.

Sampling for the first year of the monitoring program, 2010, was performed in July through October. During 2011 - 2013 biological collections were completed monthly from April through October, with additional boat electrofishing sampling completed during winter (January-March) 2011, 2012, and 2013. Temperature monitoring at the biological monitoring stations was restricted to July to October 2010 and April to October for 2011 through 2013.

Overall, during the 4 years of the study a total of 224 benthic macroinvertebrate samples were collected at a total of 10 stations (Figure 5-22). For fish, extensive collections were completed to determine their distribution and relative abundance within and outside of the thermal plume. A total of 673 collections were completed using trawl, seine, and boat electrofisher at 30 stations (Figure 5-22 through Figure 5-24). Figure 5-25 provides the location of both benthic macroinvertebrate and fish collection stations.

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

## *5.2 Biological Station Temperatures*

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, electrofishing, and seining collection stations. 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, can resolve temperatures to 0.04°F at 77°F, and have a five-minute response time in water. The loggers recorded water temperature every 15 minutes and were located in shallow shoreline locations (<5 ft water depth) on the river bottom where complete mixing of the water column occurs (see Section 3 for monitoring detail).

For the purposes of this analysis, a subset of the monitoring stations not influenced by the thermal plume (208, 220, PBAPS Intake) and all thermally influenced stations (214, 215, 189, 190, 216, and 217) will be characterized. The PBAPS Intake monitor was installed specifically for this study and is at a different location than the station's water temperature monitor used for operational purposes. 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 phenomena is coincident with River flows less than 12,000 cfs and MRPSF pumpback operations (Normandeau and Gomez and Sullivan Engineers 2012). Additionally, Station 208 is located along Peach Bottom Beach, a shallow portion of the Pond which experiences solar heating and limited water flow during lower flow conditions. 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.

Water temperatures measured in Conowingo Pond over the course of the study period (April 1 to October 31) followed a typical seasonal pattern for the Susquehanna River with warmest temperatures observed during July and August. Figure 5-1 through Figure 5-18 provide daily mean and daily instantaneous maximum water temperatures for each monitoring location during each year of the study. The highest water temperatures at the biological monitoring stations were observed in July and August at Station 214, which is along the west shoreline and is the monitoring location closest to the end of the PBAPS discharge canal. 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 220, which is upstream from the PBAPS intake along the west shoreline.

Inter-annual variation in water temperature was also evident with 2010 generally warmer than 2012 and 2012 generally warmer than 2011. Water temperatures in 2013 were generally cooler than the 2010, 2011, or 2012 with ambient water temperatures exceeding a daily mean of 80°F for only a short portion of June and August, and a few weeks in July (Figure 5-1 and Figure 5-2). The greatest contrast in ambient water temperatures among years occurred during mid-July through August 2013 when temperatures have typically been the highest. In 2013 ambient water temperatures were 6-8°F lower from mid-July through August compared to the same time period during the previous three years (Figure 5-1 and Figure 5-2). A similar pattern of lower water temperatures during mid-July through August in 2013 was also observed at the thermally influenced locations (Figure 5-4 through Figure 5-9). Water temperature was generally cooler in 2013 with fewer days of temperature exceeding 90°F as daily or instantaneous maximum at the thermal stations (Table 5-1 through Table 5-4). However, the number of days that exceeded 80°F as instantaneous maximum at the thermal stations was higher in 2013. This resulted from ambient water temperatures being warmer in May and October 2013 compared to the previous years.

Weekly swings in water temperature resulting from variation in ambient temperature were also evident. For example, Station 215 water temperatures were warmer in 2012 from the end of June through mid-July and then warmer during 2011 for the remainder of July (Figure 5-5). This

pattern of inter-annual variation was evident at both the upstream and downstream stations and is related to the complex interaction of ambient water temperatures and River flows.

Table 5-1 through Table 5-4 provide a summary of the of the instantaneous maximum and mean daily water temperatures for the monitoring locations during each year of the study. Each table provides a count of the number of days that instantaneous and daily mean water temperature exceeded 80 and 90°F for each station. The basis for these two water temperature values was that 80°F corresponds to a normal summer condition (discussed further in Section 7) and 90°F corresponds to a temperature that does not typically occur under natural conditions in the Pond. The purpose was to provide a comparison of these two temperature points among the monitoring stations.

In 2013, water temperatures were cooler than the previous years, with a fewer number of days that ambient water temperatures exceeded 80°F as instantaneous maximum or daily mean. Similarly, the thermally influenced stations in 2013 had a fewer 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 2012 for all locations. However, the water temperatures observed in 2010 were also high but the monitoring period was abbreviated (not initiated until July 28) and not directly compareable 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. 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 and August, 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 elucidated in comparisons of fish and benthic macroinvertebrate community composition (e.g. species richness, diversity and evenness) between thermally influenced and non-thermally influenced collection locations.

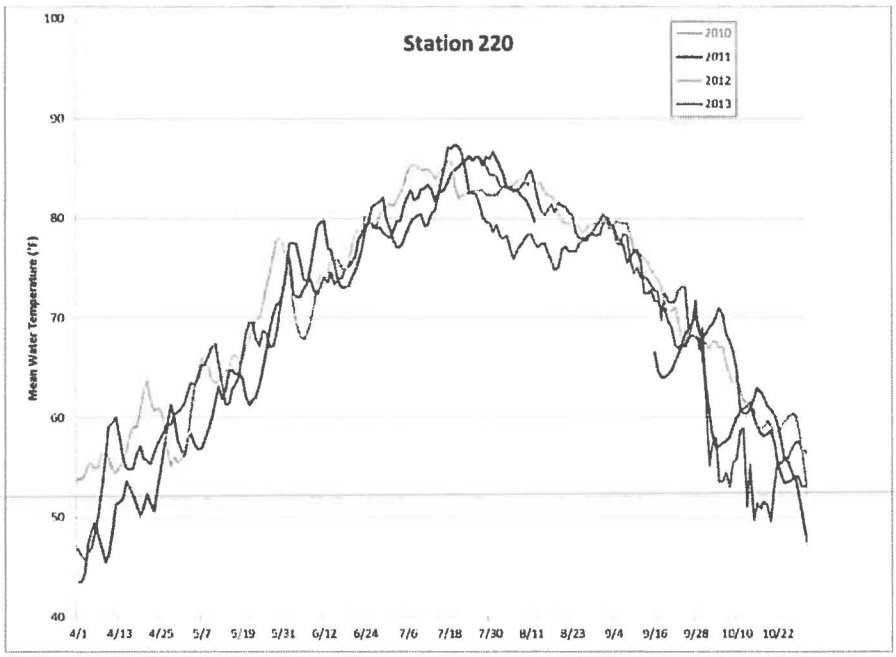



Figure 5-1. Daily mean water temperature measured at Station 220, 2010-2013.

Data not recovered for portions of August and September.

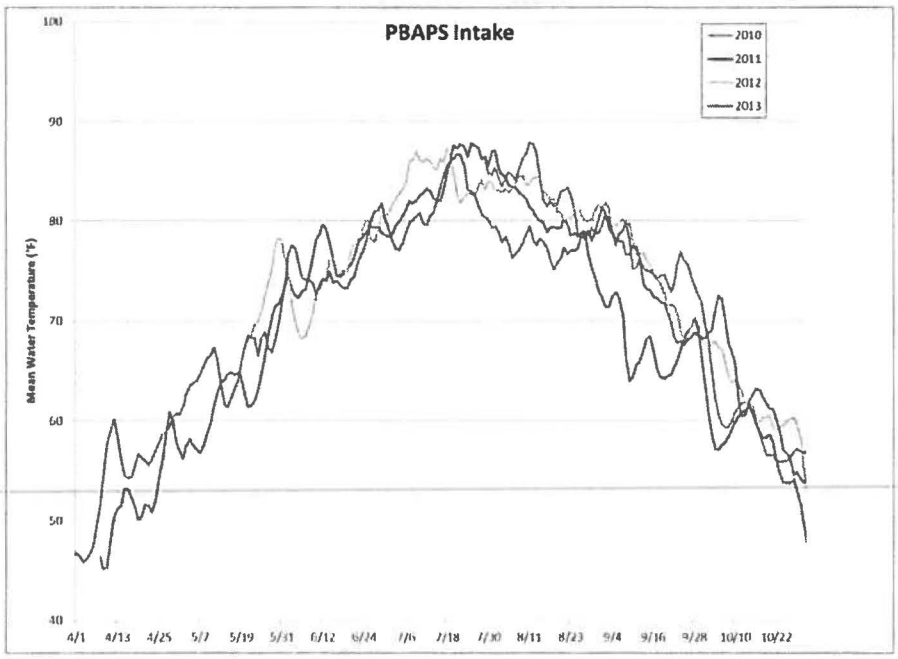



Figure 5-2. Daily mean water temperature measured at PBAPS Intake, 2010-2013.

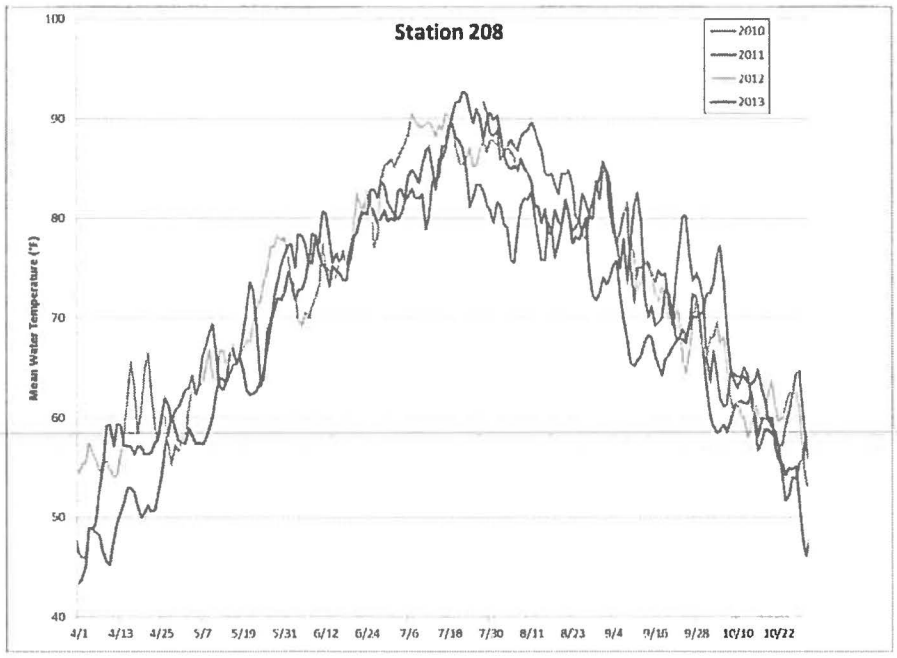



Figure 5-3. Daily mean water temperature measured at Station 208, 2010-2013.

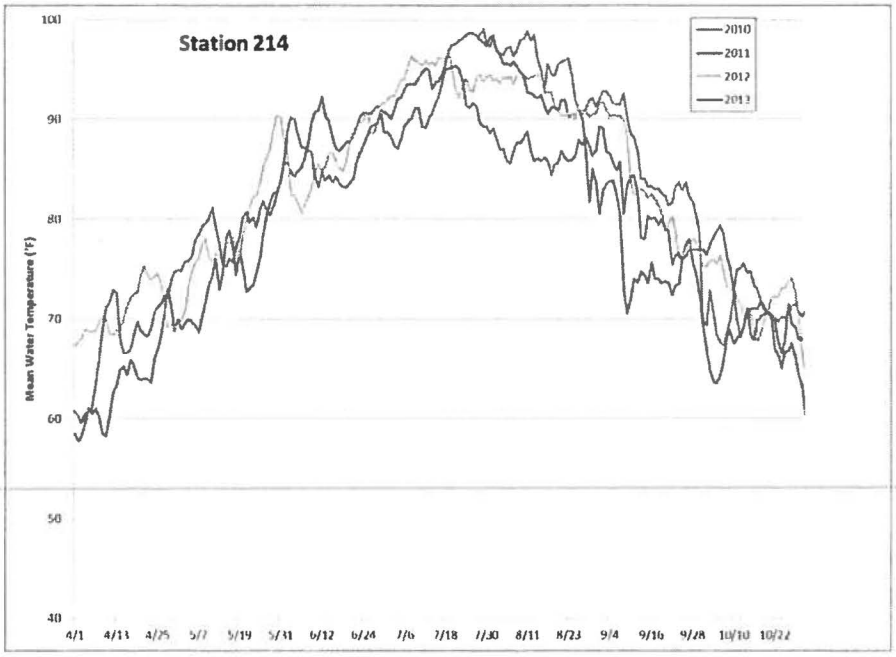



Figure 5-4. Daily mean water temperature measured at Station 214, 2010-2013.

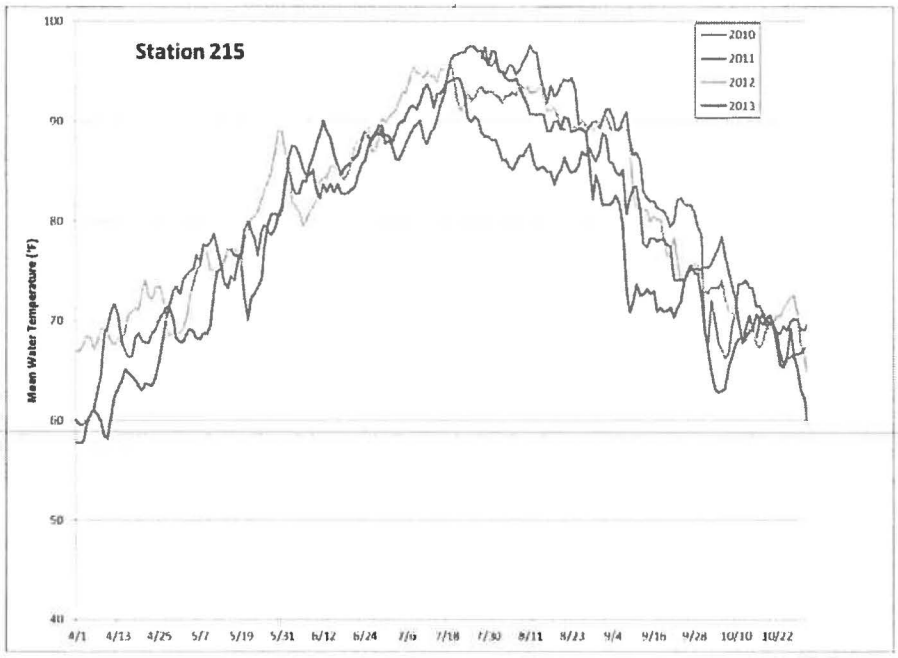



Figure 5-5. Daily mean water temperature measured at Station 215, 2010-2013.

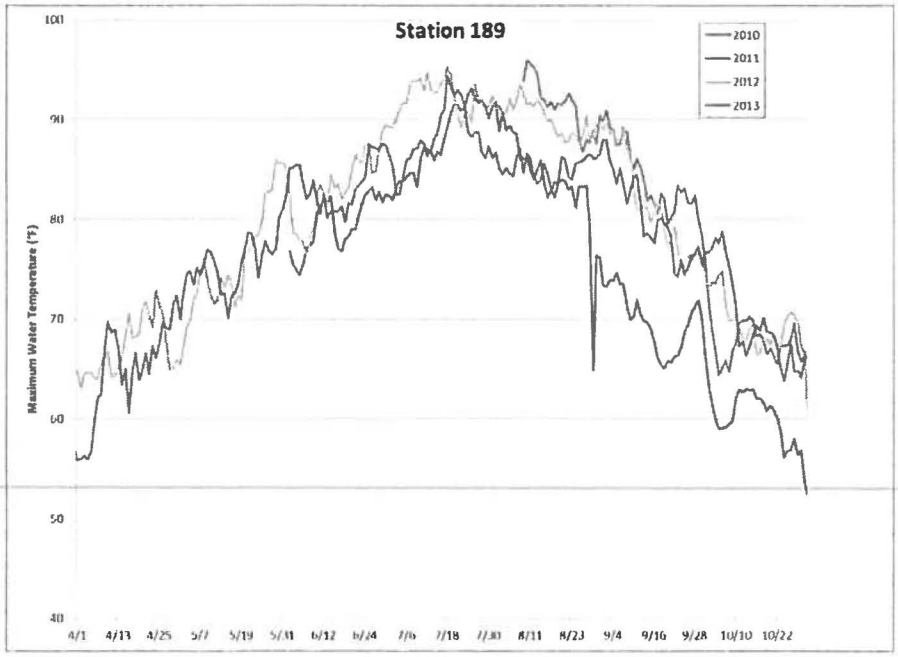



Figure 5-6. Daily mean water temperature measured at Station 189, 2010-2013.

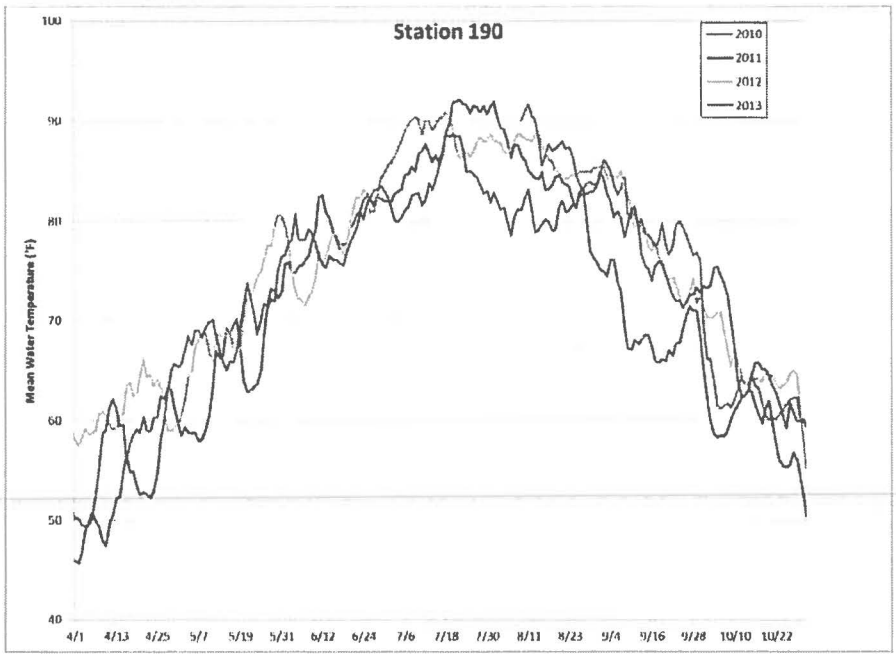



Figure 5-7. Daily mean water temperature measured at Station 190, 2010-2013.

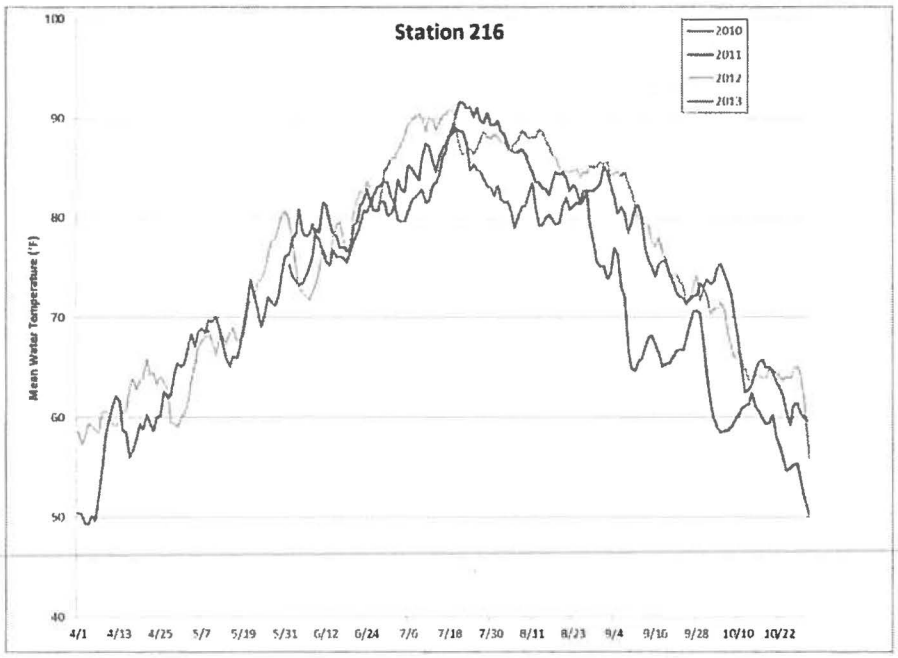



Figure 5-8. Daily mean water temperature measured at Station 216, 2010-2013.

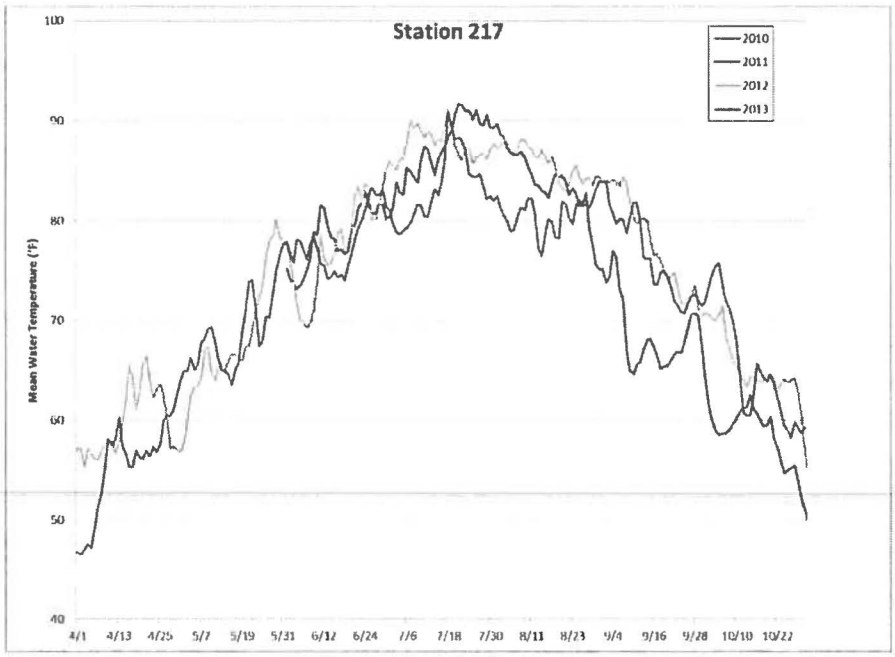



Figure 5-9. Daily mean water temperature measured at Station 217, 2010-2013.

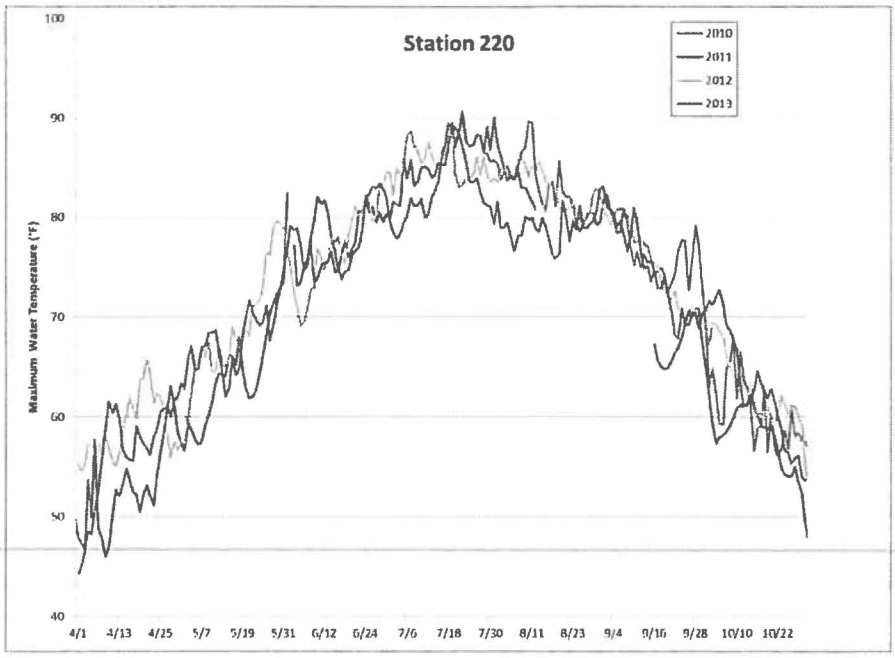



Figure 5-10. Daily maximum instantaneous water temperature measured at Station 220, 2010-2013.

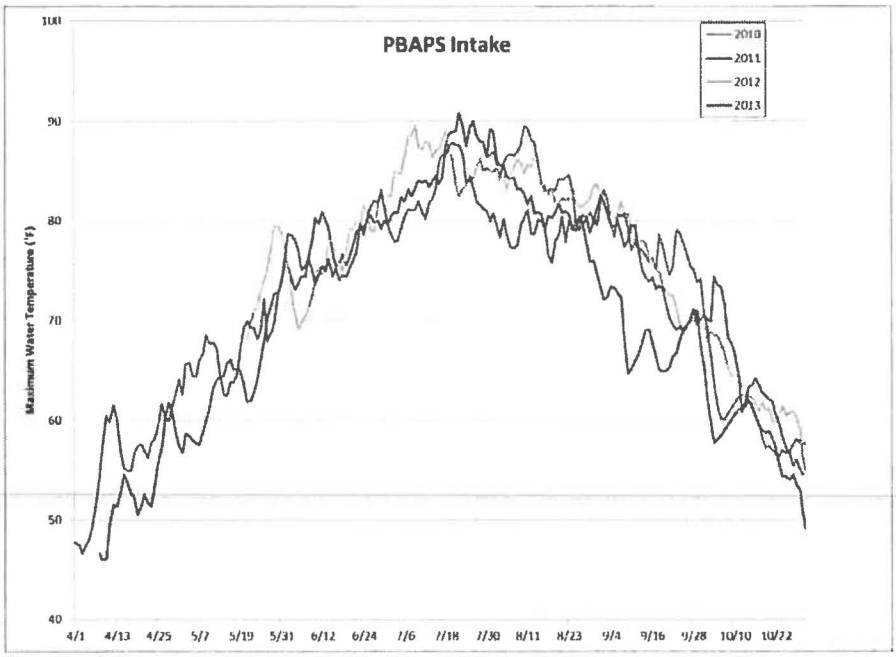



Figure 5-11. Daily maximum instantaneous water temperature measured at PBAPS Intake, 2010-2013.

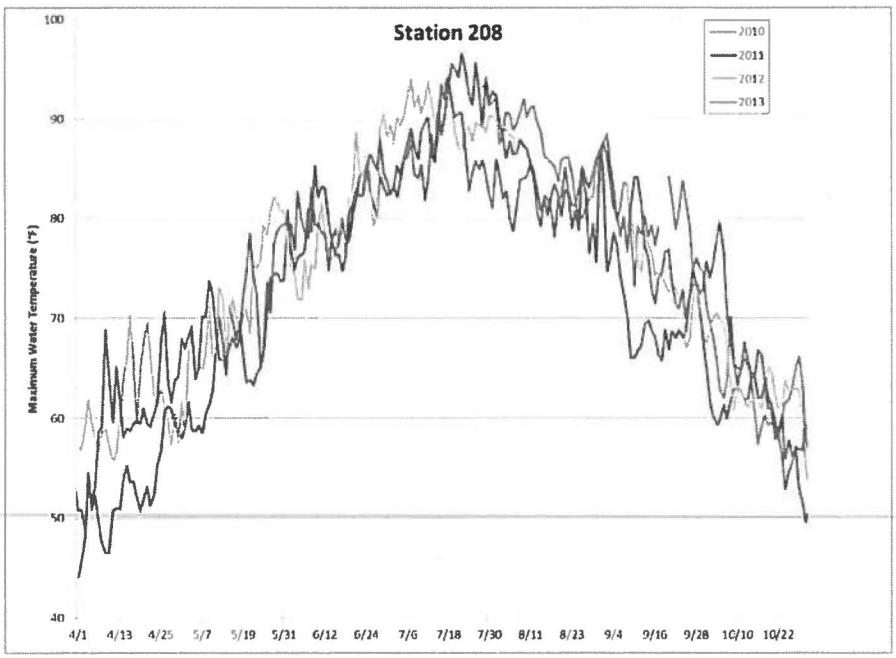



Figure 5-12. Daily maximum instantaneous water temperature measured at Station 208, 2010-2013.

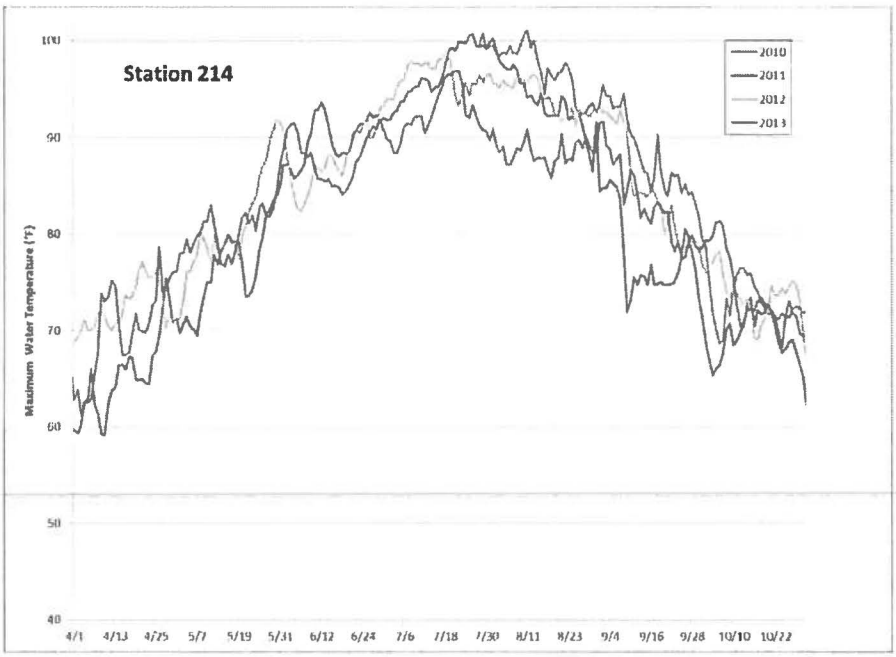



Figure 5-13. Daily maximum instantaneous water temperature measured at Station 214, 2010-2013.

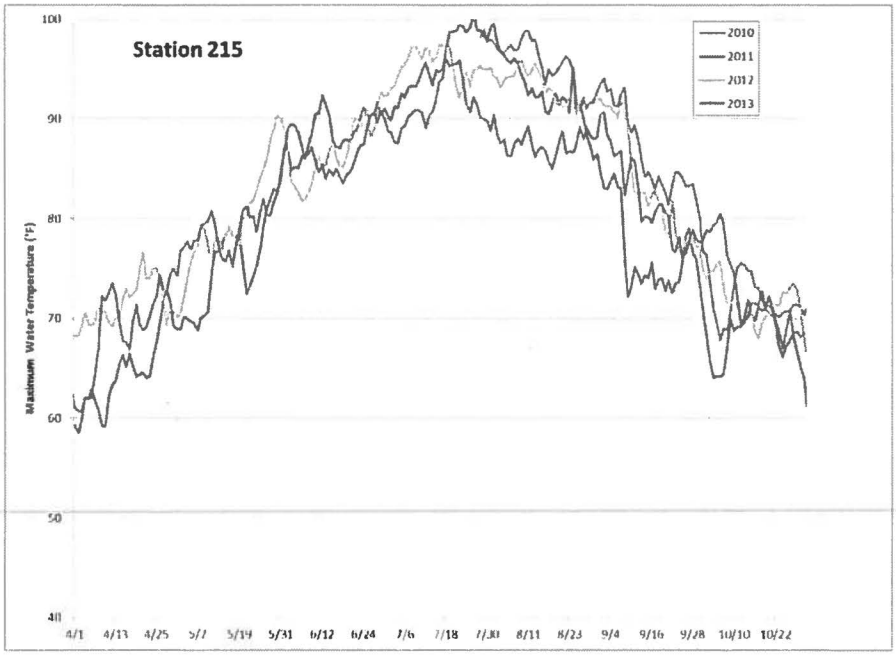



Figure 5-14. Daily maximum instantaneous water temperature measured at Station 215, 2010-2013.

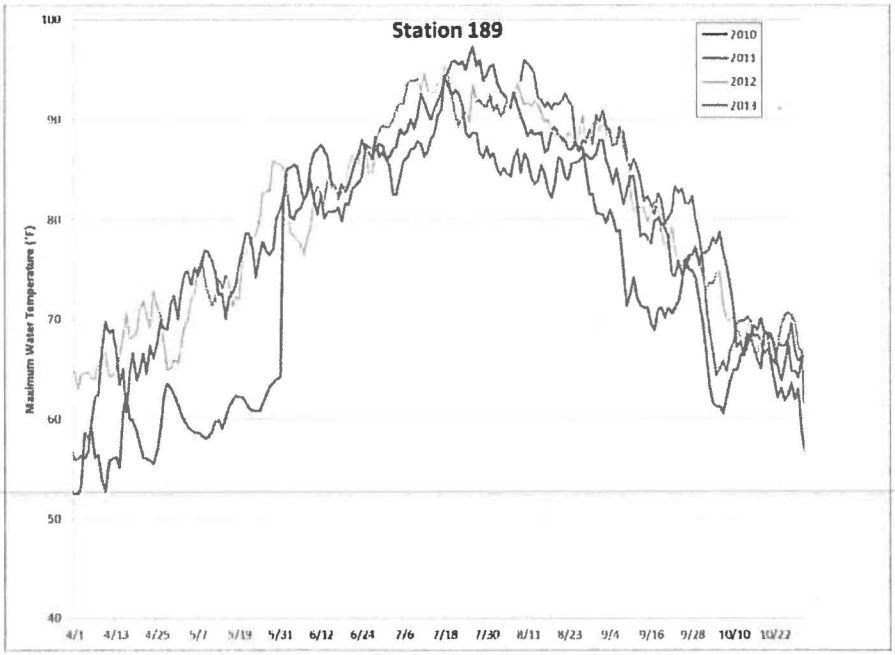



Figure 5-15. Daily maximum instantaneous water temperature measured at Station 189, 2010-2013.

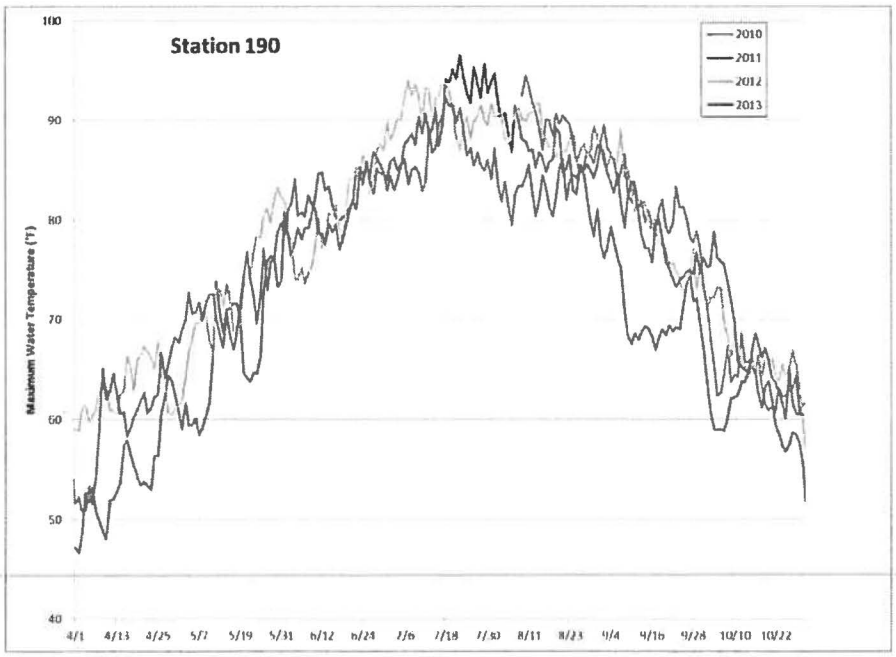



Figure 5-16. Daily maximum instantaneous water temperature measured at Station 190, 2010-2013.

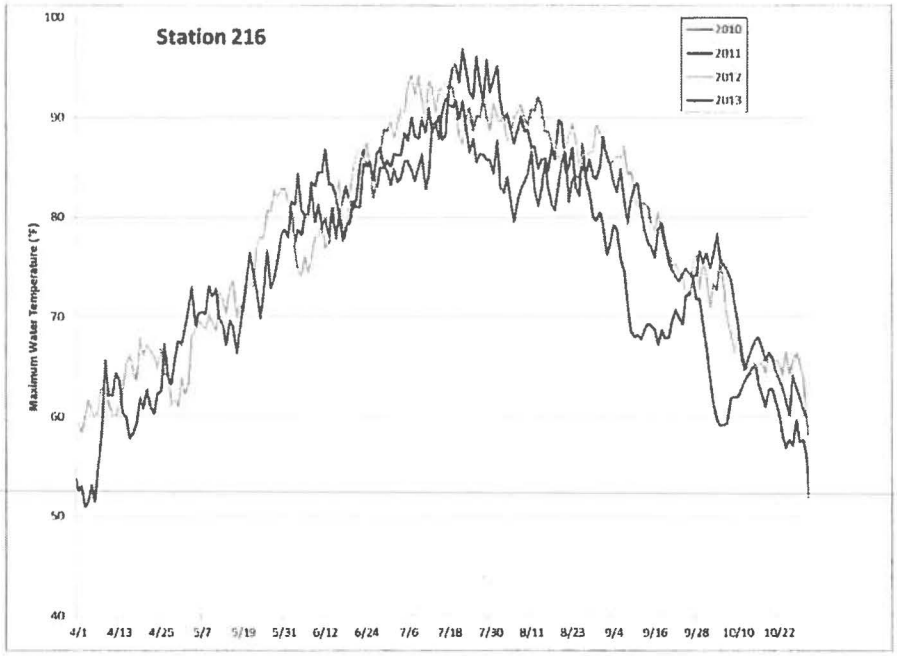



Figure 5-17. Daily maximum instantaneous water temperature measured at Station 216, 2010-2013.

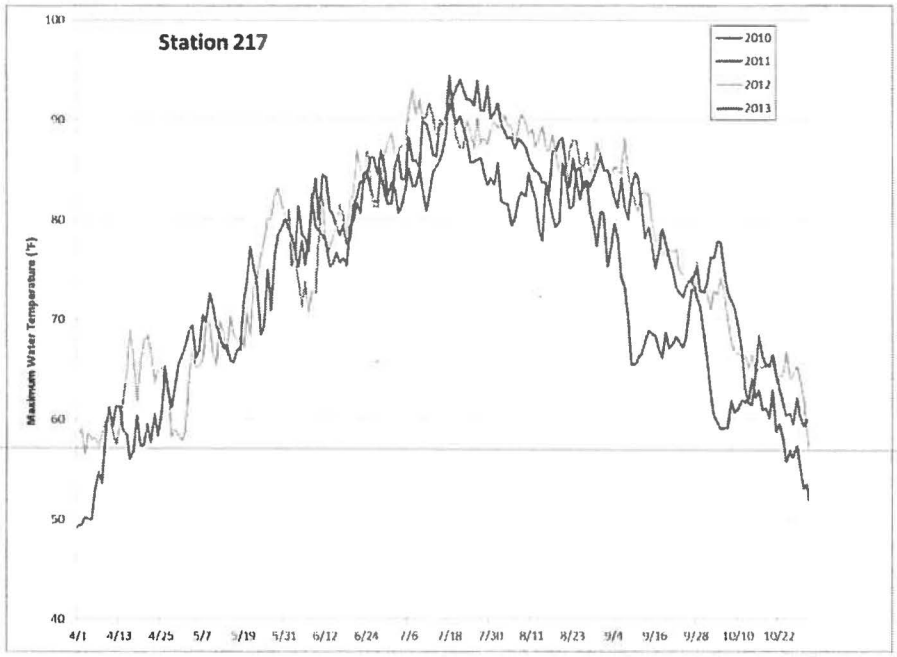



Figure 5-18. Daily maximum instantaneous water temperature measured at Station 217, 2010-2013.

Table 5-1. Summary of instantaneous maximum and mean water temperature data for multiple locations within Conowingo Pond in 2010.

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

*stations not monitored in 2010

Table 5-2. Summary of instantaneous maximum and mean water temperature data for multiple locations within Conowingo Pond in 2011.

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

Table 5-3. Summary of instantaneous maximum and mean water temperature data for multiple locations within Conowingo Pond in 2012.

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

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

Table 5-4. Summary of instantaneous maximum and mean water temperature data for multiple locations within Conowingo Pond in 2013.

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

### *5.3 Dissolved Oxygen Conditions*

Dissolved oxygen (DO) concentrations in the subsurface waters of Conowingo Pond are important in assessing the potential suitability of fish habitat that is thermally available outside of areas that are avoided because they contain water temperatures in excess of a specified avoidance temperature. As mentioned in Section 2.2, previous studies, such as Mathur *et al.* (1988), have shown that low DO concentrations tend to occur in the summer when ambient water temperatures exceed 75°F and Susquehanna River flows are less than 12,000 cfs, particularly in deeper areas in the lower third of the Pond.

In the present study, DO levels were not investigated in detail but DO concentrations and water temperatures at the surface and bottom of the Pond were routinely collected during trawl sampling (Figure 5-24). These data are summarized for 2010 through 2012 in Table 5-5 through Table 5-7. As in the previous studies, the lowest DO values (<5 mg/l) tended to occur in the deeper areas of the Pond, along the McClelland's Rock and Broad Creek transects, in July and August concurrent with River flows generally <12,000 cfs. Surface DO concentrations were relatively high and generally similar among transects. High plume temperatures did not appear to be associated with low DO values.

A more extensive DO study was performed in 1999 as reported in Normandeau (2000). Dissolved Oxygen profiling was conducted in July and August on a weekly basis at west, mid-Pond, and east locations on four transects over a wide range of conditions: Fishing Creek (in the upper third of the Pond), Burkins Run (just below PBAPS), Williams Tunnel (between Burkins Run and the PA/MD state line), and State Line. Figure 5-19, taken from Normandeau (2000), shows the average weekly surface and bottom DO concentrations taken along the four transects, and shows that surface DO concentrations were generally similar among transects. However, corresponding bottom DO values were lower in June through much of August, particularly at the deeper water stations along the east shore on Williams Tunnel and State Line transects, as shown in Table 5-8, also taken from Normandeau (2000).

Table 5-5. Dissolved oxygen and water temperature measured during trawl collections in Conowingo Pond, July through October 2010.

12 & 13 July 2010 Flow: 7,759 & 12,192 cfs[a]

| | McClellan's Rock | | | Below Burkins Run | | | | Below PBAPS | | | Broad Creek | | | PBAPS Intake | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station No. | 331 | 332 | 333 | 381 | 382 | 383 | 384 | 371 | 372 | 373 | 341 | 342 | 343 | 321 | 322 | 323 |
| **Water Temp. (°F)** | | | | | | | | | | | | | | | | |
| Surface Start | 90.0 | 91.4 | 90.5 | 97.2 | 87.8 | 88.7 | 86.4 | 90.0 | 87.8 | 87.4 | 86.4 | 86.9 | 87.8 | 85.1 | 86.4 | 86.0 |
| End | 94.1 | 87.4 | 89.1 | 97.3 | 88.7 | 90.0 | 89.2 | 90.0 | 87.8 | 89.1 | 86.7 | 87.8 | 88.2 | 86.0 | 86.4 | 86.4 |
| Bottom Start | 84.2 | 88.7 | 83.8 | 86.0 | 84.6 | 82.8 | 88.7 | 84.2 | 84.6 | 87.4 | 87.4 | 86.4 | 84.2 | 82.8 | 84.6 | 86.0 |
| End | 86.2 | 82.4 | 82.0 | 93.2 | 85.1 | 83.3 | 88.9 | 84.7 | 83.5 | 86.0 | 86.7 | 86.7 | 86.2 | 82.4 | 82.0 | 84.4 |
| **Diss. Oxygen (mg/l)** | | | | | | | | | | | | | | | | |
| Surface Start | 8.5 | 8.0 | 8.4 | 8.0 | 8.4 | 8.0 | 8.0 | 8.0 | 7.9 | 8.4 | 7.2 | 7.8 | 7.2 | 7.8 | 7.4 | 7.8 |
| End | 8.1 | 8.5 | 7.9 | 7.8 | 8.2 | 5.5 | 7.9 | 8.3 | 7.2 | 8.3 | 6.2 | 7.2 | 7.4 | 8.2 | 7.3 | 7.8 |
| Bottom Start | 7.2 | 7.8 | 6.8 | 7.5 | 7.5 | 7.8 | 7.2 | 6.8 | 7.8 | 8.5 | 6.5 | 7.0 | 3.5 | 7.1 | 7.2 | 7.6 |
| End | 6.2 | 6.7 | 6.7 | 7.8 | 6.8 | 6.8 | 7.6 | 7.1 | 7.0 | 8.7 | 5.4 | 5.8 | 4.9 | 7.2 | 6.3 | 6.7 |

16 & 17 August 2010 Flow: 7,812 & 9,777 cfs

| Station No. | 331 | 332 | 333 | 381 | 382 | 383 | 384 | 371 | 372 | 373 | 341 | 342 | 343 | 321 | 322 | 323 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water Temp. (°F)** | | | | | | | | | | | | | | | | |
| Surface Start | 89.6 | 88.2 | 87.8 | 95.4 | 88.2 | 87.4 | 86.9 | 88.2 | 84.6 | 85.1 | 85.1 | 86.0 | 84.6 | 82.8 | 83.8 | 84.6 |
| End | 83.8 | 86.0 | 80.6 | 83.3 | 82.0 | 81.0 | 85.1 | 81.0 | 81.0 | 82.4 | 84.7 | 82.4 | 80.6 | 79.7 | 80.2 | 80.6 |
| Bottom Start | 90.0 | 87.3 | 87.4 | 91.8 | 85.8 | 86.0 | 85.8 | 85.8 | 84.4 | 85.5 | 85.1 | 86.0 | 86.9 | 81.5 | 82.4 | 83.8 |
| End | 81.0 | 81.3 | 80.2 | 81.7 | 82.4 | 80.2 | 84.7 | 83.7 | 82.4 | 81.1 | 84.9 | 81.9 | 84.0 | 79.5 | 80.2 | 81.0 |
| **Diss. Oxygen (mg/l)** | | | | | | | | | | | | | | | | |
| Surface Start | 7.5 | 7.5 | 7.8 | 7.5 | 8.2 | 7.4 | 7.8 | 7.5 | 8.0 | 7.6 | 7.2 | 7.5 | 7.0 | 7.9 | 7.9 | 7.5 |
| End | 6.2 | 5.8 | 6.6 | 6.8 | 6.5 | 6.0 | 7.3 | 6.8 | 7.0 | 8.1 | 7.0 | 4.8 | 4.3 | 6.7 | 7.0 | 6.9 |
| Bottom Start | 7.7 | 7.8 | 7.9 | 7.6 | 8.0 | 7.5 | 7.3 | 7.8 | 7.6 | 7.3 | 7.1 | 7.6 | 7.2 | 7.5 | 8.0 | 7.8 |
| End | 6.0 | 6.6 | 6.8 | 5.9 | 6.6 | 5.9 | 6.4 | 7.4 | 7.1 | 6.2 | 6.6 | 5.4 | 6.0 | 6.2 | 7.0 | 7.2 |

20 & 21 September 2010 Flow: 4,966 & 4,501 cfs

| Station No. | 331 | 332 | 333 | 381 | 382 | 383 | 384 | 371 | 372 | 373 | 341 | 342 | 343 | 321 | 322 | 323 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water Temp. (°F)** | | | | | | | | | | | | | | | | |
| Surface Start | 80.2 | 76.1 | 76.1 | 81.0 | 76.1 | 76.6 | 75.2 | 74.3 | 75.6 | 75.2 | 74.3 | 75.6 | 76.1 | 75.2 | 75.2 | 73.8 |
| End | 82.4 | 79.0 | 75.7 | 82.8 | 76.1 | 76.6 | 77.2 | 82.6 | 76.1 | 76.1 | 75.2 | 76.1 | 76.1 | 73.9 | 74.8 | 73.8 |
| Bottom Start | 75.9 | 75.2 | 74.8 | 77.0 | 76.1 | 75.2 | 77.0 | 75.2 | 75.6 | 75.2 | 75.2 | 75.2 | 75.2 | 75.6 | 73.8 | 72.0 |
| End | 73.0 | 76.6 | 73.9 | 77.5 | 76.1 | 75.2 | 77.0 | 80.4 | 76.1 | 76.1 | 75.4 | 75.4 | 75.6 | 73.9 | 74.7 | 72.7 |
| **Diss. Oxygen (mg/l)** | | | | | | | | | | | | | | | | |
| Surface Start | 8.4 | 8.2 | 8.6 | 8.8 | 8.8 | 8.0 | 9.0 | 9.0 | 8.4 | 6.8 | 7.2 | 7.6 | 8.2 | 9.2 | 9.2 | 7.9 |
| End | 8.6 | 8.4 | 8.8 | 9.2 | 8.9 | 8.4 | 8.5 | 9.1 | 8.6 | 8.0 | 7.6 | 8.0 | 8.0 | 9.5 | 9.3 | 8.5 |
| Bottom Start | 8.0 | 7.6 | 6.5 | 7.5 | 8.6 | 6.2 | 8.8 | 8.4 | 8.4 | 6.5 | 6.9 | 7.8 | 7.5 | 9.4 | 7.8 | 6.7 |
| End | 8.0 | 7.6 | 7.5 | 8.5 | 8.8 | 6.2 | 8.4 | 9.3 | 8.5 | 7.9 | 7.3 | 7.2 | 7.3 | 9.5 | 8.9 | 7.2 |

18 & 22 October 2010 Flow: 23,586 & 23,024 cfs

| Station No. | 331 | 332 | 333 | 381 | 382 | 383 | 384 | 371 | 372 | 373 | 341 | 342 | 343 | 321 | 322 | 323 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water Temp. (°F)** | | | | | | | | | | | | | | | | |
| Surface Start | 63.0 | 57.0 | 56.8 | 69.8 | 58.8 | 59.4 | 61.7 | 62.2 | 58.1 | 58.6 | 60.4 | 59.7 | 57.6 | 57.6 | 57.6 | 58.1 |
| End | 66.4 | 55.8 | 55.8 | 58.6 | 58.1 | 57.4 | 58.8 | 57.6 | 57.9 | 57.9 | 59.9 | 58.6 | 55.8 | 57.0 | 57.6 | 58.1 |
| Bottom Start | 57.4 | 57.0 | 55.9 | 70.0 | 57.9 | 59.4 | 59.0 | 69.4 | 57.0 | 57.2 | 59.5 | 58.6 | 57.0 | 57.6 | 57.6 | 58.1 |
| End | 56.8 | 55.8 | 55.8 | 68.9 | 57.4 | 57.2 | 58.5 | 68.4 | 57.0 | 57.4 | 59.4 | 58.5 | 55.8 | 57.2 | 57.6 | 57.9 |
| **Diss. Oxygen (mg/l)** | | | | | | | | | | | | | | | | |
| Surface Start | 11.2 | 11.5 | 11.1 | 10.2 | 10.5 | 10.6 | 10.3 | 10.8 | 10.8 | 10.3 | 10.6 | 10.7 | 10.8 | 10.8 | 10.5 | 10.6 |
| End | 10.8 | 10.9 | 10.9 | 10.1 | 10.4 | 10.5 | 10.2 | 10.5 | 10.7 | 10.0 | 10.3 | 10.6 | 10.6 | 10.4 | 10.2 | 10.2 |
| Bottom Start | 10.6 | 11.0 | 10.6 | 10.5 | 10.5 | 10.0 | 10.1 | 10.5 | 9.6 | 10.4 | 10.1 | 10.1 | 10.4 | 10.6 | 10.2 | 10.0 |
| End | 10.5 | 10.8 | 10.7 | 10.4 | 10.4 | 10.1 | 9.9 | 10.5 | 10.4 | 10.0 | 9.9 | 10.3 | 10.4 | 10.2 | 10.1 | 9.8 |

[a] Daily average River flow at Holtwood.

Table 5-6. Dissolved oxygen and water temperature measured during trawl collections in Conowingo Pond, April through October 2011.

13 & 14 April 2011 Flow: 107,257 & 115,914 cfs

| | McClellan's Rock | | | Below Burkins Run | | | | Below PBAPS | | | Broad Creek | | | PBAPS Intake | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station No. | 331 | 332 | 333 | 381 | 382 | 383 | 384 | 371 | 372 | 373 | 341 | 342 | 343 | 321 | 322 | 323 |
| **Water Temp. (°F)** | | | | | | | | | | | | | | | | |
| Surf. Start | 59.9 | 50.0 | 49.6 | 56.8 | 48.9 | 49.6 | 49.3 | 61.7 | 49.8 | 49.6 | 51.4 | 52.2 | 50.0 | 50.0 | 49.6 | 48.6 |
| End | 57.6 | 49.6 | 49.3 | 57.4 | 48.7 | 48.7 | 48.9 | 60.4 | 49.6 | 49.5 | 51.4 | 52.5 | 50.4 | 49.6 | 49.6 | 48.4 |
| Bot. Start | 50.4 | 49.6 | 49.6 | 52.2 | 48.6 | 48.9 | 49.1 | 50.0 | 49.8 | 49.1 | 51.1 | 51.4 | 49.8 | 50.0 | 49.6 | 48.6 |
| End | 51.1 | 49.6 | 48.9 | 55.0 | 48.7 | 48.7 | 48.9 | 53.8 | 49.6 | 49.5 | 51.3 | 52.0 | 50.2 | 49.6 | 49.6 | 48.4 |
| **Diss. Oxygen (mg/l)** | | | | | | | | | | | | | | | | |
| Surf. Start | 11.2 | 11.4 | 11.6 | 11.5 | 11.4 | 11.8 | 11.4 | 11.2 | 11.5 | 11.5 | 11.6 | 11.0 | 11.6 | 11.6 | 11.8 | 11.9 |
| End | 11.4 | 11.8 | 11.8 | 11.7 | 11.8 | 11.9 | 11.6 | 11.6 | 11.9 | 11.9 | 11.6 | 11.7 | 11.6 | 12.0 | 12.0 | 12.0 |
| Bot. Start | 10.6 | 11.0 | 10.2 | 11.8 | 11.5 | 11.4 | 11.2 | 11.7 | 11.8 | 11.6 | 10.8 | 10.2 | 9.6 | 11.9 | 11.7 | 12.0 |
| End | 11.4 | 11.2 | 11.2 | 11.8 | 11.8 | 11.6 | 11.2 | 12.0 | 11.8 | 11.7 | 10.3 | 10.4 | 10.8 | 11.9 | 11.9 | 12.2 |
| Depth (ft) | 24 | 15 | 26 | 14 | 11 | 22 | 8 | 16 | 15 | 6 | 15 | 28 | 30 | 15 | 19 | 22 |

10 & 11 May 2011 Flow: 79,188 & 67,950 cfs

| Station No. | 331 | 332 | 333 | 381 | 382 | 383 | 384 | 371 | 372 | 373 | 341 | 342 | 343 | 321 | 322 | 323 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water Temp. (°F)** | | | | | | | | | | | | | | | | |
| Surf. Start | 70.7 | 59.4 | 59.0 | 65.8 | 59.4 | 59.0 | 59.0 | 66.6 | 58.1 | 57.2 | 63.3 | 62.2 | 59.4 | 57.2 | 57.2 | 58.1 |
| End | 72.0 | 59.4 | 60.8 | 67.1 | 59.4 | 59.4 | 62.1 | 65.3 | 58.5 | 57.6 | 63.0 | 66.2 | 59.7 | 57.6 | 57.7 | 58.5 |
| Bot. Start | 59.0 | 59.0 | 59.0 | 58.3 | 58.6 | 58.6 | 58.6 | 57.9 | 57.2 | 57.2 | 61.2 | 59.9 | 57.2 | 57.2 | 57.2 | 57.6 |
| End | 59.5 | 59.2 | 59.0 | 58.3 | 59.0 | 59.0 | 59.4 | 58.5 | 57.9 | 57.6 | 63.0 | 60.3 | 59.2 | 57.6 | 57.6 | 58.3 |
| **Diss. Oxygen (mg/l)** | | | | | | | | | | | | | | | | |
| Surf. Start | 10.2 | 10.4 | 10.5 | 10.4 | 10.8 | 10.8 | 10.8 | 10.4 | 10.2 | 10.5 | 10.4 | 10.6 | 10.6 | 10.6 | 10.4 | 10.6 |
| End | 10.2 | 10.6 | 10.5 | 10.8 | 10.9 | 10.9 | 10.7 | 10.7 | 10.8 | 10.7 | 10.7 | 10.8 | 10.6 | 10.8 | 10.7 | 10.8 |
| Bot. Start | 10.4 | 10.2 | 10.5 | 10.6 | 10.8 | 10.6 | 10.4 | 10.0 | 10.6 | 10.5 | 9.8 | 10.4 | 10.4 | 10.5 | 10.2 | 10.4 |
| End | 10.5 | 10.4 | 10.5 | 10.8 | 10.5 | 10.6 | 10.6 | 10.9 | 10.8 | 10.8 | 10.4 | 10.2 | 10.6 | 10.6 | 10.5 | 10.6 |
| Depth (ft) | 24 | 11 | 19 | 18 | 10 | 20 | 6 | 20 | 16 | 6 | 5 | 27 | 24 | 18 | 20 | 22 |

13 & 15 June 2011 Flow: 35,491 & 38,038 cfs

| Station No. | 331 | 332 | 333 | 381 | 382 | 383 | 384 | 371 | 372 | 373 | 341 | 342 | 343 | 321 | 322 | 323 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water Temp. (°F)** | | | | | | | | | | | | | | | | |
| Surf. Start | 84.4 | 78.6 | 76.8 | 85.6 | 79.2 | 77.9 | 78.8 | 84.6 | 78.8 | 77.4 | 79.2 | 80.2 | 79.9 | 77.9 | 78.1 | 78.4 |
| End | 87.8 | 77.0 | 77.0 | 86.9 | 79.2 | 79.7 | 79.2 | 84.0 | 79.2 | 79.2 | 81.1 | 80.6 | 80.2 | 78.8 | 78.8 | 78.8 |
| Bot. Start | 77.5 | 77.4 | 76.8 | 78.4 | 78.8 | 78.1 | 78.8 | 78.1 | 78.8 | 77.4 | 78.6 | 78.8 | 77.0 | 78.4 | 78.8 | 78.4 |
| End | 77.2 | 77.0 | 77.0 | 78.8 | 79.3 | 79.2 | 79.0 | 78.8 | 79.2 | 79.2 | 81.1 | 77.9 | 78.4 | 78.8 | 78.8 | 78.8 |
| **Diss. Oxygen (mg/l)** | | | | | | | | | | | | | | | | |
| Surf. Start | 8.6 | 8.7 | 8.3 | 8.0 | 8.8 | 8.5 | 9.0 | 8.0 | 8.4 | 8.4 | 7.5 | 9.0 | 8.7 | 8.0 | 7.9 | 8.0 |
| End | 8.8 | 8.6 | 7.9 | 8.1 | 8.6 | 9.0 | 9.0 | 8.2 | 8.3 | 8.1 | 8.7 | 8.7 | 8.5 | 8.1 | 8.1 | 8.2 |
| Bot. Start | 7.7 | 8.4 | 8.2 | 7.8 | 8.2 | 8.0 | 8.8 | 8.0 | 8.0 | 8.1 | 6.6 | 7.6 | 7.4 | 7.8 | 7.6 | 8.0 |
| End | 8.1 | 8.4 | 7.3 | 7.6 | 8.2 | 8.2 | 8.8 | 8.0 | 8.2 | 8.1 | 8.0 | 7.3 | 8.1 | 8.0 | 8.0 | 8.1 |
| Depth (ft) | 26 | 12 | 20 | 20 | 10 | 18 | 6 | 20 | 13 | 6 | 7 | 29 | 32 | 17 | 20 | 19 |

14 & 18 July 2011 Flow: 12,050 & 9,171 cfs

| Station No. | 331 | 332 | 333 | 381 | 382 | 383 | 384 | 371 | 372 | 373 | 341 | 342 | 343 | 321 | 322 | 323 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water Temp. (°F)** | | | | | | | | | | | | | | | | |
| Surf. Start | 95.4 | 87.8 | 89.2 | 93.4 | 85.6 | 87.3 | 87.4 | 89.6 | 85.1 | 83.8 | 93.6 | 91.8 | 94.1 | 81.1 | 81.9 | 82.4 |
| End | 95.5 | 90.7 | 90.0 | 92.5 | 85.6 | 86.0 | 85.3 | 88.2 | 84.7 | 84.0 | 93.6 | 92.8 | 92.8 | 81.5 | 81.9 | 81.9 |
| Bot. Start | 83.3 | 84.2 | 82.8 | 93.4 | 85.6 | 83.8 | 85.6 | 82.2 | 85.1 | 82.8 | 88.7 | 82.8 | 82.0 | 81.0 | 80.8 | 82.2 |
| End | 84.6 | 84.2 | 85.3 | 85.8 | 82.6 | 83.8 | 84.7 | 86.4 | 84.7 | 83.5 | 90.0 | 82.4 | 87.8 | 81.5 | 81.9 | 81.9 |
| **Diss. Oxygen (mg/l)** | | | | | | | | | | | | | | | | |
| Surf. Start | 8.0 | 8.4 | 9.0 | 7.9 | 7.9 | 8.1 | 8.2 | 7.8 | 7.9 | 7.1 | 9.6 | 9.8 | 8.6 | 7.3 | 7.2 | 7.3 |
| End | 8.2 | 8.8 | 8.2 | 7.9 | 8.4 | 8.2 | 8.9 | 7.8 | 7.3 | 7.3 | 9.6 | 9.8 | 9.0 | 7.3 | 7.2 | 7.0 |
| Bot. Start | 5.5 | 5.0 | 5.0 | 7.7 | 7.4 | 6.7 | 6.1 | 7.1 | 7.6 | 7.1 | 8.2 | 2.5 | 2.8 | 7.4 | 7.0 | 6.6 |
| End | 6.3 | 6.0 | 3.7 | 7.4 | 6.7 | 6.2 | 8.7 | 7.7 | 7.3 | 6.9 | 8.8 | 2.4 | 6.7 | 7.0 | 7.0 | 6.4 |
| Depth (ft) | 24 | 11 | 19 | 13 | 8 | 17 | 4 | 12 | 6 | 6 | 8 | 30 | 30 | 12 | 16 | 16 |

Flow = Daily average River flow at Holtwood

## Table 5-6. Continued.

15 & 16 August 2011 Flow: 14,667 & 13,822 cfs

| Station No. | 331 | 332 | 333 | 381 | 382 | 383 | 384 | 371 | 372 | 373 | 341 | 342 | 343 | 321 | 322 | 323 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water Temp. (°F)** | | | | | | | | | | | | | | | | |
| Surf. Start | 85.6 | 84.0 | 82.8 | 92.3 | 83.8 | 84.2 | 84.6 | 88.2 | 83.5 | 82.8 | 82.0 | 81.9 | 82.0 | 81.0 | 81.0 | 82.4 |
| End | 88.2 | 82.8 | 82.4 | 91.8 | 83.7 | 83.8 | 83.5 | 84.6 | 82.9 | 82.8 | 82.4 | 81.9 | 82.0 | 79.3 | 80.2 | 82.0 |
| Bot. Start | 82.2 | 84.2 | 80.1 | 81.0 | 80.6 | 80.2 | 84.6 | 82.4 | 80.2 | 80.6 | 82.2 | 82.0 | 81.0 | 79.7 | 79.7 | 80.2 |
| End | 82.0 | 82.9 | 80.6 | 80.6 | 80.4 | 80.2 | 82.0 | 81.9 | 80.2 | 80.6 | 82.4 | 81.9 | 82.0 | 79.3 | 79.5 | 80.2 |
| **Diss. Oxygen (mg/l)** | | | | | | | | | | | | | | | | |
| Surf. Start | 7.4 | 7.2 | 7.3 | 7.9 | 8.3 | 8.2 | 7.8 | 7.9 | 7.8 | 6.8 | 6.8 | 6.9 | 7.6 | 7.9 | 7.9 | 7.2 |
| End | 7.5 | 7.6 | 7.5 | 8.2 | 7.7 | 7.6 | 8.7 | 8.0 | 7.7 | 6.8 | 6.7 | 7.4 | 7.4 | 7.3 | 7.9 | 7.7 |
| Bot. Start | 6.8 | 7.1 | 6.4 | 7.3 | 7.4 | 7.0 | 7.4 | 7.5 | 7.2 | 7.2 | 6.7 | 7.3 | 6.1 | 7.4 | 7.2 | 6.8 |
| End | 6.6 | 7.2 | 6.4 | 7.3 | 7.3 | 6.8 | 8.2 | 7.4 | 6.8 | 6.2 | 6.6 | 7.3 | 6.8 | 6.7 | 7.2 | 7.0 |
| Depth (ft) | 26 | NA | 22 | 18 | 10 | 19 | NA | 18 | 12 | 8 | 7 | 28 | 34 | 14 | 15 | 18 |

19 & 20 September 2011 Flow: 52,035 & 44,669 cfs

| Station No. | 331 | 332 | 333 | 381 | 382 | 383 | 384 | 371 | 372 | 373 | 341 | 342 | 343 | 321 | 322 | 323 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water Temp. (°F)** | | | | | | | | | | | | | | | | |
| Surf. Start | 69.4 | 67.1 | 66.2 | 68.9 | 64.8 | 65.3 | 65.3 | 72.0 | 64.8 | 64.0 | 66.2 | 68.4 | 67.6 | 63.9 | 64.0 | 64.0 |
| End | 73.0 | 68.0 | 64.8 | 72.9 | 65.7 | 64.8 | 66.7 | 72.9 | 64.4 | 64.4 | 66.6 | 68.0 | 66.6 | 63.9 | 64.0 | 64.4 |
| Bot. Start | 64.4 | 64.4 | 64.8 | 64.2 | 64.4 | 64.4 | 65.3 | 64.0 | 65.3 | 63.0 | 64.4 | 64.4 | 64.6 | 63.9 | 64.0 | 64.0 |
| End | 64.4 | 64.4 | 64.8 | 64.0 | 64.6 | 64.4 | 64.2 | 64.2 | 64.4 | 64.4 | 66.6 | 64.4 | 64.6 | 63.9 | 64.0 | 64.0 |
| **Diss. Oxygen (mg/l)** | | | | | | | | | | | | | | | | |
| Surf. Start | 10.5 | 10.4 | 9.6 | 10.6 | 10.4 | 10.4 | 10.2 | 10.4 | 10.4 | 9.8 | 10.8 | 10.8 | 9.5 | 10.8 | 11.2 | 10.4 |
| End | 10.2 | 10.6 | 10.4 | 10.3 | 10.3 | 10.6 | 8.9 | 10.4 | 10.6 | 10.0 | 10.9 | 10.3 | 10.0 | 120.6 | 10.5 | 10.4 |
| Bot. Start | 10.8 | 10.3 | 10.0 | 10.5 | 10.5 | 10.4 | 10.2 | 10.5 | 10.5 | 9.2 | 11.0 | 11.0 | 9.8 | 10.4 | 10.8 | 10.3 |
| End | 10.7 | 10.6 | 10.6 | 10.6 | 10.6 | 10.6 | 7.6 | 10.5 | 10.6 | 10.1 | 10.9 | 10.2 | 10.1 | 10.5 | 10.5 | 10.7 |
| Depth (ft) | 26 | 12 | 22 | 17 | 7 | 17 | 4 | 18 | 6 | 4 | 4 | 23 | 30 | 16 | 17 | 13 |

11 & 12 October 2011 Flow: 46,280 & 42,092 cfs

| Station No. | 331 | 332 | 333 | 381 | 382 | 383 | 384 | 371 | 372 | 373 | 341 | 342 | 343 | 321 | 322 | 323 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water Temp. (°F)** | | | | | | | | | | | | | | | | |
| Surf. Start | 60.6 | 60.4 | 60.4 | 66.4 | 60.6 | 60.4 | 61.2 | 64.2 | 60.8 | 61.3 | 61.3 | 62.4 | 61.3 | 66.6 | 59.9 | 60.4 |
| End | 60.6 | 60.4 | 60.4 | 65.7 | 60.8 | 60.8 | 60.8 | 63.9 | 60.8 | 60.8 | 61.3 | 62.1 | 61.5 | 67.6 | 60.1 | 59.9 |
| Bot. Start | 60.6 | 60.4 | 60.3 | 67.1 | 60.4 | 60.3 | 60.4 | 60.4 | 61.0 | 61.0 | 60.6 | 60.4 | 59.9 | 59.9 | 59.9 | 59.5 |
| End | 60.6 | 60.6 | 60.4 | 64.4 | 60.6 | 60.6 | 60.6 | 60.8 | 60.8 | 60.8 | 61.0 | 60.6 | 60.3 | 60.3 | 60.1 | 59.5 |
| **Diss. Oxygen (mg/l)** | | | | | | | | | | | | | | | | |
| Surf. Start | 11.2 | 10.2 | 10.4 | 10.6 | 10.4 | 10.3 | 10.2 | 10.7 | 10.6 | 10.4 | 10.2 | 10.5 | 10.4 | 10.7 | 10.4 | 10.4 |
| End | 9.9 | 10.2 | 10.7 | 10.4 | 10.4 | 10.3 | 9.8 | 10.5 | 10.0 | 10.4 | 10.1 | 10.4 | 10.6 | 10.4 | 10.4 | 10.4 |
| Bot. Start | 11.3 | 10.2 | 10.3 | 10.4 | 10.2 | 10.1 | 10.2 | 10.6 | 10.4 | 10.2 | 9.8 | 10.4 | 10.2 | 10.5 | 10.4 | 10.4 |
| End | 9.9 | 10.3 | 10.6 | 10.4 | 10.4 | 10.4 | 9.6 | 10.6 | 10.4 | 10.3 | 10.0 | 10.2 | 10.0 | 10.6 | 10.4 | 10.4 |
| Depth (ft) | 14 | 18 | 13 | 11 | 9 | 16 | 5 | 16 | 6 | 8 | 7 | 25 | 32 | 25 | 12 | 30 |

Flow = Daily average River flow at Holtwood

Table 5-7. Dissolved oxygen and water temperature measured during trawl collections in Conowingo Pond, April through October 2012.

6 & 11 April 2012 Flow: 27,209 & 19,766 cfs

| | McClellan's Rock | | | Below Burkins Run | | | | Below PBAPS | | | Broad Creek | | | PBAPS Intake | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station No. | 331 | 332 | 333 | 381 | 382 | 383 | 384 | 371 | 372 | 373 | 341 | 342 | 343 | 321 | 322 | 323 |
| **Water Temp. (°F)** | | | | | | | | | | | | | | | | |
| Surf. Start | 64.0 | 55.4 | 53.2 | 66.2 | 55.0 | 53.6 | 54.9 | 61.2 | 53.6 | 52.2 | 59.4 | 58.6 | 58.1 | 54.0 | 53.6 | 53.6 |
| End | 64.4 | 54.0 | 53.8 | 62.1 | 54.1 | 54.5 | 54.9 | 56.8 | 54.0 | 53.6 | 59.2 | 57.6 | 55.9 | 53.6 | 53.6 | 53.6 |
| Bot. Start | 58.6 | 55.4 | 53.6 | 57.2 | 55.0 | 53.6 | 54.5 | 54.5 | 54.0 | 52.2 | 59.0 | 58.6 | 57.6 | 53.6 | 53.6 | 53.8 |
| End | 56.8 | 54.1 | 53.6 | 61.7 | 54.3 | 54.0 | 54.9 | 55.4 | 54.0 | 53.6 | 59.2 | 56.7 | 54.7 | 53.6 | 53.6 | 53.8 |
| **Diss. Oxygen (mg/l)** | | | | | | | | | | | | | | | | |
| Surf. Start | 11.2 | 11.5 | 11.2 | 12.5 | 12.4 | 12.4 | 13.2 | 12.7 | 12.5 | 12.3 | 12.2 | 11.4 | 11.4 | 12.4 | 12.2 | 11.9 |
| End | 11.2 | 11.2 | 10.8 | 12.3 | 12.6 | 13.3 | 12.8 | 12.5 | 13.0 | 12.3 | 11.6 | 11.3 | 11.0 | 12.4 | 11.9 | 12.0 |
| Bot. Start | 12.0 | 12.2 | 12.2 | 12.5 | 13.1 | 12.9 | 13.8 | 12.8 | 12.6 | 12.0 | 12.4 | 13.4 | 13.2 | 12.5 | 12.1 | 12.0 |
| End | 13.0 | 12.3 | 11.9 | 12.6 | 12.8 | 13.3 | 13.3 | 12.8 | 13.0 | 12.4 | 11.5 | 11.8 | 12.0 | 12.6 | 12.0 | 12.0 |
| Depth (ft) | 24 | 13 | 19 | 16 | 9 | 18 | 4 | 12 | 5 | 5 | 7 | 30 | 27 | 12 | 18 | 14 |

25 May 2012 Flow: 42,258 cfs

| Station No. | 331 | 332 | 333 | 381 | 382 | 383 | 384 | 371 | 372 | 373 | 341 | 342 | 343 | 321 | 322 | 323 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water Temp. (°F)** | | | | | | | | | | | | | | | | |
| Surf. Start | 77.7 | 68.0 | 71.6 | 80.2 | 70.2 | 69.8 | 72.0 | 78.4 | 71.6 | 71.6 | 72.0 | 73.4 | 74.3 | 73.4 | 73.4 | 74.3 |
| End | 81.0 | 70.3 | 71.4 | 82.0 | 70.9 | 71.8 | 74.3 | 73.9 | 71.6 | 73.2 | 72.9 | 72.9 | 75.0 | 72.9 | 73.0 | 73.8 |
| Bot. Start | 70.0 | 68.4 | 68.9 | 77.7 | 69.8 | 68.2 | 72.0 | 70.2 | 69.4 | 70.7 | 72.0 | 69.8 | 69.8 | 70.5 | 70.2 | 70.2 |
| End | 69.4 | 68.4 | 68.4 | 69.8 | 69.6 | 69.3 | 71.4 | 69.6 | 69.4 | 70.7 | 72.9 | 70.0 | 70.3 | 71.2 | 71.1 | 69.8 |
| **Diss. Oxygen (mg/l)** | | | | | | | | | | | | | | | | |
| Surf. Start | 9.5 | 9.6 | 9.2 | 9.5 | 9.8 | 9.4 | 10.5 | 9.5 | 10.0 | 9.5 | 8.8 | 8.6 | 9.4 | 10.2 | 9.8 | 10.2 |
| End | 9.6 | 9.6 | 9.6 | 9.4 | 10.0 | 10.7 | 10.2 | 9.7 | 9.9 | 10.1 | 8.8 | 9.3 | 9.7 | 9.8 | 10.0 | 10.2 |
| Bot. Start | 9.2 | 9.0 | 9.0 | 9.5 | 9.5 | 8.8 | 10.0 | 9.4 | 9.6 | 9.5 | 8.8 | 8.8 | 9.0 | 9.8 | 9.4 | 9.4 |
| End | 9.2 | 9.0 | 8.7 | 9.2 | 9.7 | 9.4 | 9.5 | 9.7 | 9.5 | 10.0 | 8.4 | 8.8 | 9.0 | 9.9 | 9.7 | 9.4 |
| Depth (ft) | 25 | 12 | 17 | 15 | 10 | 18 | 5 | 15 | 18 | 4 | 5 | 24 | 18 | 15 | 18 | 14 |

21 & 22 June 2012 Flow: 18,360 & 17,241 cfs

| Station No. | 331 | 332 | 333 | 381 | 382 | 383 | 384 | 371 | 372 | 373 | 341 | 342 | 343 | 321 | 322 | 323 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water Temp. (°F)** | | | | | | | | | | | | | | | | |
| Surf. Start | 84.4 | 82.4 | 81.0 | 84.6 | 81.0 | 80.8 | 82.2 | 82.4 | 79.9 | 80.6 | 82.0 | 82.8 | 82.8 | 77.5 | 78.6 | 78.8 |
| End | 86.4 | 81.0 | 82.0 | 82.0 | 80.8 | 82.8 | 84.4 | 81.0 | 78.8 | 80.6 | 82.0 | 82.0 | 83.3 | 77.0 | 77.4 | 79.0 |
| Bot. Start | 77.0 | 80.2 | 76.6 | 76.5 | 75.6 | 75.6 | 81.0 | 76.5 | 75.2 | 79.2 | 80.8 | 76.6 | 75.6 | 75.4 | 75.2 | 75.6 |
| End | 77.4 | 79.2 | 77.9 | 76.5 | 77.0 | 75.6 | 81.7 | 76.3 | 77.2 | 79.5 | 81.7 | 78.3 | 80.2 | 76.6 | 75.7 | 75.9 |
| **Diss. Oxygen (mg/l)** | | | | | | | | | | | | | | | | |
| Surf. Start | 8.5 | 7.9 | 8.2 | 8.5 | 9.4 | 9.8 | 9.2 | 8.6 | 8.8 | 10.3 | 8.8 | 11.2 | 10.0 | 10.3 | 9.2 | 10.3 |
| End | 8.4 | 8.7 | 8.7 | 8.8 | 9.0 | 9.0 | 9.8 | 9.5 | 8.6 | 10.2 | 8.7 | 9.0 | 8.9 | 7.8 | 9.0 | 10.4 |
| Bot. Start | 8.5 | 8.4 | 7.6 | 8.4 | 8.2 | 7.6 | 9.6 | 8.4 | 7.6 | 10.2 | 8.5 | 6.9 | 7.6 | 7.8 | 7.5 | 7.6 |
| End | 8.0 | 8.1 | 8.3 | 8.5 | 9.1 | 7.0 | 11.2 | 8.3 | 8.5 | 10.6 | 8.7 | 8.2 | 8.6 | 7.2 | 7.4 | 7.5 |
| Depth (ft) | 25 | 11 | 22 | 22 | 8 | 19 | 5 | 18 | 8 | 5 | 4 | 22 | 17 | 13 | 16 | 14 |

16 & 17 July 2012 Flow: 6,947 & 8,046 cfs

| Station No. | 331 | 332 | 333 | 381 | 382 | 383 | 384 | 371 | 372 | 373 | 341 | 342 | 343 | 321 | 322 | 323 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water Temp. (°F)** | | | | | | | | | | | | | | | | |
| Surf. Start | 95.0 | 91.0 | 91.6 | 93.6 | 88.7 | 88.5 | 90.0 | 91.0 | 89.2 | 88.7 | 89.2 | 89.4 | 91.4 | 84.6 | 86.7 | 87.4 |
| End | 95.2 | 89.4 | 90.7 | 91.2 | 89.6 | 90.0 | 90.5 | 89.4 | 89.2 | 88.0 | 89.2 | 90.9 | 91.8 | 86.0 | 86.7 | 86.9 |
| Bot. Start | 86.4 | 89.6 | 84.0 | 87.8 | 87.8 | 84.2 | 90.0 | 86.9 | 85.6 | 88.2 | 89.1 | 86.4 | 82.2 | 84.6 | 83.3 | 84.6 |
| End | 85.5 | 84.2 | 83.8 | 85.5 | 85.5 | 83.8 | 89.8 | 86.0 | 86.0 | 87.3 | 89.1 | 86.0 | 88.2 | 84.0 | 83.7 | 85.6 |
| **Diss. Oxygen (mg/l)** | | | | | | | | | | | | | | | | |
| Surf. Start | 8.5 | 8.0 | 8.5 | 7.9 | 8.2 | 7.9 | 8.0 | 8.1 | 8.1 | 8.1 | 7.8 | 8.0 | 8.2 | 8.0 | 8.0 | 8.1 |
| End | 8.7 | 9.2 | 8.7 | 8.2 | 8.4 | 8.2 | 8.7 | 8.3 | 7.9 | 7.9 | 7.7 | 8.4 | 8.3 | 8.7 | 8.6 | 8.4 |
| Bot. Start | 3.0 | 6.7 | 4.0 | 7.4 | 7.5 | 5.8 | 7.6 | 8.0 | 6.5 | 8.0 | 7.0 | 2.3 | 0.6 | 7.4 | 6.0 | 6.1 |
| End | 6.8 | 5.1 | 4.3 | 6.6 | 5.8 | 5.0 | 8.4 | 7.5 | 6.4 | 7.2 | 7.4 | 1.7 | 5.9 | 6.8 | 6.3 | 7.0 |
| Depth (ft) | 26 | 12 | 22 | 18 | 9 | 18 | 5 | 13 | 10 | 6 | 5 | 27 | 25 | 13 | 16 | 12 |

Flow = Daily average River flow at Holtwood

## Table 5-7. Continued.

13 & 14 August 2012 Flow: 8,514 & 9,014 cfs

| Station No. | 331 | 332 | 333 | 381 | 382 | 383 | 384 | 371 | 372 | 373 | 341 | 342 | 343 | 321 | 322 | 323 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water Temp. (°F)** | | | | | | | | | | | | | | | | |
| Surf. Start | 92.8 | 88.0 | 88.2 | 94.1 | 87.8 | 89.6 | 90.0 | 90.5 | 86.4 | 87.4 | 87.4 | 86.2 | 86.9 | 84.4 | 84.9 | 85.6 |
| End | 93.6 | 87.1 | 87.8 | 90.1 | 88.7 | 89.8 | 90.1 | 87.8 | 86.5 | 85.6 | 87.3 | 87.3 | 87.4 | 83.8 | 83.7 | 84.9 |
| Bot. Start | 85.1 | 88.0 | 84.2 | 86.9 | 84.6 | 83.8 | 89.2 | 85.6 | 84.2 | 85.6 | 86.9 | 85.6 | 84.2 | 83.3 | 83.3 | 85.1 |
| End | 84.2 | 83.7 | 87.8 | 85.5 | 85.3 | 83.3 | 86.5 | 85.5 | 85.8 | 85.6 | 87.3 | 85.5 | 87.3 | 83.5 | 82.8 | 83.3 |
| **Diss. Oxygen (mg/l)** | | | | | | | | | | | | | | | | |
| Surf. Start | 7.2 | 6.8 | 6.8 | 7.5 | 7.8 | 7.6 | 7.8 | 7.8 | 7.6 | 7.4 | 5.9 | 6.6 | 7.0 | 7.8 | 8.0 | 7.2 |
| End | 7.0 | 6.7 | 6.6 | 8.0 | 7.6 | 7.3 | 9.4 | 7.9 | 7.2 | 7.6 | 6.3 | 6.8 | 7.2 | 7.7 | 8.0 | 7.9 |
| Bot. Start | 5.0 | 6.2 | 3.8 | 7.0 | 5.4 | 4.5 | 7.9 | 7.2 | 5.2 | 8.6 | 5.6 | 4.0 | 3.2 | 7.5 | 6.8 | 7.0 |
| End | 5.8 | 5.3 | 5.6 | 7.2 | 5.3 | 4.3 | 13.8 | 7.5 | 6.4 | 7.8 | 6.1 | 3.8 | 6.4 | 7.8 | 7.1 | 5.6 |
| Depth (ft) | 24 | 13 | 22 | 17 | 9 | 19 | 5 | 13 | 7 | 5 | 5 | 28 | 22 | 15 | 17 | 15 |

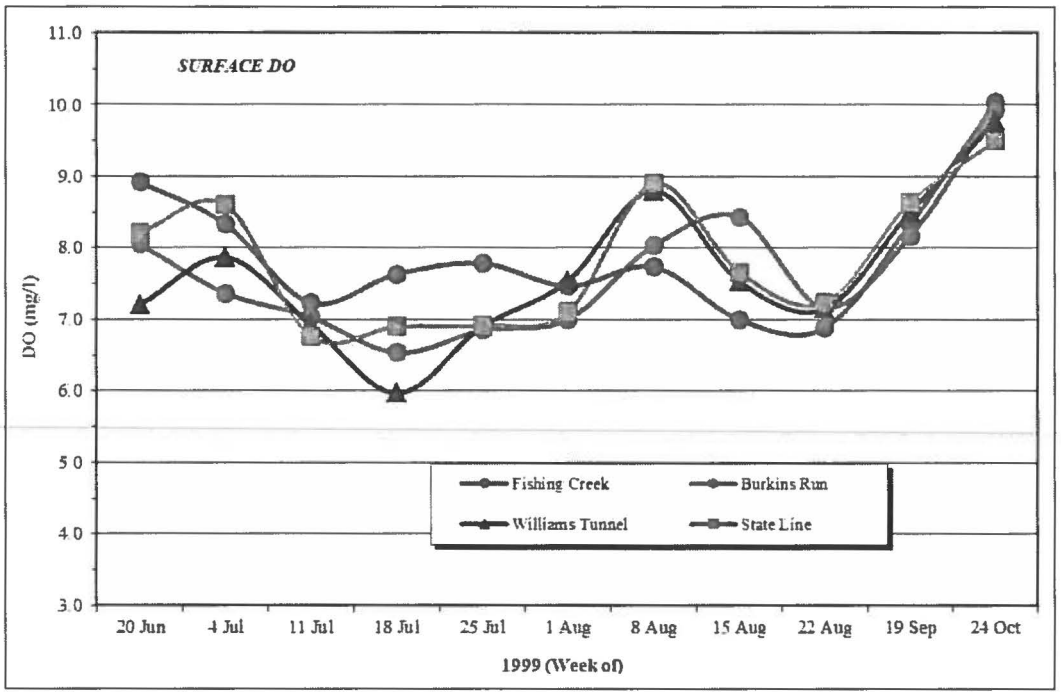
10 & 11 September 2012 Flow: 10,070 & 10,012 cfs

| Station No. | 331 | 332 | 333 | 381 | 382 | 383 | 384 | 371 | 372 | 373 | 341 | 342 | 343 | 321 | 322 | 323 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water Temp. (°F)** | | | | | | | | | | | | | | | | |
| Surf. Start | 82.6 | 82.4 | 80.8 | 84.2 | 80.8 | 78.3 | 79.7 | 78.4 | 78.6 | 78.4 | 81.5 | 82.0 | 81.0 | 74.8 | 75.6 | 75.9 |
| End | 83.7 | 82.6 | 81.5 | 82.2 | 81.1 | 78.3 | 78.8 | 77.4 | 78.4 | 77.4 | 81.3 | 82.0 | 81.9 | 74.8 | 75.6 | 76.5 |
| Bot. Start | 82.2 | 81.5 | 81.5 | 82.4 | 81.0 | 77.0 | 79.3 | 75.9 | 76.8 | 73.2 | 81.5 | 80.6 | 82.0 | 75.2 | 75.4 | 75.4 |
| End | 82.4 | 82.8 | 81.5 | 79.2 | 81.3 | 77.0 | 74.3 | 76.8 | 76.8 | 76.3 | 81.3 | 82.0 | 81.9 | 75.2 | 75.6 | 75.6 |
| **Diss. Oxygen (mg/l)** | | | | | | | | | | | | | | | | |
| Surf. Start | 8.0 | 7.9 | 8.0 | 8.2 | 8.4 | 9.2 | 9.5 | 8.4 | 9.0 | 8.9 | 6.4 | 7.4 | 7.0 | 7.6 | 7.3 | 7.8 |
| End | 7.9 | 8.1 | 8.0 | 8.3 | 8.2 | 9.2 | 11.6 | 8.5 | 8.7 | 8.8 | 6.9 | 7.7 | 7.9 | 7.2 | 7.4 | 7.8 |
| Bot. Start | 7.7 | 7.5 | 7.9 | 7.3 | 8.6 | 7.5 | 9.2 | 7.7 | 7.9 | 5.4 | 4.6 | 7.5 | 7.0 | 7.3 | 7.1 | 7.2 |
| End | 7.1 | 8.0 | 7.6 | 8.6 | 8.3 | 7.1 | 10.8 | 7.9 | 7.8 | 8.0 | 6.6 | 7.6 | 7.4 | 6.9 | 7.2 | 6.9 |
| Depth (ft) | 25 | 11 | 21 | 17 | 9 | 17 | 5 | 15 | 11 | 5 | 5 | 25 | 18 | 14 | 16 | 14 |

8 & 9 October 2012 Flow: 13,256 & 12,229 cfs

| Station No. | 331 | 332 | 333 | 381 | 382 | 383 | 384 | 371 | 372 | 373 | 341 | 342 | 343 | 321 | 322 | 323 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water Temp. (°F)** | | | | | | | | | | | | | | | | |
| Surf. Start | 70.0 | 63.1 | 64.0 | 71.2 | 64.4 | 65.3 | 66.2 | 71.2 | 64.4 | 64.8 | 64.9 | 66.0 | 64.8 | 63.5 | 64.4 | 64.2 |
| End | 71.2 | 63.5 | 63.9 | 70.2 | 64.2 | 64.4 | 64.6 | 68.0 | 63.9 | 64.4 | 66.4 | 66.6 | 65.7 | 63.9 | 64.4 | 64.4 |
| Bot. Start | 64.0 | 64.0 | 64.0 | 65.3 | 64.4 | 64.6 | 66.2 | 64.4 | 64.4 | 64.8 | 64.9 | 65.3 | 64.4 | 64.0 | 64.4 | 64.2 |
| End | 63.9 | 63.5 | 63.9 | 64.4 | 64.4 | 64.4 | 64.4 | 64.8 | 64.0 | 64.4 | 66.6 | 64.8 | 65.1 | 64.0 | 64.4 | 64.4 |
| **Diss. Oxygen (mg/l)** | | | | | | | | | | | | | | | | |
| Surf. Start | 8.8 | 8.4 | 8.6 | 8.5 | 8.8 | 8.4 | 8.0 | 8.6 | 8.5 | 8.2 | 8.2 | 8.5 | 8.2 | 8.5 | 8.6 | 8.5 |
| End | 8.3 | 8.2 | 8.1 | 8.7 | 8.5 | 8.4 | 8.3 | 8.5 | 8.7 | 8.1 | 8.3 | 8.5 | 8.4 | 8.6 | 8.4 | 8.3 |
| Bot. Start | 8.2 | 8.1 | 7.6 | 8.0 | 8.1 | 8.2 | 7.8 | 7.9 | 8.2 | 7.8 | 7.5 | 8.3 | 8.0 | 8.4 | 8.2 | 7.9 |
| End | 8.0 | 7.9 | 7.8 | 7.8 | 8.3 | 7.7 | 7.9 | 8.3 | 8.2 | 7.7 | 8.2 | 7.8 | 7.9 | 8.4 | 8.2 | 8.1 |
| Depth (ft) | 25 | 10 | 26 | 16 | 9 | 20 | 5 | 15 | 10 | 7 | 5 | 28 | 25 | 16 | 18 | 14 |

Flow = Daily average River flow at Holtwood



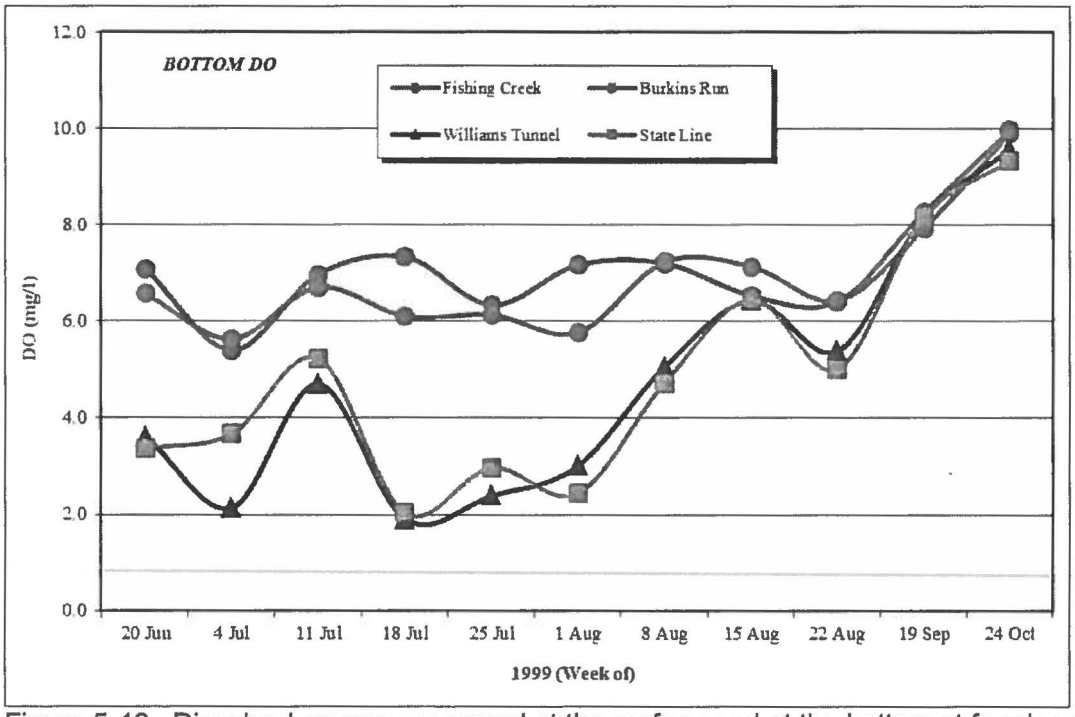




Figure 5-19. Dissolved oxygen measured at the surface and at the bottom at four locations in Conowingo Pond, June to October 1999. Reproduced from Normandeau Associates 2000.

Table 5-8. Selected weekly DO profiles at transect locations (W = western area; M = mid-pond; and E = eastern area) in Conowingo Pond, June-October 1999. Reproduced from Normandeau Associates 2000.

| | | Week of | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 20-Jun | | | 11-Jul | | | 25-Jul | | | 8-Aug | | | 22-Aug | | | 19-Sep | | | 24-Oct | | |
| | Depth | W | M | E | W | M | E | W | M | E | W | M | E | W | M | E | W | M | E | W | M | E |
| *Fishing Creek* | 0 | 8.6 | 8.8 | 9.4 | 6 | 7.3 | 8.4 | 8.0 | 8.0 | 7.4 | 6.8 | 8.2 | 8.2 | 6.6 | 6.9 | 7.2 | 8.7 | 8.2 | 8.1 | 10.1 | 10.0 | 10.0 |
| | 5 | 7.0 | 8.6 | - | 5.9 | 7.3 | 8.4 | 7.0 | 7.9 | - | 6.9 | 8.2 | - | 6.5 | 6.9 | - | 8.6 | 8.2 | - | 10.0 | 9.9 | 10.0 |
| | 10 | 6.6 | 7.7 | - | 5.9 | 7.1 | 8.2 | 6.7 | 7.7 | - | 6.9 | 7.9 | - | 6.4 | - | - | 8.5 | 8.2 | - | 10.0 | 9.9 | - |
| | 15 | 6.3 | - | - | 5.8 | - | - | - | - | - | 6.9 | - | - | 6.4 | - | - | - | - | - | 10.0 | - | - |
| | Bottom | 6.0 | 5.1 | 10.2 | 5.7 | 7.1 | 8.1 | 6.2 | 5.6 | 7.3 | 6.9 | 6.6 | 8.1 | 6.4 | 5.8 | 7.1 | 8.5 | 8.2 | 8.1 | 10.0 | 10.0 | 9.9 |
| *Burkins Run* | 0 | 7.6 | 8.3 | 8.3 | 7.1 | 7.1 | 6.9 | 7.1 | 6.4 | 7.1 | 8 | 7.5 | 8.6 | 7.2 | 7.1 | 7.3 | 8.2 | 8.2 | 8.1 | 9.9 | 9.8 | 10.1 |
| | 5 | 7.7 | 6.5 | - | 7.1 | 7 | - | 7.2 | 6.1 | - | 8 | 6.9 | - | 7.1 | 6.8 | - | 8.2 | 8.2 | - | 9.9 | 9.7 | - |
| | 10 | 7.8 | - | - | 7.1 | 6.4 | - | - | - | - | - | 7.0 | - | - | - | - | 8.0 | 8.3 | - | 9.9 | 9.7 | - |
| | 15 | - | - | - | - | - | - | - | - | - | - | 7.3 | - | - | - | - | - | - | - | - | - | - |
| | Bottom | 7.9 | 5.1 | 6.8 | 7.1 | 6.1 | 6.9 | 7.1 | 5.3 | 6.0 | 8 | 7.1 | 6.6 | 7.0 | 6.0 | 6.4 | 8.0 | 7.8 | 8.0 | 9.9 | 9.7 | 10.1 |
| *Williams Tunnel* | 0 | 7.1 | 7.2 | 7.4 | 7.1 | 6.8 | 6.9 | 6.8 | 6.9 | 7.1 | 9 | 8.4 | 9 | 7.1 | 7.2 | 7.2 | 8.4 | 8.5 | 8.6 | 9.8 | 9.7 | 9.8 |
| | 5 | 6.8 | 7.0 | 7.3 | 6.8 | 6.7 | 6.8 | 6.6 | 6.8 | 6.8 | 8.6 | 8 | 8.8 | 6.8 | 6.9 | 7.1 | 8.4 | 8.5 | 8.6 | 9.7 | 9.7 | 9.8 |
| | 10 | 6.1 | 6.9 | 7.1 | 6 | 6.5 | 6.6 | 6.3 | 6.1 | 5.9 | 7.8 | 8 | 8.1 | 6.7 | 6.9 | 6.9 | 8.4 | 8.3 | 8.6 | 9.6 | 9.6 | 9.7 |
| | 15 | 5.8 | 5.1 | 6.4 | - | - | 6.2 | 4.7 | - | 3.6 | - | - | 4.5 | 6.5 | - | 6.7 | 8.5 | - | 8.6 | 9.6 | 9.5 | 9.7 |
| | 20 | - | - | 4.8 | - | - | 5.6 | - | - | 2.7 | - | - | 5.4 | - | - | - | - | - | 8.5 | - | - | 9.6 |
| | 25 | - | - | 1.0 | - | - | 4.6 | - | - | 2.2 | - | - | 5 | - | - | - | - | - | 8.5 | - | - | 9.6 |
| | Bottom | 3.4 | 4.0 | 3.5 | 4.5 | 5.9 | 3.7 | 2.9 | 3.2 | 1.2 | 6.1 | 5 | 4.1 | 5.4 | 5.3 | 5.5 | 8.0 | 8.2 | 8.3 | 9.7 | 9.5 | 9.5 |
| *PA/MD State Line* | 0 | 8.7 | 8.3 | 7.7 | 7 | 6.7 | 6.6 | 7.2 | 6.6 | 7.0 | 9.4 | 8.6 | 8.7 | 7.4 | 7.2 | 7.2 | 8.5 | 8.7 | 8.7 | 9.4 | 9.6 | 9.5 |
| | 5 | 8.5 | 8.2 | 7.7 | 6.7 | 6.6 | 6.5 | 6.9 | 6.1 | 6.8 | 8 | 8.5 | 8.6 | 7.3 | 7.2 | 7.1 | 8.4 | 8.6 | 8.6 | 9.4 | 9.6 | 9.5 |
| | 10 | 8.0 | 8.5 | 7.4 | 6.6 | 6.6 | 6.3 | 6.4 | 5.9 | 6.1 | 8 | 7.9 | 7.6 | 7.2 | 7.0 | 7.0 | 8.3 | 8.4 | 8.6 | 9.4 | 9.5 | 9.5 |
| | 15 | 7.7 | 6.5 | 5.8 | 6.4 | - | 6.1 | 6.2 | - | 5.5 | 7 | 6.9 | 6.4 | 7.2 | 6.4 | 6.6 | 8.5 | 8.1 | 8.6 | 9.3 | 9.5 | 9.5 |
| | 20 | 5.3 | - | 4.0 | - | - | 6.1 | - | - | 3.3 | 4.0 | - | 3.9 | - | - | 6.1 | - | - | 8.5 | 9.2 | - | 9.4 |
| | 25 | - | - | 2.9 | - | - | 6.1 | - | - | 1.6 | - | - | 3.1 | - | - | 6.0 | - | - | 8.5 | - | - | 9.4 |
| | 30 | - | - | 2.4 | - | - | 4.4 | - | - | 1.6 | - | - | 3.5 | - | - | 5.5 | - | - | 8.4 | - | - | 9.4 |
| | 35 | - | - | 2.2 | - | - | 4.3 | - | - | 0.6 | - | - | 3.9 | - | - | - | - | - | 8.5 | - | - | 9.3 |
| | 40 | | - | 2.0 | - | - | 4.1 | - | - | 0.1 | - | - | 4.0 | - | - | - | - | - | 8.3 | - | - | 9.3 |
| | Bottom | 2.5 | 5.8 | 1.9 | 5.4 | 6.4 | 3.9 | 3.2 | 4.4 | 1.4 | 3.5 | 6.8 | 3.9 | 5.3 | 5.5 | 4.3 | 8.3 | 8.0 | 8.2 | 9.2 | 9.5 | 9.3 |

### *5.4 Shoreline Habitat*

*Introduction*

In considering the potential effects of the PBAPS thermal discharge, it is necessary to understand not only the distribution of the thermal plume but the types of aquatic habitats that experience elevated temperatures. To facilitate evaluation of potential thermal effects on benthic macroinvertebrates and fish in shallow shoreline habitat, the amount of shallow shoreline habitat in the non-thermally and thermally affected areas were quantified. Shallow shoreline areas are important habitats for both the benthic macroinvertebrates and fish within Conowingo Pond.

For this study, the benthic macroinvertebrate community was assessed for only the wadeable shoreline habitats in the Pond, specifically to characterize the composition and abundance of organisms within this habitat type. Similarly, the fish community that used the shallow shoreline habitats was characterized by both electrofishing and seining. This study did not evaluate the much more extensive benthic macroinvertebrate habitats or communities in the deeper offshore areas of the Pond. However, the fish community residing on the bottom of the Pond in offshore areas was assessed using a bottom trawl. The thermal monitoring and modeling has shown that elevated water temperatures are primarily a surface phenomenon in the open water portions of the Pond and along the west shoreline areas in close proximity to the PBAPS discharge canal. This is why the focus of the habitat analysis is on the shallow shoreline areas.

*Methods*

The shallow shoreline habitats were quantified within the impounded portions of Conowingo Pond from the upper end of Lower Bear Island, which is in the vicinity of MRPSF, downstream to Conowingo Dam (Figure 5-21). This analysis excludes the shallow shoreline areas upstream from Lower Bear Island where the waterbody is more characteristic of a free-flowing riverine system and also excludes the mouths of tributary streams. GIS was used along with the bathymetry dataset developed for the Conowingo Hydroelectric Facility relicensing project to quantify the shoreline habitats (URS 2011). For the purposes of this analysis shallow habitats were defined as those that were less than or equal to 10 feet in depth at the maximum Pond elevation of 110 feet, which approximates the maximum water level for the Conowingo Pond. No attempt was made to determine the quality of shallow shoreline habitat, rather, the focus was to quantify the approximate areas of this type of habitat in the Pond. It is clear from field observations that the quality of shallow shoreline habitat is variable with portions of the shallow shoreline habitat having steeply sloping banks that are likely a less productive type of benthic macroinvertebrate habitat.

*Results*

The total water surface area in the Pond, as used in this analysis, is approximately 8,327 acres with 3,593 acres upstream from the end of the PBAPS discharge canal and 4,734 acres downstream from the discharge canal (Figure 5-20). This total includes approximately 488.2 acres of shallow shoreline between elevation 110 and 100 feet (Table 5-9). A total of 306.8

acres of shallow shoreline habitat occurs upstream from the PBAPS discharge canal and is not significantly affected by the thermal plume. Areas downstream that are potentially affected by the thermal plume total 181.1 acres. Most of the shallow shoreline habitat in the Pond, as determined in this analysis, is concentrated in the upper portion or along the eastern shoreline. A small portion of this shallow shoreline habitat occurs within close proximity of the PBAPS discharge canal (Figure 5-21). The amount of shallow shoreline habitat from the end of the discharge canal to Station 215 is approximately 12 acres (Table 5-10). This is the primary area of potential thermal impact to both benthic organisms and fishes. The amount of shallow shoreline habitat from Station 215 downstream to Station 189 is 7.3 acres (Table 5-11).

*Discussion*

The shallow shoreline habitat analysis indicates that Conowingo Pond contains generally steep shorelines with relatively small amounts of shallow shoreline. Shallow shoreline habitat comprises a small proportion (5.86%) of the total Conowingo Pond surface area from the vicinity of MRPSF to Conowingo Dam. Greater amounts of shallow shoreline habitat are present upstream of the PBAPS discharge canal as compared to downstream. These upstream habitats are unaffected by the thermal plume except the vicinity of Station 208 is occasionally thermally affected at low River flows and concurrent pump up operation of MRPSF. Shallow shoreline comprises approximately 8.5% of the total surface area in Conowingo Pond that is present upstream from the PBAPS discharge canal. In contrast shallow shoreline comprises only 3.8% of the Pond total surface area that is located downstream of the PBAPS discharge. Limited shallow shoreline habitat is present directly downstream from the discharge canal in the primary area of potential thermal impact. Thus, only a small amount of habitat is exposed to the highest temperature water from the PBAPS discharge before the thermal plume mixes with ambient temperature water and disperses and moves offshore primarily on the surface of the Pond.

The primary area of potential effect comprises less than 19 acres of the total shallow shoreline habitat. Subsequent sections of this chapter evaluate benthos and fish community impacts observed within these shallow shoreline habitats. The 19 acres of potential shoreline habitat effect is conservatively high because this was calculated at maximum pool elevation and includes areas that may be dry during summer and other times of the year. The combination of operation of MRPSF and Conowingo Hydroelectric facility results in fluctuations in Pond elevation throughout the course of the year. The annual average water elevation for the Pond during 2004 to 2010 was 108.1 ft (URS 2011). Also, the Federal Energy Regulatory Commission (FERC) license for the Conowingo Hydroelectric Project permits a minimum Pond elevation of 101.2 ft which would expose most of the shallow shoreline habitat within the near-field impact zone.

The location of the PBAPS discharge on the west shore and in the middle section of Conowingo Pond is advantageous in terms of reducing the amount of shallow shoreline habitat exposed to the highest temperature water. The design of the jet discharge is also important as it rapidly entrains ambient water into the plume, thus quickly diluting the high temperature water from the discharge canal.

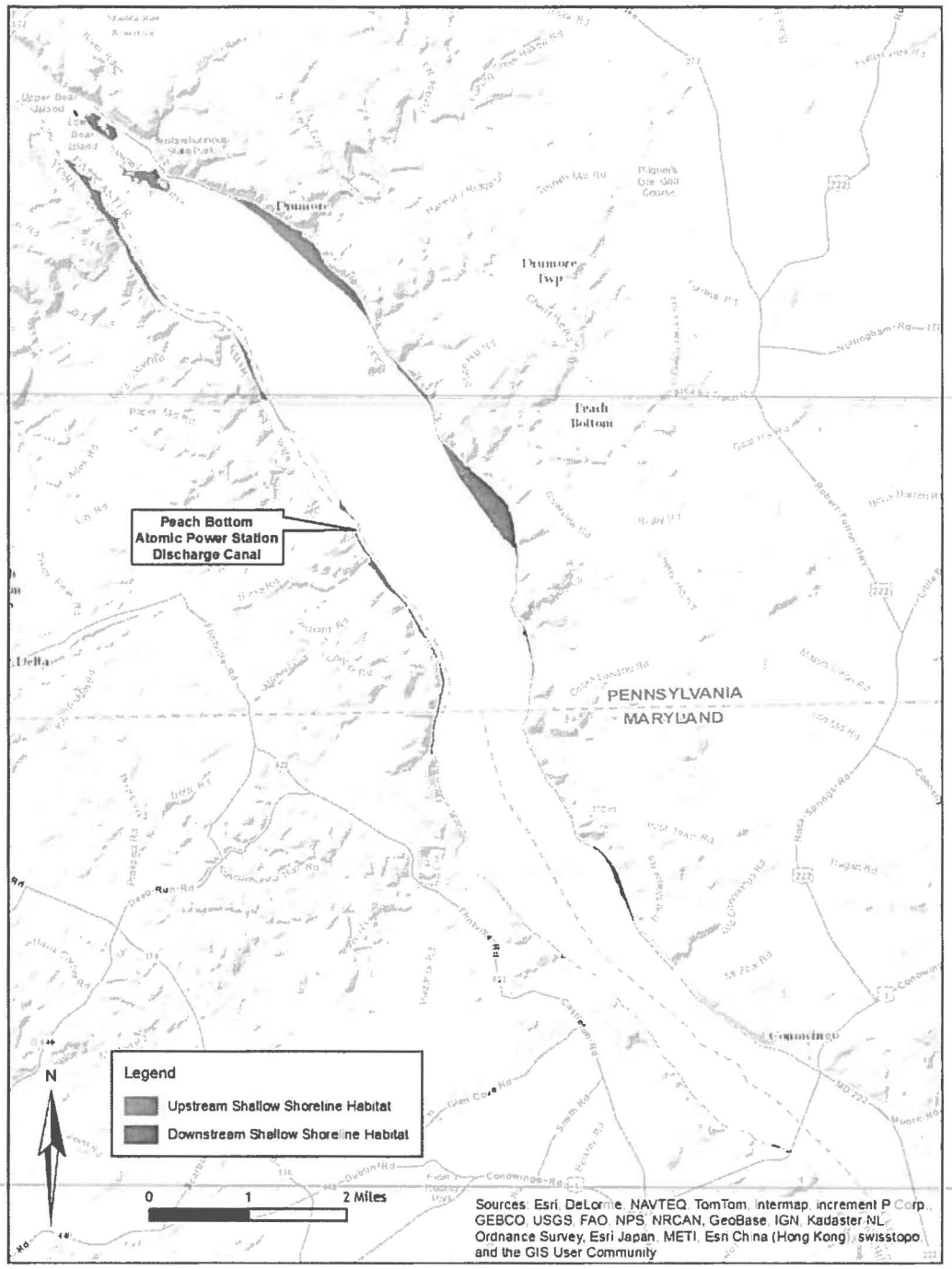



Figure 5-20. Area of shallow shoreline habitat within Conowingo Pond.

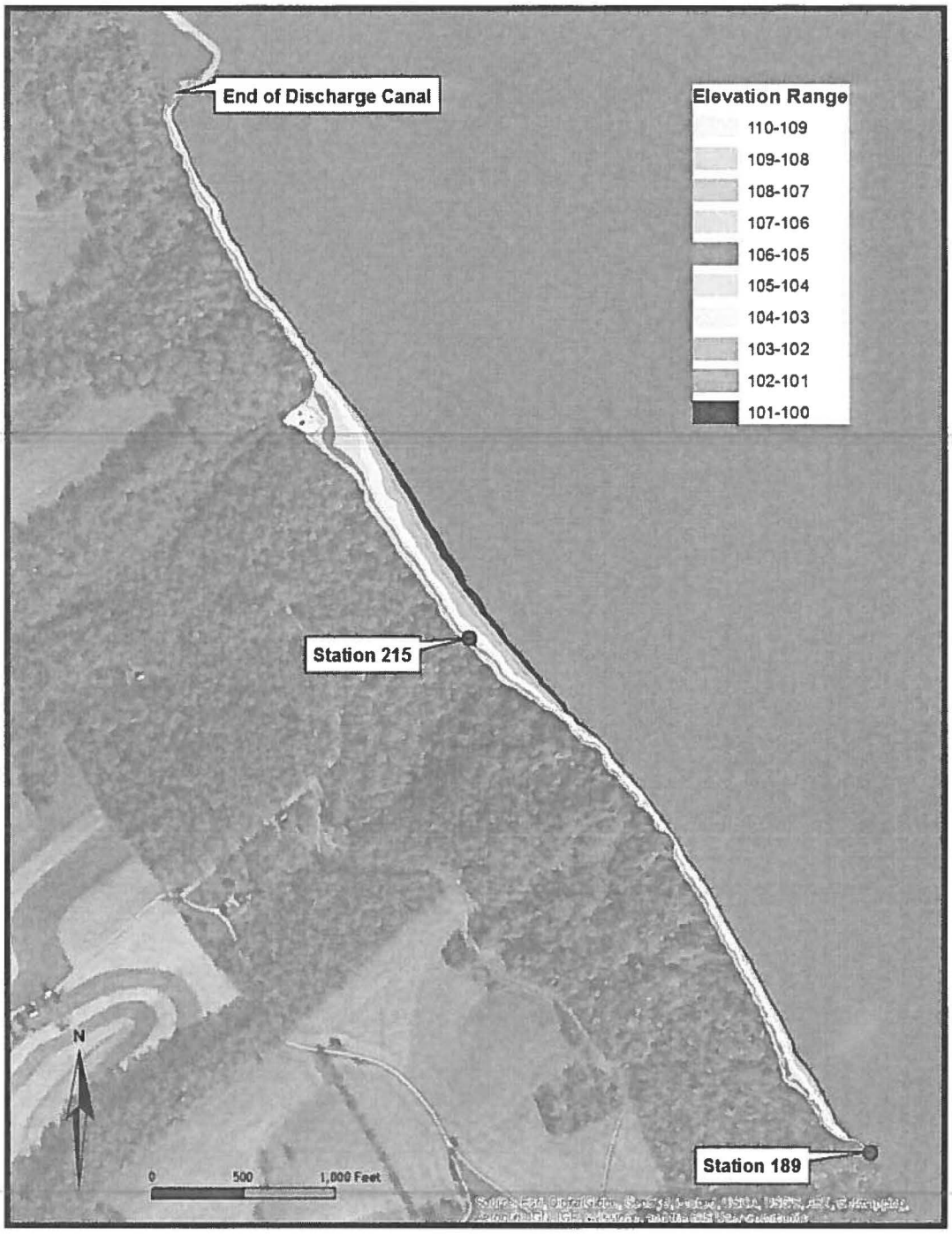



Figure 5-21. Shallow shoreline habitat in the vicinity of the PBAPS discharge canal.

Table 5-9. Amount of shallow shoreline habitat in Conowingo Pond from vicinity of MRPSF downstream to Conowingo Dam.

| Conowingo Pond Elevation (1 ft intervals) | Water Depth (feet) | Shallow shoreline habitat | | |
|---|---|---|---|---|
| | | Acres | Total acres at Elevation[2] | % of Total Pond Surface Area[1] |
| 110-109 | 1 | 11.9 | 488.2 | 5.86 |
| 109-108 | 2 | 12.9 | 476.3 | 5.72 |
| 108-107 | 3 | 19.2 | 463.4 | 5.56 |
| 107-106 | 4 | 55.1 | 444.2 | 5.33 |
| 106-105 | 5 | 88.6 | 389.2 | 4.67 |
| 105-104 | 6 | 63.7 | 300.6 | 3.61 |
| 104-103 | 7 | 70.2 | 236.9 | 2.85 |
| 103-102 | 8 | 68.0 | 166.8 | 2.00 |
| 102-101 | 9 | 52.6 | 98.8 | 1.19 |
| 101-100 | 10 | 46.2 | 46.2 | 0.55 |

[1]Total surface area of Conowingo Pond from vicinity of MRPSS to Conowingo Dam is 8327.6 acres
Total surface area of Conowingo Pond from Holtwood Dam to Conowingo Dam is 9,000 acres
[2]Total shallow shoreline habitat for areas 10ft or less in depth at various elevations, shoreline area derived from URS bathymetry dataset which includes shallow shoreline areas within 50ft of islands but not shallow areas within the main channel

Table 5-10. Amount of shallow shoreline habitat from the end of the PBAPS discharge canal downstream to Station 215.

| Conowingo Pond Elevation (1 ft intervals) | Acres | Total acres at Elevation | % of Total Pond Surface Area[1] | % of Total Pond Shoreline Area[2] |
|---|---|---|---|---|
| 110-109 | 0.56 | 11.64 | 0.14 | 2.39 |
| 109-108 | 0.38 | 11.09 | 0.13 | 2.27 |
| 108-107 | 0.47 | 10.71 | 0.13 | 2.19 |
| 107-106 | 0.74 | 10.24 | 0.12 | 2.10 |
| 106-105 | 1.22 | 9.50 | 0.11 | 1.95 |
| 105-104 | 1.67 | 8.28 | 0.10 | 1.70 |
| 104-103 | 1.75 | 6.61 | 0.08 | 1.35 |
| 103-102 | 1.82 | 4.86 | 0.06 | 1.00 |
| 102-101 | 1.55 | 3.04 | 0.04 | 0.62 |
| 101-100 | 1.49 | 1.49 | 0.02 | 0.31 |

[1]Total surface area of Pond from vicinity of MRPPS to Conowingo Dam is 8327.6 acres
[2]Total shallow shoreline habitat is 488.2 acres for areas 10ft or less in depth at various elevations; shoreline area derived from derived from URS bathymetry dataset which includes shallow shoreline areas within 50ft of islands but not shallow areas within the main channel not adjacent to land

Table 5-11. Amount of shallow shoreline habitat from Station 215 to Station 189.

| Conowingo Pond Elevation (1 ft intervals) | Acres | Total acres at Elevation | % of Total Pond Surface Area[1] | % of Total Pond Shoreline Area[2] |
|---|---|---|---|---|
| 110-109 | 0.18 | 7.32 | 0.09 | 1.50 |
| 109-108 | 0.22 | 7.14 | 0.09 | 1.46 |
| 108-107 | 0.29 | 6.92 | 0.08 | 1.42 |
| 107-106 | 0.42 | 6.63 | 0.08 | 1.36 |
| 106-105 | 0.78 | 6.22 | 0.07 | 1.27 |
| 105-104 | 1.08 | 5.44 | 0.07 | 1.11 |
| 104-103 | 1.10 | 4.35 | 0.05 | 0.89 |
| 103-102 | 1.12 | 3.25 | 0.04 | 0.67 |
| 102-101 | 1.08 | 2.13 | 0.03 | 0.44 |
| 101-100 | 1.05 | 1.05 | 0.01 | 0.21 |

[1]Total surface area of Pond from Muddy Run station to Conowingo Dam is 8327.6 acres
Total surface area of Pond from Holtwood Dam to Conowingo Dam is 9,000 acres
[2]Total shallow shoreline habitat is 488.2 acres for areas 10ft or less in depth at various elevations; shoreline area derived from URS bathymetry datasetwhich includes shallow shoreline areas within 50ft of islands but not shallow areas within the main channel not adjacent to land

### *5.5 Benthic Macroinvertebrate Community*

A study of the benthic macroinvertebrate community was conducted to determine the influence of the thermal plume on the composition and relative abundance of the benthic macroinvertebrate, or benthos, community inhabiting shallow-water shoreline habitat in Conowingo Pond. Previous benthos surveys conducted relative to PBAPS have evaluated the benthic macroinvertebrates residing in deeper, off-shore habitats in the Pond. This is the first survey of benthos in the nearshore habitat. The benthic macroinvertebrate sampling included an assessment of habitat quality 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-approved methodology used for this study is adapted from one described in USEPA (1999) for low gradient (glide pool) streams. The methodology involves visual inspection and quantification of nine habitat parameters:

- Epifaunal Substrate/Available Cover
- Channel Alteration
- Pool Substrate Characterization
- Bank Stability
- Pool Variability

- Bank Vegetative Protection
- Sediment Deposition
- Riparian Vegetative Zone Width
- Channel Flow Status

Each 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 as follows:

| | |
|---|---|
| Optimal | 166-180 |
| Sub-optimal | 113-153 |
| Marginal | 60-100 |
| Poor | <47 |

Scores falling between these ranges are given a dual rating. For example, a score of 112 at Station 215 reported herein is described as sub-optimal/marginal.

*Macroinvertebrate Collection and Analysis*

Macroinvertebrates were collected monthly with a D-frame kick net according to a PADEP (2007) multi-habitat protocol at most of the same locations utilized for the seine collections (Figure 5-22).

Each multi-habitat sample was a composite of 10 "kicks," collected from five habitat types:

- Cobble/gravel,
- Snag,
- Coarse particulate organic matter (CPOM),
- Submerged aquatic vegetation (SAV), 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. These samples were collected in an upstream to downstream direction.

The initial project design prepared for the 2010 study-year utilized seven sample locations. Two stations, 214 and 215, were established within the influence of the thermal plume and the remaining five were in areas upstream of the thermal discharge within the Pond. The 2010 samples were collected during the months of July through October when none of the helper cooling towers were operating.

Beginning in 2011, two new sample locations (Stations 216 and 217) within the influence of the thermal plume but farther down-river near the Maryland border were added. The PADEP

requested these in order to determine whether the influence of the thermal plume on the benthic community was more spatially extensive than previously anticipated. Monthly sampling at these stations began in June 2011. The seven original locations were sampled monthly from April through October.

A tenth location was added in 2012 (Station 189). This station corresponds to electrofishing Station 189 and is located within the plume, along the west shoreline, approximately 1.3 miles downstream from the outfall. It is nearer the discharge point than Stations 216 and 217 but farther away than Stations 214 and 215. Station 189 was selected to further define the extent of thermal impact attributable to the discharge both spatially (distance from the outfall) and seasonally. The hypothesis being tested was: If impact to the benthic community is occurring in July and August when ambient temperatures were the highest, then this should be reflected in comparatively lower IBI scores. If IBI scores were consistent through summer months and into the fall, then this would indicate that the limit of seasonal impact was farther upstream. All ten stations were sampled from April through October in 2013.

All samples were preserved in the field with isopropanol and transported to Normandeau Associates' laboratory in Stowe, PA for processing and analysis. At the laboratory, the sample matrices were placed into a pan divided into twenty-eight 2-inch by 2-inch grids. Specimens were removed from a minimum of four randomly selected grids until a count of 200 (+/- 20 %) was obtained. If a sample did not contain at least 160 specimens, the matrix was processed in entirety. Specimens were sorted by type and placed into glass vials for identification.

Macroinvertebrates were identified to the genus level of scientific classification (referred to as taxa) except for midges, identified to the family level (Chironomidae), and worms, identified to class (Oligochaeta). Each taxon was then assigned a tolerance value from a list provided by PADEP. Tolerance values range from 0 to 10 where numbers between 0 and 3 indicate pollution sensitive taxa (low tolerance). Tolerance values from 4 to 6 may be interpreted to be indicative of facultative taxa. Tolerance values of 7 or greater indicate pollution tolerant taxa. 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

*Macroinvertebrate Metric Scoring*

The PADEP (2007) multi-habitat protocol used in this study was developed for determining water quality impairment based on composition of the benthic community in low gradient streams as compared to a reference set of high quality low gradient streams in Pennsylvania. Although this protocol was not developed for use in reservoirs such as Conowingo Pond or designed to address benthic community impacts associated with elevated temperature, it was

used in this study to compare the sample stations metric values and IBI scores because a more suitable protocol specifically developed for impoundments or lentic waterbodies is not yet available for Pennsylvania waters.

Benthic macroinvertebrate community composition varies depending on the type of waterbody (lentic, lotic, or tidal) and the type of habitat being surveyed. In Conowingo Pond the benthic community is characteristic of a lentic community. That is, most of the benthic organisms in shallow shoreline habitat are adapted to pool and edge habitats characterized by low current velocity. The habitat alteration due to impoundment of the Susquehanna River to create Conowingo Pond has created a more homogenous environment with small amounts of shallow shoreline habitat and shoreline habitats that are lacking habitat complexity. Most of the available benthic habitat in Conowingo Pond lies within the deeper open-water areas where the river bottom is fairly homogenous and composed of finer substrate types (sand, silt, and clay). Nonetheless, the protocol's IBI scoring system provides a tool for making comparisons among sample stations.

As specified in the protocol, a set of equations was used to produce standardized scores for each metric that were in-turn used to produce an 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. To accomplish this, some form of standardization is needed. According to the protocol, the metric values are divided by the 95$^{th}$ percentile of values generated from a broad data set obtained by PADEP to develop the IBI:

| Metric | Standardization | Metric | Standardization |
|---|---|---|---|
| Richness | observed value / 31 | Shannon Diversity | observed value / 2.43 |
| EPT Richness | observed value / 17 | Mayfly Taxa | observed value / 6 |
| Beck's 4 Index | observed value / 22 | Caddisfly Taxa | observed value / 11 |

As noted above, this protocol compares the Conowingo Pond community to a reference set of high quality low gradient streams in the Commonwealth. Thus, relatively low IBI scores can be expected for the benthic macroinvertebrate stations sampled in this study due to fact that Conowingo Pond is an impoundment.

The maximum value any standardized metric score can attain is 1.0. The IBI is calculated by simply taking the average of the six standardized scores and multiplying by 100. The higher the resulting IBI score, the more closely the data are to attaining a reference stream condition used to develop the protocol. According to the protocol, an IBI of 55 or more indicates that a station meets the Aquatic Life Use Designation assigned to the stream. In this study, the IBI threshold score of 55 is not appropriate for making this decision due to the impounded habitat. For the purposes of this study the IBI scores are only used to compare stations.

A brief summary of the metrics and whether their values increase or decrease in response to water or habitat quality degradation is provided in Table 5-15.

Statistical Analyses

The non-parametric Kruskal-Wallis test was used to determine whether statistically significant differences (p-value ≤ 0.1) in IBI scores or metric values existed among the monthly collections at each sample station. If the Kruskal-Wallis test yielded significant differences then the Kruskal-Wallis multiple comparisons test was used to determine which stations differed from each other. This nonparametric test was selected for these analyses over the analogous parametric ANOVA test because not all test groups met the assumptions of equal variances, normal distribution, and there were sample size differences among the stations. The nonparametric test was used for all analyses to streamline statistical analysis among the test metrics.

*Habitat Assessment*

*Results and Discussion*

The results of the habitat assessment are provided in Table 5-16. Station scores ranged from 75 to 113 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 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*

*Results*

Four years of study have produced a total of 108 benthic macroinvertebrate taxa from the study area. The composition and abundance of benthic macroinvertebrates was similar for each year of the study. Common macroinvertebrate taxa (>1% of total organisms) were similar among collection locations and varied from 5 to 12 taxa among stations and years (Table 5-17 through Table 5-20). A few benthic macroinvertebrate taxa comprised a large proportion of all organisms collected at each of the benthos monitoring stations. With few exceptions, Chironomidae and Oligochaeta were among the most abundant organisms for all stations and years (Table 5-17 through Table 5-20).

Other common organisms at select stations or year of collection included *Corbicula*, *Stenelmis*, *Gammarus,* and *Caenis*. *Corbicula* or Asiatic clam was introduced in the 1980s and was not observed in the Pond prior to 1980. No Plecoptera (stoneflies) and few Ephemeroptera (mayflies) or Trichoptera (caddisflies) were collected in high abundance. The mayfly *Caenis* was the only mayfly or caddisfly collected in relatively high numbers among years or stations. Other Ephemeroptera and Trichoptera that comprised >1% of total organisms included *Callibaetis, Stenacron, Oecetis, Hexagenia, Orthotrichia*, and *Maccaffertium*. Total richness of common macroinvertebrate taxa combined for all stations was also similar among years, ranging from 18 to 25 taxa (Table 5-17 to Table 5-20). Similarly, EPT richness of common macroinvertebrates combined for all stations varied among years, ranging from 4 to 9 taxa. There were some observed differences in composition of common taxa among stations. Fewer common taxa (>1% of total organisms) were collected at Station 214 in 2010-2012 as compared to the other locations. The number of common taxa collected at Station 214 in 2013 was similar to the other locations (Table 5-20). Chironomidae comprised a greater proportion (52-67 %) of the benthic community at Station 214 in 2010-2012 as compared to the other stations (Table 5-17 through Table 5-19). However, in 2013 Chironomidae abundance at Station 214 was similar to most of the other locations. *Corbicula* were more abundant at Stations 214 and 215 than at most of the other locations and *Gammarus* abundance was typically lower at Stations 214 and 215 than at the other stations.

A reduction in benthic macroinvertebrate diversity and evenness was evident during July and August at Station 214 in 2010-2012 (Table 5-21). In contrast, in 2013 diversity and evenness was higher. Three or 4 taxa comprised most of the organisms that were collected in 2010-2012 as compared to 7 or 8 taxa in 2013. Chironomidae were numerically dominant, comprising 65 and 80% of all organisms collected during July and August of 2010-2012, respectively. Chironomidae abundance in 2013 for July and August was lower ranging from 33 to 46%. *Corbicula* and Oligochaeta were also more abundant in 2010-2012 as compared to 2013. No Trichoptera and two Ephemeroptera (*Caenis* and *Callibaetis*) were collected in July and August. 2010-2012. In contrast, during 2013 four Trichoptera and three Ephemeroptera taxa were collected.

Summary metrics calculated for each station based on all years of data collection are presented in Table 5-22. The metrics Total Richness, EPT richness, Percent Chironomidae, HBI, Percent Sensitive Taxa, and Percent Oligochaeta were selected to describe the overall benthic macroinvertebrate community observed at each location. Most metric values were similar among stations. Note that Station 189 (N=11 monthly samples) and Stations 216 and 217 (N=19 monthly samples) include fewer monthly collection events compared to the other stations which results in fewer taxa being observed. Total richness ranged from 41 taxa at Station 189 to 65 taxa at Station 220. Richness at Station 214 was lower than all locations with the same number of samples. Similarly, EPT richness ranged from 11 taxa at Station 217 to 19 taxa at Stations 220 and 215. Otherwise, EPT richness was similar among stations. Percent Chironomidae was similar among most stations with the highest value observed at Station 214 (52.1%). HBI values were similar among stations with lowest value of 5.4 observed at Station 189. Percent sensitive taxa (tolerance value 0-3) was low for all stations with the highest value

at Station 216 (2.6%) and lowest at Station 221 (0.2%). Percent Oligochaeta varied from 3.6% at Station 189 to 20.7% at Station 216 with all other station values greater than 8%.

*IBI Scores*

IBI scores were low for all stations and years within and outside of the thermal plume (Figure 5-26). The lowest IBI scores were observed at Stations 214 (thermal) and 221 (non-thermal). However, IBI scores at the other thermal and non-thermal stations were similar. Other slight spatial differences were observed both between and within non-thermal and thermal station groups. Some variation was observed among years with higher scores observed during 2010 or 2013 for most locations (Figure 5-27 and Figure 5-35). Note that sampling was limited in 2010 to only July-October and scores tended to be lower in April, May, and June for most stations. Median IBI scores for Station 214 were significantly lower ($p<0.05$) than all non-thermal and thermal stations except non-thermal Station 221. The only other statistically significant differences in IBI scores were observed between Stations 216 and 221, with scores lower for Station 221 (non-thermal) as compared to Station 216 (thermal).

IBI scores also varied seasonally with higher values observed in the fall as compared to the spring for most locations (Figure 5-28 through Figure 5-36).This seasonal pattern was quite apparent for the combined scores observed for all upstream stations (Figure 5-36). IBI scores tended to increase over the course of the field season with the lowest values observed from April to June and highest values observed from August to October. This pattern was not observed at Station 214 with scores in August to October tending to be similar to April through June. Station 215 IBI scores tended to follow the pattern observed at the upstream stations with the exception of August where scores were lower for several of the collections.

Individual metrics that comprised the IBI scores were also evaluated for each monthly collection. Figure 5-29 through Figure 5-34 show the spread of the metric values for each station. For total richness the interquartile ranges overlapped for all stations except Station 214 and greater variability was observed for Stations 202, 203, and 221 (Figure 5-29). EPT richness values were generally low with wide interquartile ranges for most stations ranging from 0 to 8 taxa among stations (Figure 5-30). EPT richness values were lowest for Stations 214 and 221. Similar to EPT richness, Ephemeroptera richness values were low and variable ranging 0 to 6 taxa among stations (Figure 5-31). Fewer Ephemeroptera taxa were collected at Stations 214 and 221. Few Trichoptera were collected, as indicated by low richness values for all stations with the highest richness observed at Station 208 (Figure 5-32). Beck's Index values were similar among stations with the highest values observed at Stations 189 and 216 and lower scores at Station 214 (Figure 5-33). Shannon diversity was remarkably similar for all stations with interquartile ranges overlapping for all stations; however, values were generally lower for Station 214 (Figure 5-34).

Similar to IBI scores, individual metric values were lower at Station 214 as compared to the other stations. Station 214 metric values were statistically different ($p<0.05$) from at least one other station for all six metrics (Table 5-24). Station 215 metric values were similar to both non-thermal and thermal stations. Few significant differences were observed for Station 215 metric values in comparison to all other stations. Trichoptera richness was low at Station 215 as

compared to Station 208. Other statistically significant differences were observed between both individual non-thermal and thermal stations (Table 5-24).

Table 5-25 through Table 5-30 provide mean metric scores for each station by month of collection. Total richness was generally highest in August and September and the lowest during April and May for most stations. This general pattern was not observed at Station 214 with the lowest mean richness values at this station observed in August and highest observed during April. Similarly, mean EPT, Trichoptera, and Ephemeroptera richness were generally highest in August and September and lowest in April and May. Values of these three metrics were generally low for Stations 214 and 221, regardless of collection month. Mean Shannon diversity values were similar among most stations with the highest values observed for most stations in August through September. Mean Shannon diversity values for Station 214 were lower than all other stations during August through October and during other months within the range of values observed among the other stations. Mean Beck's Index values showed no consistent seasonal pattern with values quite variable among stations and months. However, Station 214 mean Beck's Index values were lower than other stations during July, August (tied with Station 215), and October and during other months within the range of values observed among the other stations.

*Discussion*

Most of the macroinvertebrate taxa collected in this study are lentic (prefer slow current) forms that may be considered either facultative (tolerance value = 4 – 6) or tolerant (tolerance value = 7 – 10) of water/habitat quality degradation. Few intolerant forms (tolerance value 0-3) were collected. The observed taxa are representative of a warmwater aquatic community in a lentic waterbody. The most abundant groups were Chironomidae and Oligochaeta. Many taxa within these groups are adept burrowers found in depositional areas.

Other common genera such as *Gammarus*, *Gyraulus*, *Callibaetis, Enallagma, Oecetis*, and *Orthotrichia* are associated with aquatic vegetation. Other taxa such as *Corbicula,* a filter feeding clam, show a potential affinity for the warm water and/or current introduced from the PBAPS discharge.

Station 214, located about 0.35 miles below the discharge canal, is the benthic macroinvertebrate station located closest to the end of the discharge canal. The IBI scores for Station 214 were lower than the other non-thermal and thermal stations, indicating benthos effects attributable to the heated effluent. Station 215 is the next closest station to the PBAPS discharge canal and is located 0.65 miles downstream of the canal. IBI scores at Station 215 were not significantly different from the other thermal or non-thermal stations. However, lower IBI scores were observed at this station during July and/or August.

The observations indicate that the area of potential effect to the benthic community is restricted to a narrow band of shallow-water habitat along the western shoreline. 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 July and/or August when water temperatures were the highest

(Figure 5-4 , Figure 5-5, Figure 5-36). Improvement in both IBI scores and metric values was observed during subsequent months, indicating re-colonization and recovery of the benthic community. IBI scores and metric values at Stations 214 and 215 during the spring collections are comparable to the upstream stations and indicate recovery of the benthic community. Metric values and IBI scores indicated no 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 Station 215 during the months of July and/or August. 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 Station 215 were similar to non-thermal stations and were higher than non-thermal Station 221. Station 215 benthic community observations were not significantly different from the non-thermal stations.

Station 189, the next closest station downstream, is located 1.3 miles below the discharge canal. No impact to the benthic community was observed at Station 189. The benthos collection data show that the limit of measurable effect to the shoreline benthic community is farther upstream from Station 189 in the vicinity of Station 215. Relatively high metric values and IBI scores were observed at Stations 189, 216, and 217, with values at these locations comparable to or higher than those determined for the upstream, non-thermal stations. The benthos monitoring identified and confirmed that the thermal impact is confined to the western shoreline in the vicinity of the two stations closest to the end of PBAPS discharge canal.

Field observations indicated that the amount of benthic area affected by the thermal plume is small in relation to the available benthic habitat area of Conowingo Pond. The areas of impact are confined to areas along the western shoreline directly downstream from the PBAPS discharge. This area from the end of the discharge canal downstream to Station 189 comprises less than 19 acres of the total shallow shoreline habitat. Lower IBI scores and metric values indicate that the benthic macroinvertebrate community is affected in the near-field from the PBAPS discharge canal downstream to Station 215, which encompasses approximately 12 acres of shallow shoreline habitat. The benthos survey data indicate that benthos impact is localized and temporary and occurs during July and August with recovery evident at Station 214 beginning in September.

An observable effect on the benthic community occurred during the July and August timeframe at Station 214 in 2010-2012. The observable impact at Station 215 occurred during July or August depending on the year of collection in 2010-2012. No measurable thermal impacts were detected in 2013 for either station (i.e., high IBI scores in July and August). The influence of the thermal plume resulted in fewer taxa being present in the July or August samples. During July and August the benthic community at Station 214 was dominated by a single taxon, Chironomidae, which comprised a majority of the organisms collected. This finding is consistent with studies that have shown several chironomid genera to be tolerant of elevated water temperatures (EPA 1978).

Few studies have evaluated the chronic effects of elevated water temperatures on benthic communities or specific species and most did not account for acclimation temperature. The empirical evidence gained from this study is useful in understanding the changes to the benthic community related to elevated water temperatures. A more detailed discussion of the relation between water temperature and the benthic macroinvertebrate community is provided in the last part of Section 5.5.

Lower metric values and IBI scores in July and August resulted in significantly different benthic community at Station 214 as compared to most other non-thermal and thermal stations. Removal of July and August collections from the analyses of monthly collections for all stations results in only one significantly different metric (Kruskal-Wallis, $p > 0.05$). The only significant difference was Trichoptera richness (Kruskal-Wallis, $p = 0.008$). Trichoptera richness was significantly different between Station 214 and Stations 217 and 208. This further illustrates the short-term seasonal nature of the thermal impact. Elevated water temperatures during other months did not result in detectable impact to the benthic community based on metric values and IBI score analyses.

The seasonal differences in metric values are likely related to establishment of SAV and life history patterns of certain benthic insects. Many of the Trichoptera and other taxa are obligates that depend on SAV for habitat and as a food source. This is quite apparent at several of the collection locations (e.g. Station 208) where the highest richness values where observed during the summer and fall. Station 214 did not show a similar seasonal trend. The elevated water temperatures during July and August likely limited the establishment of these specific taxa at Station 214 which led to lower overall richness values. Community composition as determined by IBI scores and metric values indicated that Station 214 benthos community is similar to other location during other months of the year. That is, richness, diversity and evenness are comparable during the spring and late fall to other non-thermal and thermally affected areas of the Pond. Interestingly, during 2013 with the lower ambient temperatures and higher River flows the IBI and metrics scores were much higher at Station 214 during July and August. The IBI score at Station 214 during July (50) was higher than all other stations during that month.

Although the PADEP multi-habitat protocol was not developed for use in reservoirs such as Conowingo Pond or designed to address benthic community impacts associated with elevated temperature, it did allow for a standardized approach to compare the collection stations. It is important to reiterate that the protocol methods employed in this study were utilized in the absence of a methodology specifically developed for impoundments and for assessing thermal impacts. The individual metrics and metric scoring criteria were not developed for assessing changes in benthos related to thermal effluents in an impounded waterbody. Thus, interpretation of the IBI scores is difficult and comparison of the IBI scores to the protocol threshold for determining water quality impact would not be appropriate.

Lastly, the shore zone benthos community was assessed and included as a component of this study at the request of PADEP. This shallow shore zone habitat is a small proportion of the entire available benthic habitat in the Pond. Most of the Pond benthic habitat is in open-water

areas not along the shoreline. In terms of total organisms and biomass the open-water areas make up a much larger portion of the benthic community in the Pond.

*Overall Conclusions*

Benthic community effects resulting from the thermal plume are localized and temporary, with the area of impact being small in comparison to the amount of similar non-thermally impacted Conowingo Pond shoreline. The area from the PBAPS discharge canal downstream to Station 215 represents approximately 12 acres of shallow shoreline habitat within Conowingo Pond from the vicinity of MRPSF to Conowingo Dam that is affected by the thermal plume. The assessment of shoreline habitat indicates a narrow band of shallow shoreline habitat within the area directly downstream from the PBAPS discharge canal.

The simple benthic macroinvertebrate community present within the Pond can continue to complete necessary life-cycle stages regardless of the limited impact area and temporary impacts due to thermal discharge. This is evident in that benthic community persists in nearby shallow shoreline habitat and re-colonization of impacted areas occurs during September when water temperatures decrease and in subsequent months re-colonization continues. The benthic community present within the areas with lower IBI scores is similar to the other stations during the spring. This temporary local change to the benthic community does not affect the food resources of fish (see Section 5.6 Fish Condition).

Benthic macroinvertebrate collections were successfully completed from 2010-2013. The data indicate that:

- Benthic community impacts resulting from the thermal plume are local and temporary and limited to a small proportion of the available shallow shoreline habitat within Conowingo Pond.
- The composition and relative abundance of the benthic community were similar during all 4 years with variable numbers of cooling towers in operation.
- The benthic community was characterized by similar diversity both within and outside of the thermal plume.
- Temporary impact, in terms of lower IBI scores, was observed at Stations 214 and 215. The lower IBI scores occurred after a sustained period of high water temperatures for a portion of July and August and, thereafter, recovery took place.
- Observations over the course of the entire collection period indicated that no substantial reduction in community heterogeneity or trophic structure was observed at Stations 214 and 215.
- There was no observed impact to the benthic community at the three thermally-influenced Stations (189, 216 and 217) that are farthest downstream from the discharge canal.
- The benthic community was able to sustain itself through cyclical seasonal changes both within and outside of the thermal plume.
- There is a balanced indigenous benthic community within Conowingo Pond.

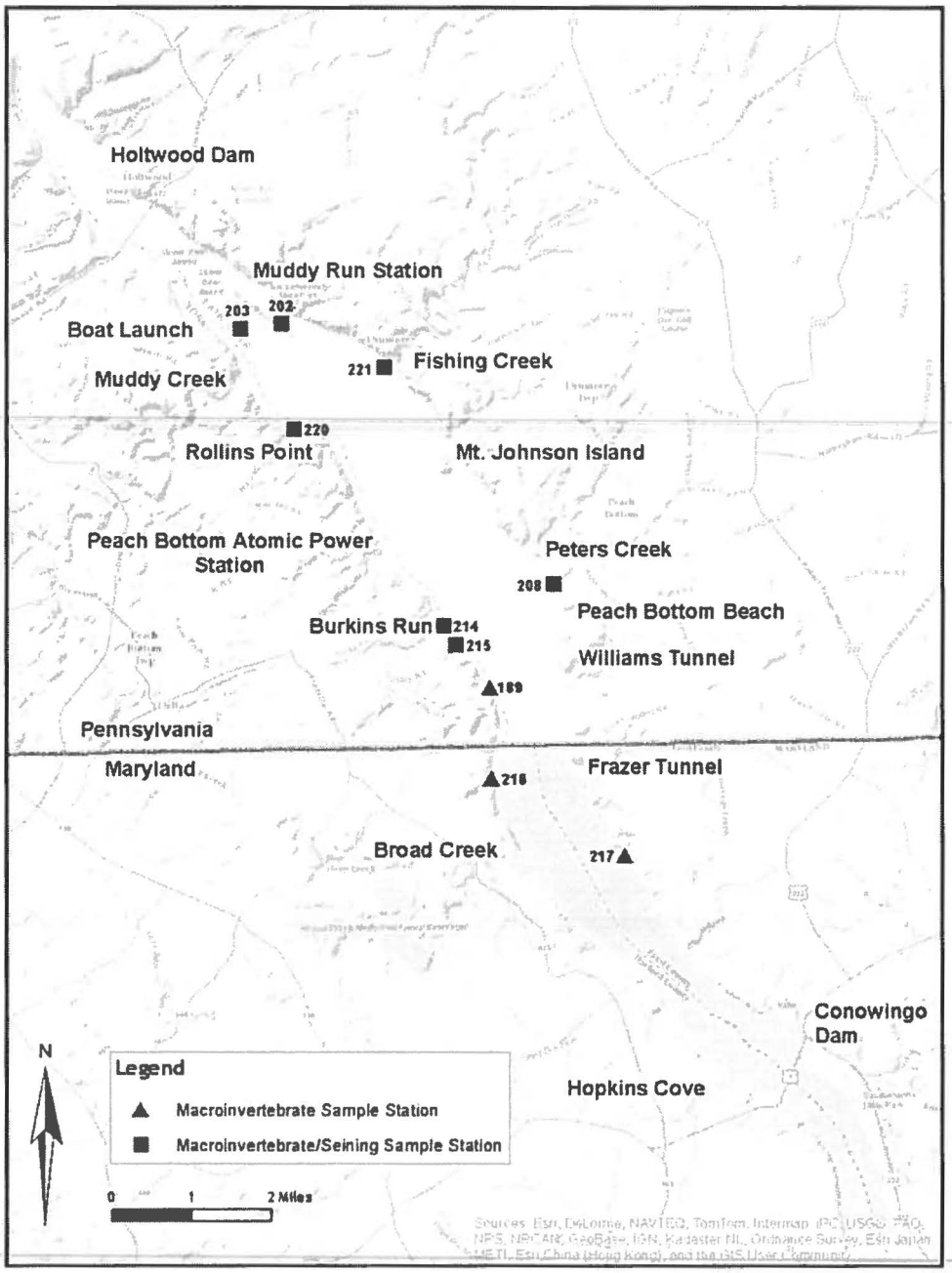



Figure 5-22. Location of seine and benthic macroinvertebrate collection stations.

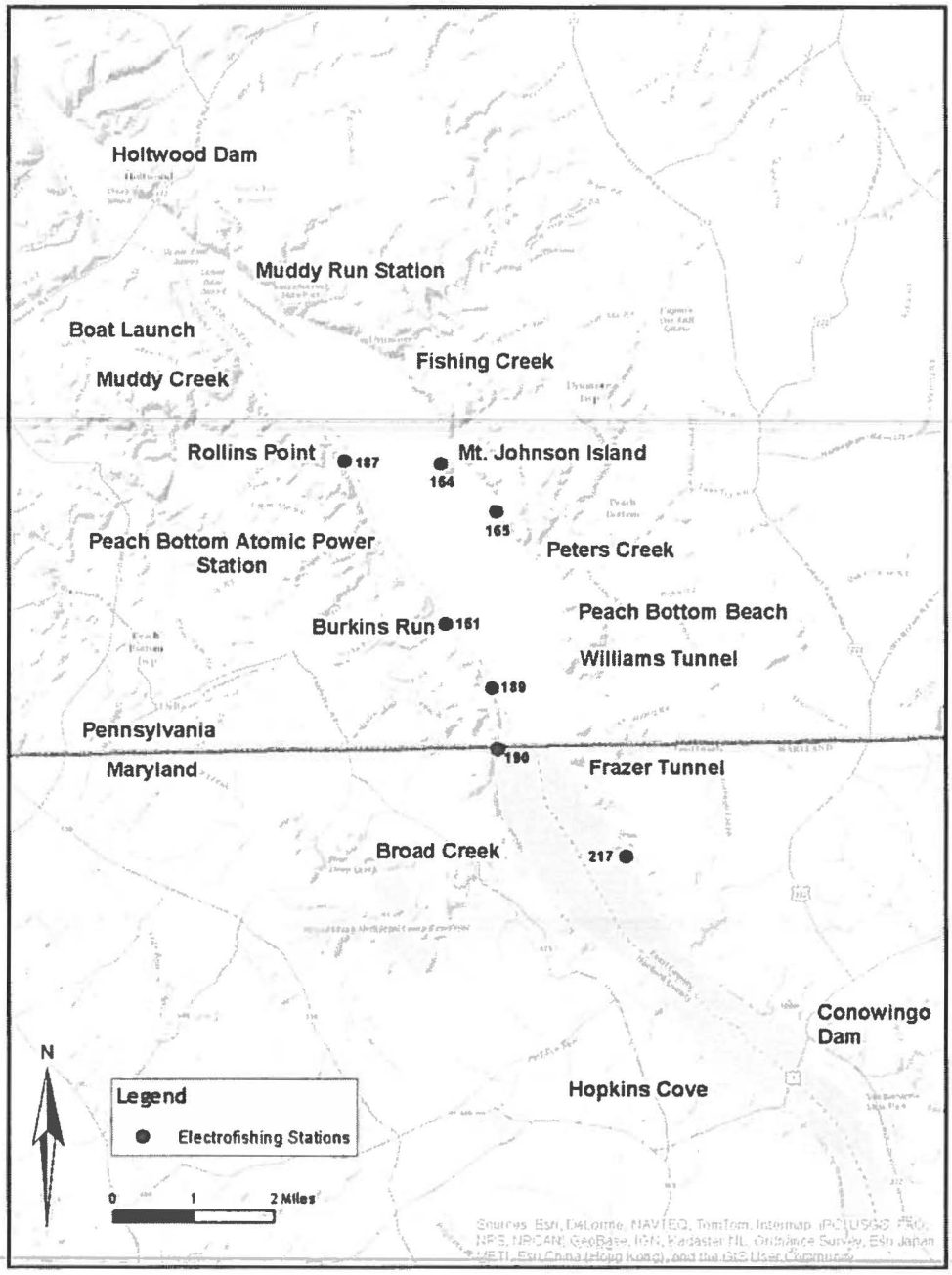



Figure 5-23. Location of electrofishing collection stations.

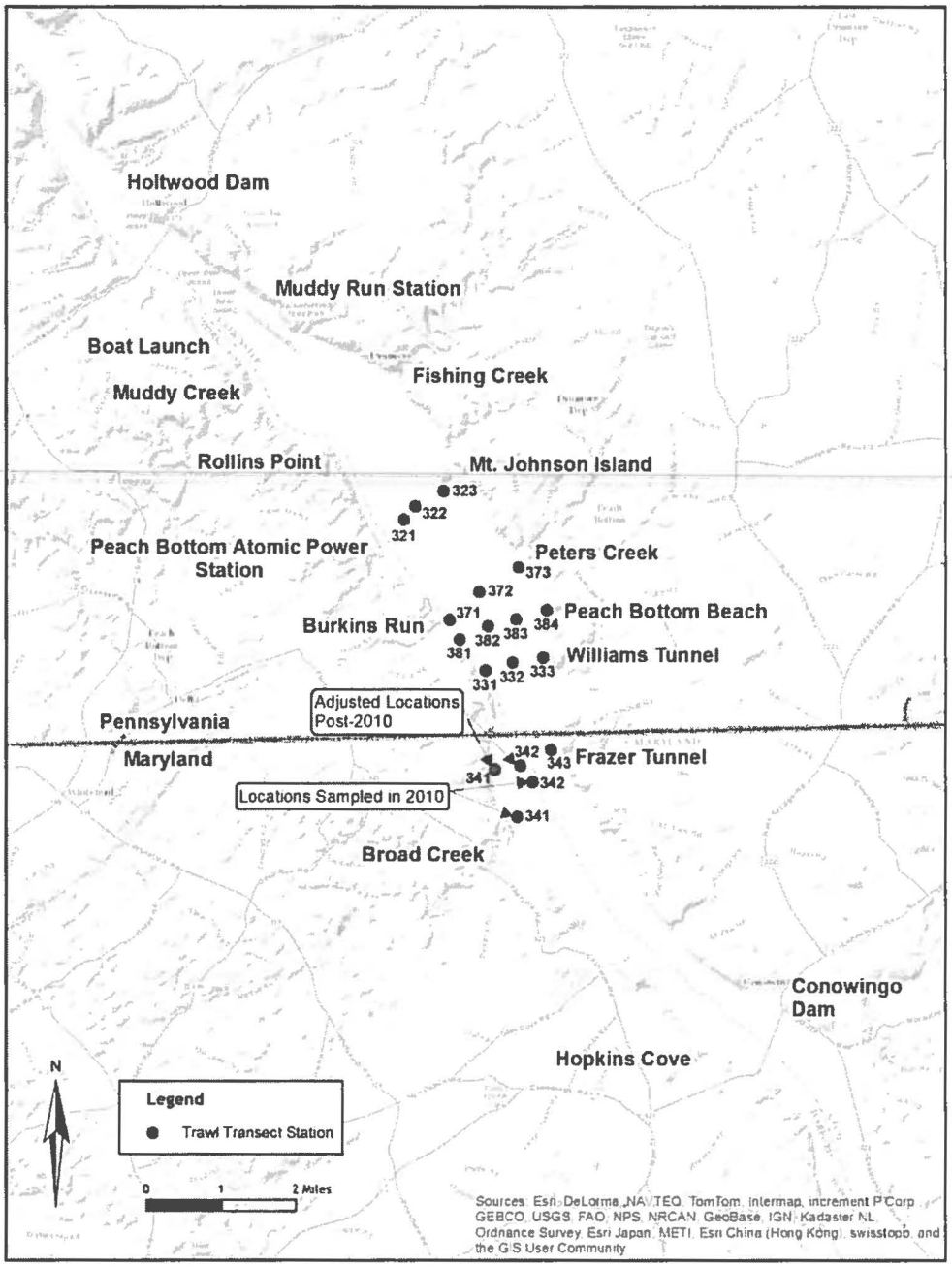



Figure 5-24. Location of trawl collection stations.

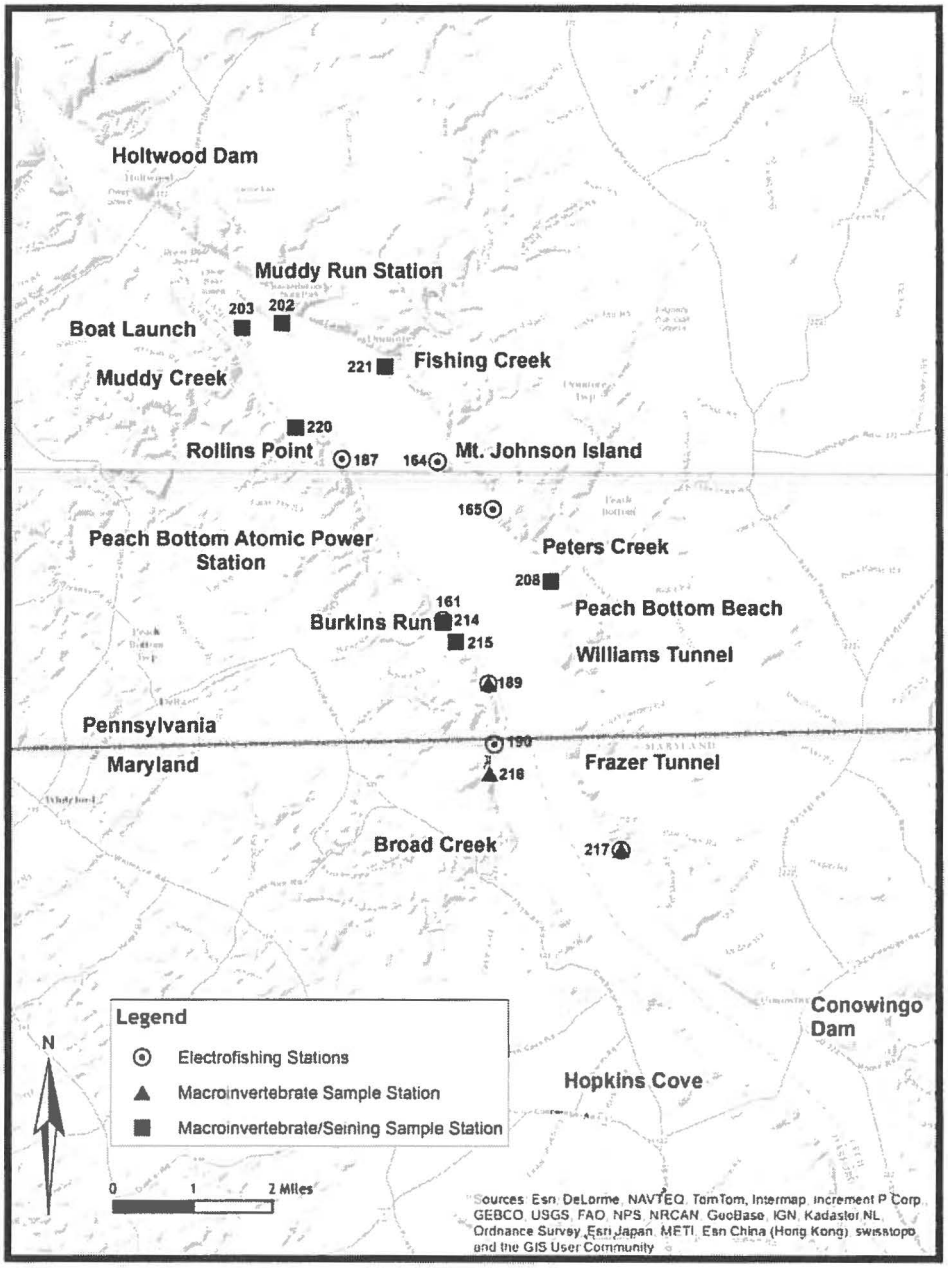



Figure 5-25. Combined map showing locations of seine, benthic macroinvertebrate, and electrofishing collection stations.

Table 5-12. Description of seine and benthos stations in Conowingo Pond (negative values indicate upstream from the discharge canal).

| Station | Description | Distance From End Of Discharge Canal | |
|---|---|---|---|
| | | Meters | Miles |
| 189 | Rock outcropping at north side of Michael's Run to 'McClellan's Rock'. | 2,128 | 1.32 |
| 202 | Southeast shore of Sicily Island. | -6,331 | -3.93 |
| 203 | West shore of Big Chestnut Island. | -6,683 | -4.15 |
| 208 | Peach Bottom Beach. | -2,449 | -1.52 |
| 214 | Beach at the mouth of Burkins Run. | 591 | 0.37 |
| 215 | Campground boat launch' - about 250 m below the mouth of Burkins Run. | 1,049 | 0.65 |
| 216 | Below site 190, small cove at end of Line Bridge Road | 3,919 | 2.44 |
| 217 | 2,000 m above the mouth of Conowingo Creek. | 6,466 | 4.02 |
| 220 | Coal Cabin boat launch. | -4,410 | -2.74 |
| 221 | Fishing Creek confluence - northwest side of shoal. | -4,765 | -2.96 |

Table 5-13. Description of trawl transects in Conowingo Pond. (negative values indicate upstream from the discharge canal).

| Station | Description | Distance From End Of Discharge Canal | |
|---|---|---|---|
| | | Meters | Miles |
| | *Transect 2* | | |
| 321 | Off PBAPS Unit 2. | -1,824 | -1.13 |
| 322 | Mid-pond between Mt. Johnson Island and PBAPS. | -2,035 | -1.26 |
| 323 | Below Mt. Johnson Island. | -2,343 | -1.46 |
| | *Transect 3* | | |
| 331 | McClellan's Rock. | 1,911 | 1.19 |
| 332 | Mid-pond between McClellan's Rock and William's Tunnel. | 2,195 | 1.36 |
| 333 | William's Tunnel. | 2,678 | 1.66 |
| | *Transect 4* | | |
| 341 | Broad Creek. | 5,022 | 3.12 |
| 342 | Mid-pond off Broad Creek. | 4,483 | 2.79 |
| 343 | Wildcat Tunnel. | 4,114 | 2.56 |
| | *Transect 7* | | |
| 371 | Burkins Run (Stonewall Point). | 589 | 0.37 |
| 372 | Mid-pond between Burkins Run and the former Ichthyological Associates dock. | 1,013 | 0.63 |
| 373 | Ichthyological Associates Dock. | 1,965 | 1.22 |
| | *Transect 8* | | |
| 381 | Campground boat launch below Burkins Run. | 1,042 | 0.65 |
| 382 | 500 m off west shore | 1,322 | 0.82 |
| 383 | 500 m of East shore. | 1,841 | 1.14 |
| 384 | Chester County Water Intake. | 2,456 | 1.53 |

Table 5-14. Description of electrofishing stations in Conowingo Pond. (negative values indicate upstream from the discharge canal).

| Station | Description | Distance From End Of Discharge Canal | |
|---|---|---|---|
| | | Meters | Miles |
| 161 | Rock outcropping above Burkins Run to PBAPS discharge structure. | 545 | 0.34 |
| 164 | Southwest shoreline of Mt. Johnson Island. | -2,741 | -1.70 |
| 165 | East shoreline above Peters Creek. | -2,159 | -1.34 |
| 187 | South of Rollins Point to first cabin. | -3,325 | -2.07 |
| 189 | Rock outcropping at north side of Michael's Run to 'McClellan's Rock'. | 2,128 | 1.32 |
| 190 | First cabin below Michaels Run to mouth. | 3,285 | 2.04 |
| 217 | 2,000 m above the mouth of Conowingo Creek. | 6,466 | 4.02 |

Table 5-15. 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 5-16 Habitat assessment scores for the 10 benthos stations.

| | Non-thermal Stations | | | | | Thermal Stations | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | 202 | 203 | 220 | 221 | 208 | 214 | 215 | 189 | 216 | 217 |
| Epifaunal Substrate/Available Cover | 10 | 10 | 15 | 14 | 15 | 15 | 15 | 14 | 11 | 13 |
| Pool Substrate Characterization | 5 | 10 | 16 | 15 | 15 | 15 | 15 | 12 | 11 | 14 |
| Pool Variability | 5 | 15 | 5 | 5 | 5 | 5 | 5 | 11 | 5 | 5 |
| Channell Alteration | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| Sediment Deposition | 5 | 5 | 15 | 5 | 15 | 10 | 15 | 18 | 14 | 16 |
| Channel Flow Status | 14 | 14 | 16 | 10 | 15 | 15 | 15 | 13 | 20 | 20 |
| Condition of Banks | 15 | 15 | 15 | 14 | 15 | 15 | 15 | 7 | 18 | 18 |
| Bank Vegetative Protection | 5 | 5 | 10 | 15 | 15 | 18 | 15 | 10 | 12 | 16 |
| Riparian Vegetative Zone Width | 15 | 15 | 15 | 15 | 15 | 19 | 16 | 10 | 6 | 6 |
| Total Score | 75 | 90 | 108 | 94 | 111 | 113 | 112 | 96 | 97 | 108 |

Table 5-17. Percent composition of common benthic macroinvertebrates (>1%) collected from Conowingo Pond, July-October 2010.

| Taxon | | Station | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 202 | 203 | 208 | 220 | 221 | 214 | 215 |
| | Oligochaeta | 17.2 | 13.9 | 8.2 | 13.1 | 21.6 | 11.4 | 16.3 |
| | Acariformes | 1.4 | 1.2 | 1.5 | 2.7 | 4.6 | | 4.1 |
| Bivalvia | *Corbicula* | 2.6 | 3.0 | 2.9 | 4.3 | 3.6 | 14.2 | 19.1 |
| Gastropoda | *Ferrissia* | 7.9 | 4.0 | | | | | |
| | *Goniobasis* | 1.8 | 2.5 | | | | | |
| | *Gyraulus* | | | 16.5 | 6.6 | 1.7 | | |
| | *Helisoma* | 2.8 | | 3.9 | 2.6 | | | |
| | *Physa* | 2.8 | 5.8 | 6.4 | | | 2.1 | 10.5 |
| Odonata | *Enallagma* | 3.7 | 7.0 | | 1.1 | 6.1 | | |
| Amphipoda | *Gammarus* | 12.8 | 5.3 | | 6.0 | 5.5 | | 1.5 |
| Ephemeroptera | *Caenis* | 9.5 | 20.1 | 21.0 | 35.2 | 3.9 | 2.7 | 3.1 |
| | *Callibaetis* | | | 2.9 | | 2.4 | | |
| | *Hexagenia* | | | | | | | 1.2 |
| | *Stenacron* | 2.0 | 2.6 | | | | | |
| Trichoptera | *Oecetis* | | | 2.1 | | | | |
| | *Orthotrichia* | | | 2.0 | | | | |
| Diptera | Chironomidae | 29.0 | 28.9 | 28.5 | 22.3 | 47.4 | 67.2 | 38.9 |
| Coleoptera | *Stenelmis* | | | | | | | 1.4 |
| Total Richness | | 12 | 11 | 11 | 9 | 9 | 5 | 9 |
| Total EPT | | 2 | 2 | 4 | 1 | 2 | 1 | 2 |

Table 5-18. Percent composition of common benthic macroinvertebrates (>1%) collected from Conowingo Pond, April-October 2011.

| | | Station | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Taxon | | 202 | 203 | 208 | 220 | 221 | 214 | 215 | 216[a] | 217[a] |
| | Nematoda | 2.5 | 1.4 | 1.1 | | 1.5 | | | | |
| | Oligochaeta | 17.0 | 29.9 | 15.9 | 24.6 | 31.9 | 22.4 | 21.6 | 32.7 | 16.5 |
| | Acariformes | | | 14.7 | | 3.6 | | | 2.2 | 3.8 |
| Bivalvia | *Corbicula* | 1.2 | 1.4 | | | 2.0 | 16.0 | 25.0 | 7.1 | 2.1 |
| | *Pisidium* | 1.4 | | | | 2.1 | | | | |
| Gastropoda | *Goniobasis* | | 10.0 | | | | | | | |
| | *Gyraulus* | | | 1.4 | | | | | | |
| | *Helisoma* | | | 1.1 | | | | | | |
| | *Physa* | | | 2.0 | | | | | | |
| Odonata | *Enallagma* | | | 1.2 | 1.5 | | | | | 2.3 |
| Amphipoda | *Gammarus* | 23.7 | 13.4 | 10.2 | 13.0 | 7.0 | 1.8 | 3.2 | 11.0 | 6.2 |
| Ephemeroptera | *Caenis* | 3.5 | 2.3 | 9.8 | 3.2 | | 2.2 | 1.7 | 9.7 | 20.1 |
| | *Hexagenia* | | | | 2.1 | | 1.7 | 3.0 | 1.2 | |
| | *Stenacron* | | | | | | | | 1.2 | |
| Trichoptera | *Orthotrichia* | | | 1.8 | | | | | | 1.5 |
| Diptera | *Psychoda* | | | | | 2.2 | | | | |
| | Chironomidae | 30.4 | 27.6 | 36.9 | 46.9 | 44.1 | 52.0 | 39.9 | 28.6 | 42.6 |
| Coleoptera | *Stenelmis* | 11.2 | 9.1 | | | 1.1 | | | | |
| Total Richness | | 8 | 8 | 11 | 6 | 9 | 6 | 6 | 8 | 8 |
| EPT Richness | | 1 | 1 | 2 | 2 | 0 | 2 | 2 | 3 | 2 |

[a]Collection occurred from June-October

Table 5-19. Percent composition of common benthic macroinvertebrates (>1%) collected from Conowingo Pond, April-October 2012.

| | | Station | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Taxon | | 202 | 203 | 208 | 220 | 221 | 214 | 215 | 189[a] | 216 | 217 |
| | Nematoda | 3.0 | 3.6 | 1.4 | | 1.7 | | | | 1.0 | |
| | Oligochaeta | 28.2 | 11.2 | 5.5 | 7.4 | 19.6 | 16.0 | 7.0 | 6.2 | 19.7 | 7.0 |
| | Acariformes | 1.0 | | 20.2 | 3.2 | 2.6 | 1.0 | 4.1 | 10.1 | 2.6 | 7.1 |
| Bivalvia | *Corbicula* | 7.5 | 12.1 | 2.9 | 2.6 | 3.0 | 10.5 | 14.7 | 22.1 | 3.0 | 2.2 |
| Gastropoda | *Fossaria* | | | | | | 9.1 | 4.3 | | | |
| | *Goniobasis* | | 7.1 | | | | | | | | |
| | *Gyraulus* | | | 2.8 | 4.2 | 13.1 | | | | | |
| | Lymnaeidae | | | | | | | 1.0 | | | |
| | *Physa* | | | | | 1.2 | 5.5 | 7.3 | | | |
| | *Pisidium* | 1.2 | | | | | | | | | |
| Odonata | *Argia* | | | | | 1.6 | | | | | |
| | *Enallagma* | | | | | 1.6 | | 1.1 | | | |
| Amphipoda | *Crangonyx* | 2.2 | | | | | | | | 1.0 | |
| | *Gammarus* | 24.0 | 19.7 | 9.0 | 12.7 | 2.6 | | 7.5 | 4.8 | 15.8 | 5.7 |
| Ephemeroptera | *Caenis* | | 5.6 | 28.2 | 10.0 | 1.6 | 1.4 | 4.1 | | 16.9 | 28.6 |
| | *Maccaffertium* | | 2.0 | | 1.7 | | | | | 2.3 | 1.7 |
| | *Stenacron* | | 2.5 | | | | | | 5.3 | | |
| | *Hexagenia* | | | | | | | 3.7 | 5.7 | | |
| Trichoptera | *Orthotrichia* | | | | | | | | | | 1.2 |
| Diptera | Chironomidae | 25.4 | 18.4 | 23.9 | 50.9 | 46.7 | 53.2 | 39.4 | 41.6 | 32.9 | 39.3 |
| Coleoptera | *Stenelmis* | 1.9 | 14.7 | | | | | 2.6 | | | |
| Total Richness | | 9 | 10 | 8 | 8 | 11 | 7 | 12 | 7 | 9 | 8 |
| EPT Richness | | 0 | 3 | 1 | 2 | 1 | 1 | 2 | 2 | 2 | 3 |

[a]Collections occurred from July-October

Table 5-20. Percent composition of common benthic macroinvertebrates (>1%) collected from Conowingo Pond, April-October 2013.

| | | Station | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Taxon | | 202 | 203 | 208 | 220 | 221 | 214 | 215 | 189 | 216 | 217 |
| | Oligochaeta | 3.0 | 5.8 | 3.5 | 2.3 | 10.9 | 5.3 | 2.8 | 2.4 | 13.6 | 12.2 |
| | Acariformes | | | 13.6 | 1.4 | 4.6 | 2.5 | 5.4 | 2.4 | 1.2 | 4.3 |
| Turbellaria | *Dugesia* | | | 1.2 | | | | | | | |
| Bivalvia | *Corbicula* | 3.0 | 7.2 | 1.1 | 13.2 | 2.5 | 14.0 | 14.5 | 3.9 | 4.2 | |
| Gastropoda | *Ferrissia* | | 1.6 | | 2.3 | | | | | | |
| | *Goniobasis* | | 2.1 | | | | | | | | |
| | *Gyraulus* | | | 7.4 | 2.8 | 9.0 | 2.3 | | | | 1.5 |
| | *Helisoma* | | | 1.7 | | 5.2 | | | | | |
| | *Physa* | | | 5.0 | | 2.8 | 4.9 | 6.6 | 2.7 | | |
| Odonata | *Enallagma* | | | | | | 1.0 | | | | |
| Amphipoda | *Crangonyx* | | | | | | | | 2.5 | 4.2 | |
| | *Gammarus* | 37.9 | 32.6 | 11.9 | 10.3 | 9.7 | 3.2 | 8.1 | 41.8 | 13.4 | 8.5 |
| Isopoda | *Caecidotea* | | | | | | | | 2.4 | 4.3 | |
| Ephemeroptera | *Caenis* | 3.5 | 5.0 | 23.5 | 17.3 | 3.5 | 18.9 | 12.4 | 1.7 | 27.2 | 26.3 |
| | *Stenacron* | | | | | | | 1.0 | 1.9 | | |
| | *Callibaetis* | | | 1.7 | | | | | | | |
| | *Hexagenia* | | | | | | | 2.9 | | | |
| | *Maccaffertium* | | | | | | | | | 1.2 | |
| | *Stenonema* | | | | | | | 1.5 | | 2.1 | |
| Trichoptera | *Hydroptila* | 1.1 | | | | | | | | | |
| | *Oecetis* | | | | | 1.2 | | | | | |
| | *Orthotrichia* | | | 1.7 | | | | | | | 1.7 |
| Lepidoptera | *Acentria* | | | | | 1.8 | | | | | |
| Diptera | Chironomidae | 42.3 | 38.2 | 22.5 | 41.9 | 43.0 | 43.1 | 40.6 | 33.7 | 23.7 | 37.6 |
| Coleoptera | *Dubiraphia* | 1.1 | | | | | | | | | |
| Total Richness | | 7 | 7 | 12 | 8 | 11 | 9 | 10 | 10 | 10 | 7 |
| EPT Richness | | 2 | 1 | 3 | 1 | 2 | 1 | 4 | 2 | 3 | 2 |

Table 5-21. Benthic community composition at Station 214 during July and August, 2010-2012 and July and August 2013.

| | July 2010-2012 | | July 2013 | | August 2010-2012 | | August 2013 | |
|---|---|---|---|---|---|---|---|---|
| Taxon | Number | Percent Composition | Number | Percent Composition | Number | Percent Composition | Number | Percent Composition |
| Acariformes | 3 | 0.5 | 11 | 5.6 | 1 | 0.2 | 15 | 6.8 |
| Acentria | | | 1 | 0.5 | | | | |
| Argia | | | | | | | 1 | 0.5 |
| Caenis | 36 | 5.7 | 27 | 13.8 | 1 | 0.2 | 48 | 21.8 |
| Callibaetis | | | | | 1 | 0.2 | 1 | 0.5 |
| Centroptilum | | | | | | | 1 | 0.5 |
| Ceratopogon | | | 1 | 0.5 | | | | |
| Chironomidae | 409 | 65.1 | 65 | 33.3 | 436 | 80.0 | 101 | 45.9 |
| Corbicula | 112 | 17.8 | 1 | 0.5 | 13 | 2.4 | 34 | 15.5 |
| Enallagma | 4 | 0.6 | 1 | 0.5 | 5 | 0.9 | 2 | 0.9 |
| Gammarus | | | 32 | 16.4 | | | | |
| Gomphidae | | | | | 1 | 0.2 | | |
| Goniobasis | | | 6 | 3.1 | | | | |
| Gyraulus | | | 26 | 13.3 | | | 1 | 0.5 |
| Hexagenia | | | 2 | 1.0 | | | | |
| Hydroptila | | | 1 | 0.5 | | | 2 | 0.9 |
| Nematoda | 4 | 0.6 | | | 1 | 0.2 | | |
| Oecetis | | | 1 | 0.5 | | | | |
| Orconectes | 1 | 0.2 | | | | | | |
| Oligochaeta | 56 | 8.9 | 1 | 0.5 | 80 | 14.7 | | |
| Orthotrichia | | | | | | | 1 | 0.5 |
| Physa | 2 | 0.3 | 9 | 4.6 | 6 | 1.1 | 12 | 5.5 |
| Pisidium | 1 | 0.2 | | | | | | |
| Stenacron | | | 5 | 2.6 | | | 1 | 0.5 |
| Stenonema | | | 3 | 1.5 | | | | |
| Triaenodes | | | 2 | 1.0 | | | | |
| Total Organisms | 628 | | 195 | | 545 | | 220 | |
| Total Richness | 10 | | 18 | | 10 | | 13 | |
| EPT Richness | 1 | | 7 | | 2 | | 6 | |

Table 5-22. Summary metrics for benthos community, 2010-2013.

| Metric | 189 | 202 | 203 | 208 | 214 | 215 | 216 | 217 | 220 | 221 |
|---|---|---|---|---|---|---|---|---|---|---|
| Total Organisms | 1,881 | 4,257 | 4,543 | 5,035 | 4,700 | 4,780 | 3,650 | 3,870 | 4,987 | 4,477 |
| Total Richness | 41 | 52 | 55 | 55 | 49 | 54 | 45 | 44 | 65 | 56 |
| Total EPT Richness | 14 | 16 | 14 | 16 | 13 | 19 | 15 | 11 | 19 | 13 |
| Percent Chironomidae | 36.1 | 32.9 | 28.7 | 27.7 | 52.1 | 39.8 | 28.4 | 39.6 | 42.2 | 45.1 |
| HBI | 5.4 | 6.1 | 6.2 | 6.6 | 6.4 | 6.2 | 6.6 | 6.6 | 6.3 | 6.9 |
| % Sensitive (TV 0-3) | 0.3 | 0.5 | 1.2 | 1.1 | 0.2 | 0.8 | 2.6 | 1.5 | 0.9 | 0.2 |
| Percent Oligochaeta | 3.6 | 15.1 | 14.2 | 8.1 | 13.9 | 11.1 | 20.7 | 11.5 | 11.6 | 20.5 |

Table 5-23. Mean and median IBI scores for stations within Conowingo Pond, 2010-2013.

| Station | IBI Score | | Number of Samples |
|---|---|---|---|
| | Mean | Median | |
| 189 | 30.9 | 28.8[h] | 11 |
| 202 | 30.0 | 29.5[f] | 22 |
| 203 | 29.9 | 31[b] | 23 |
| 208 | 31.6 | 30.5[e] | 25 |
| 214 | 20.5 | 18.8[abcdefgh] | 25 |
| 215 | 29.5 | 28.3[g] | 25 |
| 216 | 32.7 | 34.5[ci] | 19 |
| 217 | 31.0 | 30.9[d] | 19 |
| 220 | 31.3 | 31.5[a] | 25 |
| 221 | 23.7 | 23.6[i] | 25 |

IBI scores followed by the same letter were signficantly different (Kruskal-Wallis test, $p<0.001$)

Table 5-24. Median metric values for benthic macroinvertebrate collection locations in Conowingo Pond, 2010-2013.

| Station | Median | | | | | | Total Number of Samples |
|---|---|---|---|---|---|---|---|
| | Beck's Index | Ephemeroptera Richness | Trichoptera Richness | EPT Richness | Total Richness | Shannon Diversity | |
| 189 | 4[bdj] | 3[d] | 0[h] | 3 | 11 | 1.3 | 11 |
| 202 | 3[i] | 2 | 1 | 4 | 12[b] | 1.6[d] | 22 |
| 203 | 3[k] | 2 | 0[b] | 3 | 12[e] | 1.5[c] | 23 |
| 208 | 3[gj] | 2 | 2[abcdfh] | 4[ad] | 12[f] | 1.6[b] | 25 |
| 214 | 2[abefhik] | 1[b] | 0[aeg] | 1[abce] | 8[abcdef] | 1.2[abcdef] | 25 |
| 215 | 3[h] | 3[c] | 0[d] | 3 | 11 | 1.6[e] | 25 |
| 216 | 4[acg] | 3[ab] | 0[c] | 3[e] | 12[d] | 1.7[a] | 19 |
| 217 | 3[e] | 2 | 1[e] | 4[cf] | 12[c] | 1.5 | 19 |
| 220 | 3[f] | 2[e] | 1[g] | 4[bg] | 14[ag] | 1.6[f] | 25 |
| 221 | 2[cd] | 1[acde] | 0[f] | 2[dfg] | 11[g] | 1.2 | 25 |

Metric values followed by the same letter were significantly different (Kruskal-Wallis test, $p \leq 0.001$)

Table 5-25. Mean total richness observed by month at each station, 2010-2013.

| Station | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|
| st189 | 9.0 | 16.0 | 11.0 | 11.0 | 11.5 | 10.5 | 12.5 |
| st217 | 10.5 | 11.5 | 10.3 | 13.3 | 13.7 | 14.7 | 12.7 |
| st202 | 12.7 | 11.3 | 11.0 | 11.8 | 14.5 | 17.0 | 12.3 |
| st203 | 12.0 | 7.7 | 10.3 | 11.3 | 15.3 | 15.3 | 13.3 |
| st208 | 10.7 | 9.7 | 10.0 | 12.8 | 15.5 | 13.3 | 11.5 |
| st214 | 10.3 | 9.0 | 10.0 | 9.8 | 7.8 | 9.3 | 8.0 |
| st215 | 12.7 | 10.7 | 11.3 | 10.8 | 10.8 | 12.8 | 11.0 |
| st216 | 13.5 | 11.5 | 9.7 | 11.7 | 14.7 | 12.0 | 14.0 |
| st220 | 11.3 | 11.3 | 12.3 | 12.5 | 16.5 | 14.3 | 15.3 |
| st221 | 8.0 | 10.3 | 10.7 | 8.8 | 13.0 | 12.5 | 13.5 |

Table 5-26. Mean EPT richness observed by month at each station, 2010-2013.

| Station | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|
| st189 | 3.0 | 5.0 | 3.0 | 3.0 | 3.0 | 3.5 | 3.0 |
| st217 | 3.0 | 2.0 | 2.0 | 4.0 | 4.0 | 5.3 | 3.7 |
| st202 | 2.7 | 1.3 | 1.3 | 2.8 | 4.8 | 5.0 | 4.0 |
| st203 | 2.5 | 0.7 | 0.7 | 2.8 | 3.8 | 5.5 | 3.0 |
| st208 | 2.3 | 2.3 | 1.3 | 5.0 | 5.8 | 4.5 | 4.0 |
| st214 | 0.3 | 1.0 | 2.3 | 2.5 | 2.0 | 2.0 | 2.0 |
| st215 | 2.0 | 2.0 | 2.3 | 3.8 | 2.5 | 4.5 | 3.8 |
| st216 | 4.5 | 1.5 | 2.0 | 4.0 | 5.0 | 3.7 | 3.0 |
| st220 | 1.3 | 2.3 | 2.7 | 3.8 | 4.8 | 4.0 | 3.8 |
| st221 | 0.7 | 1.0 | 1.3 | 1.5 | 3.3 | 2.8 | 2.8 |

Table 5-27. Mean Trichoptera richness observed by month at each station, 2010-2013.

| Station | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|
| st189 | 0.0 | 2.0 | 1.0 | 1.0 | 0.0 | 1.0 | 0.0 |
| st217 | 1.5 | 1.0 | 0.3 | 1.7 | 1.3 | 1.7 | 1.3 |
| st202 | 0.3 | 0.7 | 0.3 | 1.3 | 1.8 | 1.5 | 1.0 |
| st203 | 0.0 | 0.0 | 0.0 | 0.3 | 1.3 | 1.8 | 0.7 |
| st208 | 1.3 | 1.3 | 0.7 | 2.5 | 2.8 | 1.8 | 2.3 |
| st214 | 0.0 | 0.0 | 0.7 | 0.8 | 0.5 | 0.3 | 0.3 |
| st215 | 0.3 | 0.0 | 0.3 | 0.8 | 1.0 | 1.5 | 0.5 |
| st216 | 1.0 | 0.0 | 0.0 | 1.0 | 0.7 | 0.7 | 0.3 |
| st220 | 0.0 | 0.7 | 1.0 | 1.8 | 1.5 | 1.0 | 1.5 |
| st221 | 0.0 | 0.3 | 0.3 | 1.0 | 1.0 | 1.0 | 1.5 |

Table 5-28. Mean Ephemeroptera richness observed by month at each station, 2010-2013.

| Station | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|
| st189 | 3.0 | 3.0 | 1.0 | 2.0 | 3.0 | 2.5 | 3.0 |
| st217 | 1.5 | 1.0 | 1.7 | 2.3 | 2.7 | 3.7 | 2.0 |
| st202 | 2.0 | 0.7 | 1.0 | 1.5 | 3.0 | 3.5 | 3.0 |
| st203 | 2.5 | 0.7 | 0.7 | 2.5 | 2.5 | 3.8 | 2.3 |
| st208 | 1.0 | 1.0 | 0.7 | 2.5 | 3.0 | 2.8 | 1.8 |
| st214 | 0.3 | 1.0 | 1.7 | 1.8 | 1.5 | 1.5 | 1.8 |
| st215 | 1.7 | 2.0 | 2.0 | 2.8 | 1.5 | 3.0 | 3.3 |
| st216 | 3.5 | 1.5 | 1.7 | 2.7 | 4.0 | 3.0 | 2.3 |
| st220 | 1.3 | 1.7 | 1.7 | 2.0 | 3.3 | 3.0 | 2.0 |
| st221 | 0.7 | 0.7 | 0.7 | 0.5 | 2.3 | 1.8 | 1.3 |

Table 5-29. Mean Shannon diversity values observed by month at each station, 2010-2013.

| Station | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|
| st189 | 1.1 | 2.0 | 1.3 | 1.3 | 1.5 | 1.4 | 1.8 |
| st217 | 1.5 | 1.4 | 1.5 | 1.6 | 1.4 | 1.8 | 1.3 |
| st202 | 1.4 | 1.4 | 1.5 | 1.5 | 1.7 | 1.9 | 1.5 |
| st203 | 1.6 | 1.1 | 1.3 | 1.4 | 1.8 | 1.9 | 1.8 |
| st208 | 1.4 | 1.5 | 1.6 | 1.7 | 2.0 | 1.6 | 1.4 |
| st214 | 1.2 | 1.2 | 1.3 | 1.2 | 0.9 | 1.2 | 1.1 |
| st215 | 1.7 | 1.5 | 1.6 | 1.3 | 1.1 | 1.6 | 1.8 |
| st216 | 1.6 | 1.4 | 1.5 | 1.8 | 1.9 | 1.7 | 1.6 |
| st220 | 1.4 | 1.3 | 1.3 | 1.3 | 1.8 | 1.6 | 1.8 |
| st221 | 1.1 | 1.4 | 1.1 | 1.1 | 1.4 | 1.6 | 1.7 |

Table 5-30. Mean Beck's Index values observed by month at each station, 2010-2013.

| Station | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|
| st189 | 6.0 | 6.0 | 6.0 | 3.5 | 3.5 | 3.0 | 4.5 |
| st217 | 3.5 | 3.5 | 2.0 | 3.7 | 3.3 | 4.7 | 3.0 |
| st202 | 4.3 | 3.0 | 2.3 | 2.8 | 3.0 | 3.5 | 4.0 |
| st203 | 5.0 | 1.7 | 2.0 | 3.3 | 3.8 | 3.5 | 3.3 |
| st208 | 2.7 | 2.7 | 2.3 | 3.5 | 2.8 | 2.3 | 3.0 |
| st214 | 2.7 | 2.0 | 2.0 | 1.5 | 1.8 | 2.8 | 1.8 |
| st215 | 4.3 | 3.0 | 3.3 | 3.8 | 1.8 | 3.3 | 3.8 |
| st216 | 4.5 | 2.5 | 3.3 | 5.0 | 4.7 | 4.0 | 4.0 |
| st220 | 3.0 | 3.3 | 4.3 | 2.8 | 3.5 | 3.0 | 3.0 |
| st221 | 2.3 | 3.0 | 3.7 | 1.8 | 3.0 | 2.0 | 2.5 |

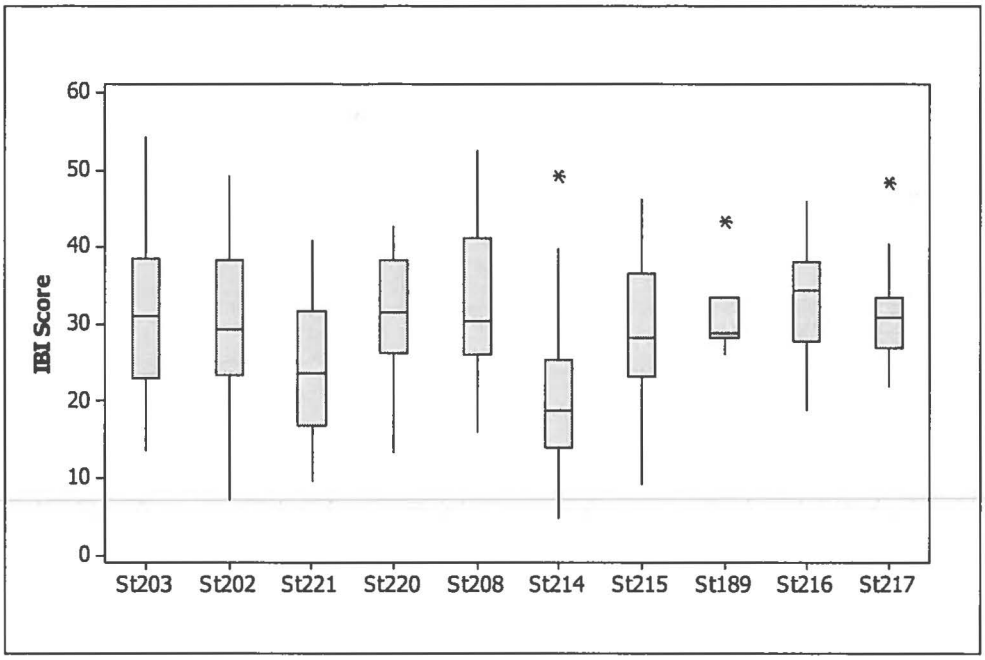



Figure 5-26. Box plot illustrating IBI Scores for each benthos station, 2010-2013. (boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, and asterisk = outlier)

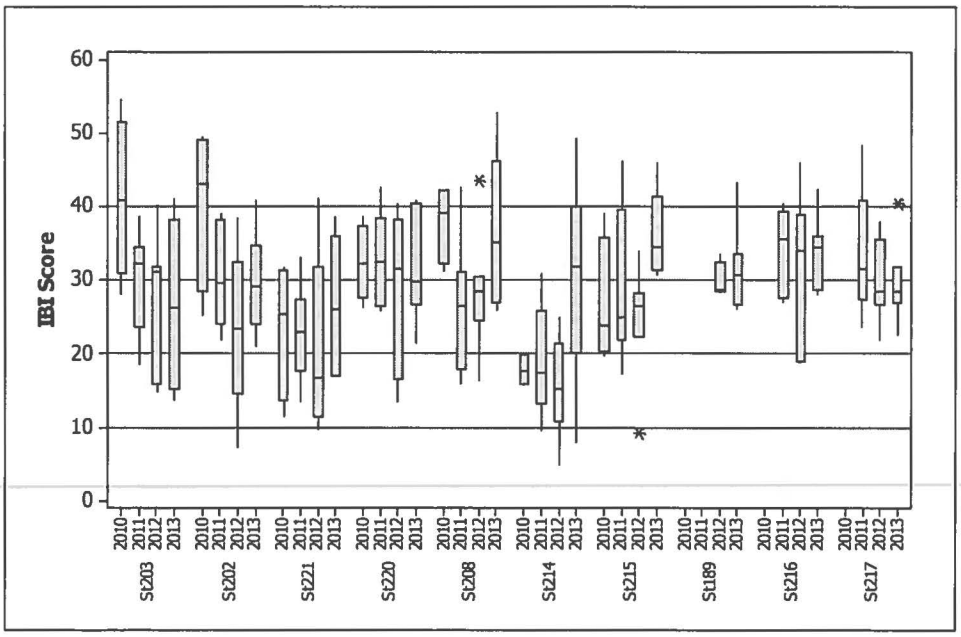



Figure 5-27. Box plot illustrating IBI scores for each year by benthos station, 2010-2013. (boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, and asterisk = outlier)

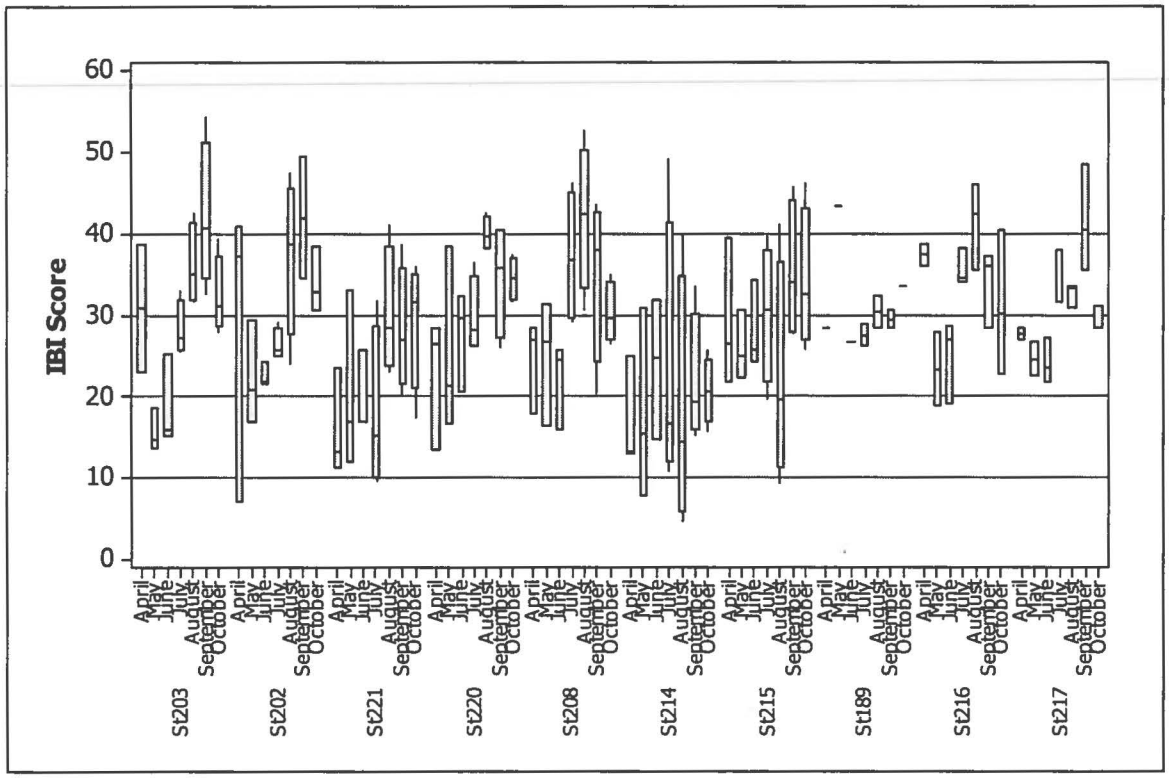



Figure 5-28. Box plot illustrating IBI scores for each month by benthos station, 2010-2013. (boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, and asterisk = outlier)

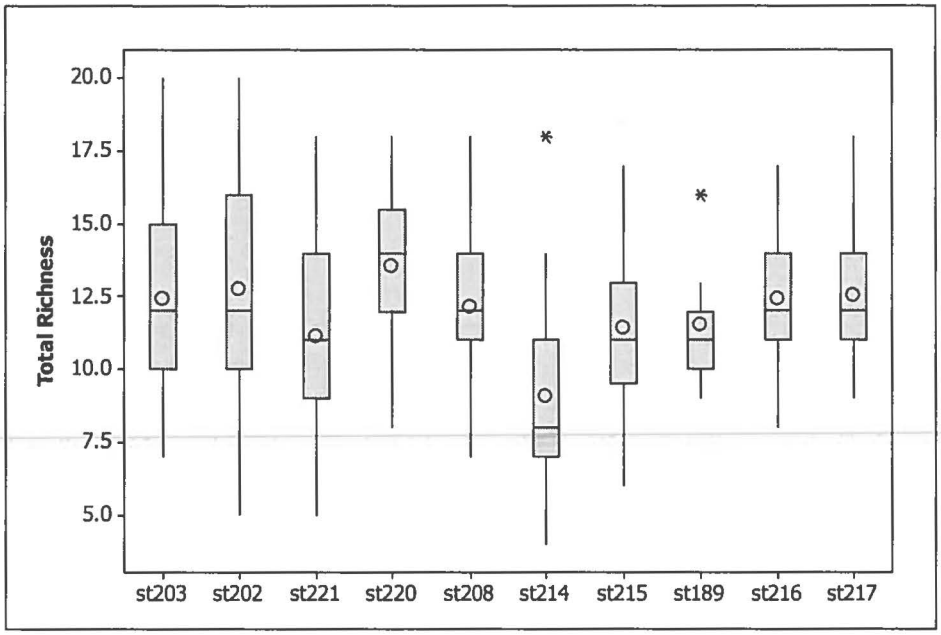



Figure 5-29. Box plot illustrating total richness for each benthos station, 2010-2013. (boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, circle = mean, and asterisk = outlier)

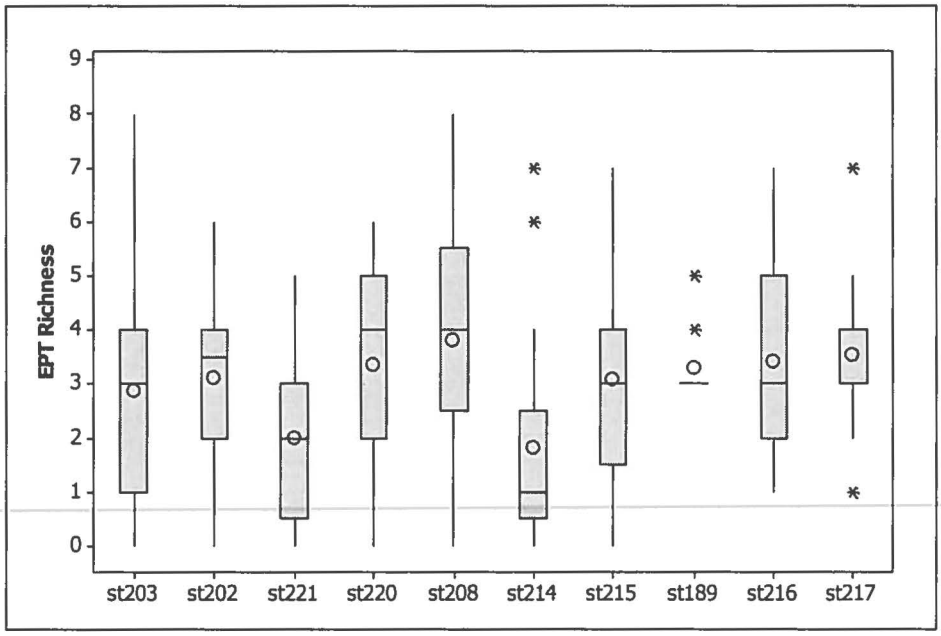



Figure 5-30. Box plot illustrating EPT richness for each benthos station, 2010-2013. (boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, circle = mean, and asterisk = outlier)

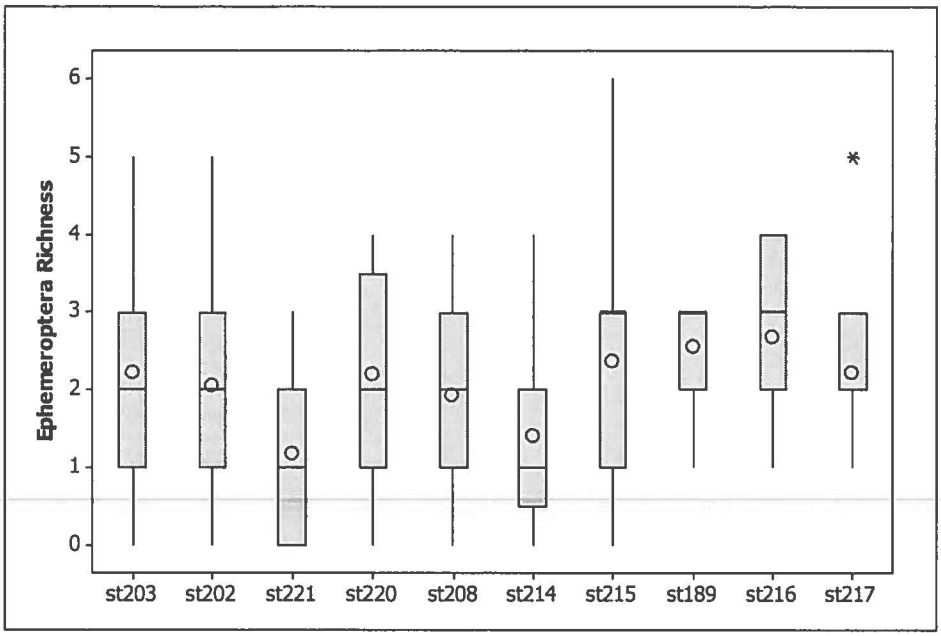



Figure 5-31. Box plot illustrating Ephemeroptera richness for each benthos station, 2010-2013. (boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, circle = mean, and asterisk = outlier)

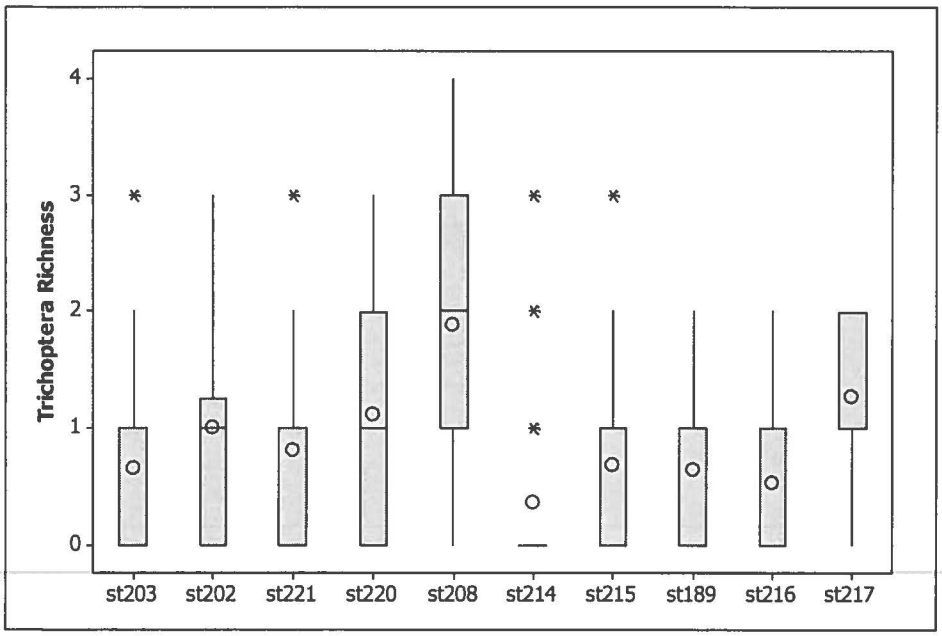



Figure 5-32. Box plot illustrating Trichoptera richness for each benthos station, 2010-2013. (boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, circle = mean, and asterisk = outlier)

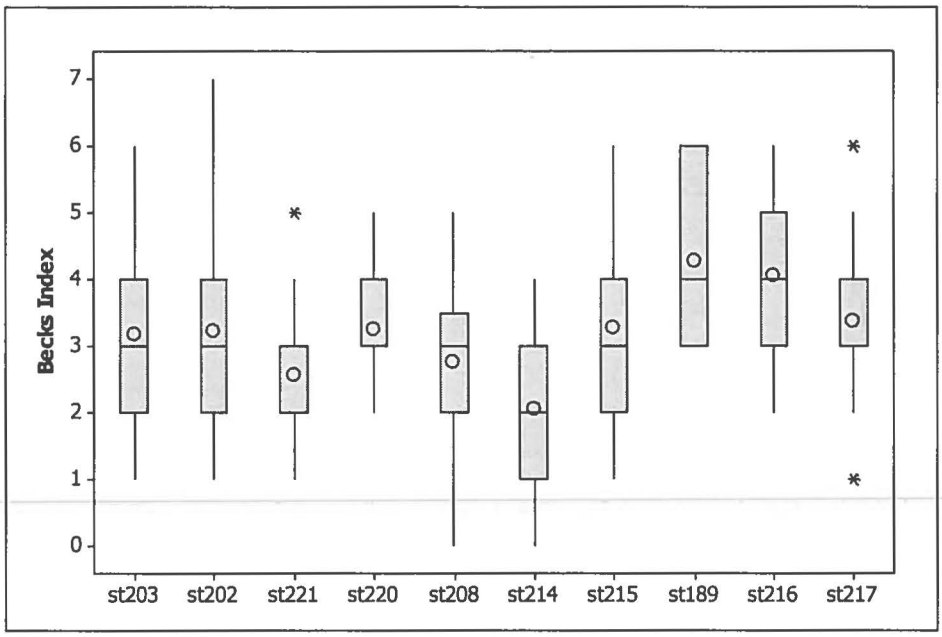



Figure 5-33. Box plot illustrating Beck's Index values for each benthos station, 2010-2013. (boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, circle = mean, and asterisk = outlier)

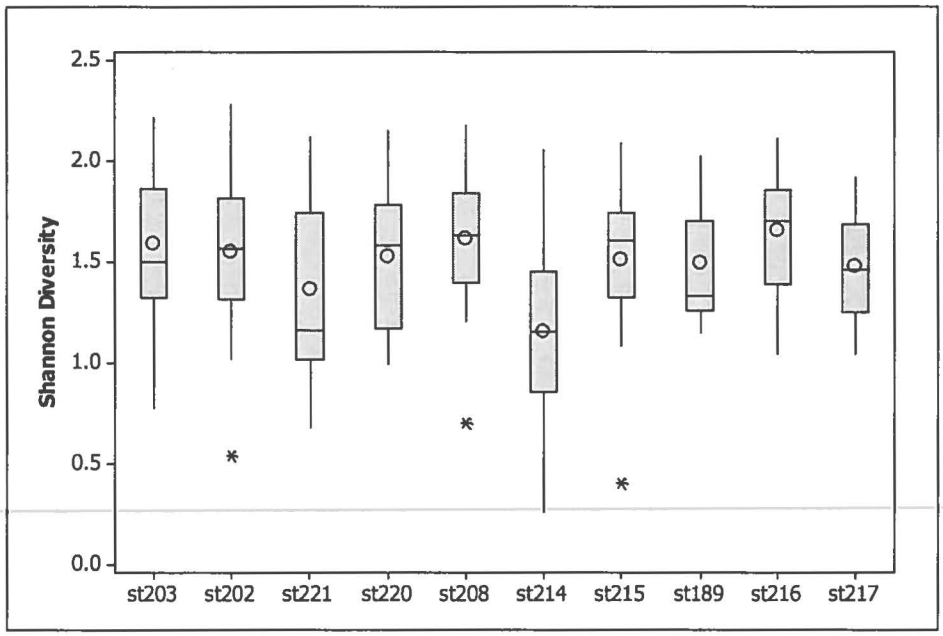



Figure 5-34. Box plot illustrating Shannon Diversity values for each benthos station, 2010-2013. (boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, circle = mean, and asterisk = outlier)

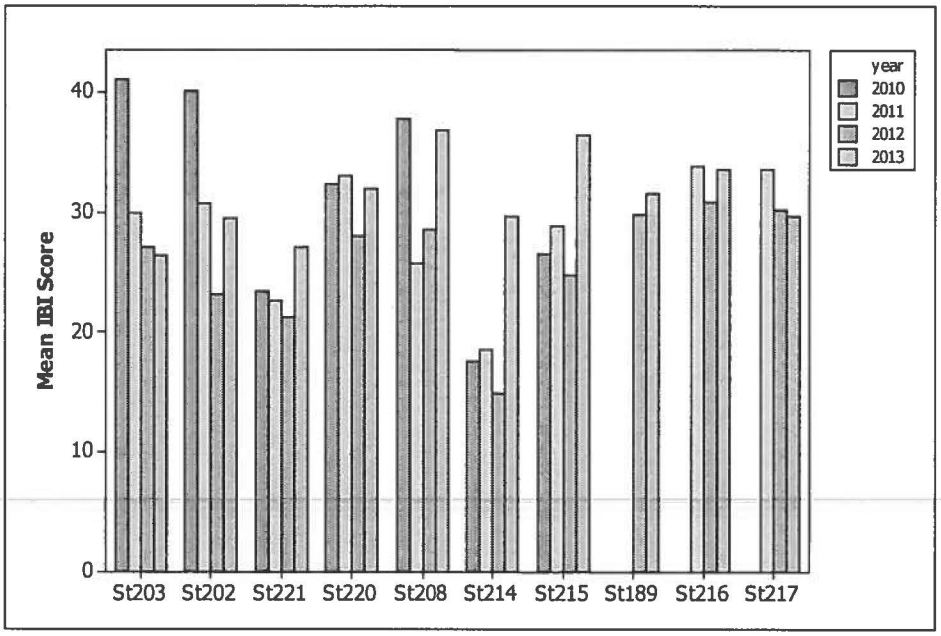



Figure 5-35. Bar chart showing relation of mean IBI scores by year for each benthos station.

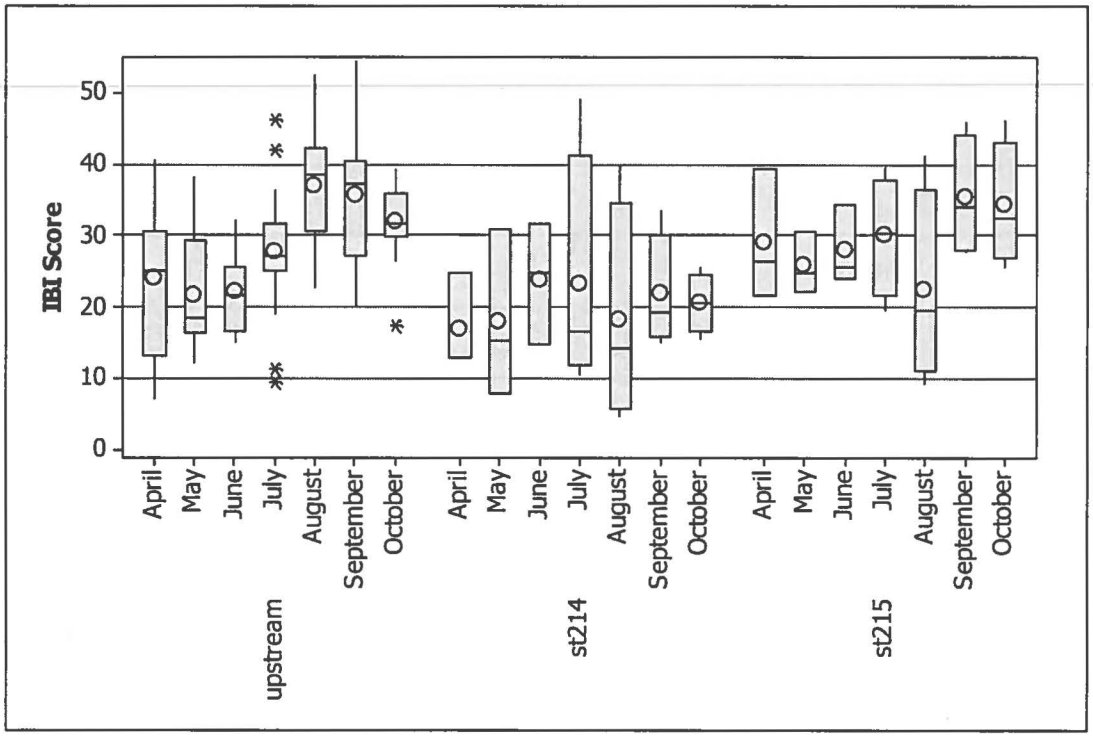



Figure 5-36. Box plot illustrating relation of monthly IBI scores for non-thermal (upstream) benthos stations and Stations 214 and 215, 2010-2013. (boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, circle = mean, and asterisk = outlier)

*Benthos-Water Temperature Observations*

A total of five thermally influenced nearshore benthos stations were sampled during the course of the study (Figure 5-22). Four of these stations are located along the western shoreline at varying distances downstream from the PBAPS discharge canal while the most-downstream station is about 4 miles downstream of PBAPS on the eastern shoreline. The relation of benthic IBI scores and water temperature observed at the thermally influenced stations is important to understanding the potential impact to benthos in thermally influenced areas of the Pond where sampling did not occur. The temperature monitoring determined the thermal history at these locations at the River bottom where benthic organisms live (Section 3). Thus, the approach taken herein was to use empirical evidence from the current study to determine water temperatures that result in impact to benthos. A study-specific temperature metric was developed that can be used to evaluate and determine conditions that result in benthic impacts. Unlike the fish-avoidance analysis on which a robust catalogue of scientific literature exists, few field studies have evaluated chronic effects of elevated temperatures on benthos and most did not account for acclimation temperature.

The following discussion regarding cumulative impact of elevated temperatures to benthic communities aids in elucidating the concept that temperature impacts to benthos are cumulative rather than instantaneous. The two thermally influenced benthos stations (214 and 215) closest to the PBAPS discharge canal outfall experienced the highest water temperatures. For both stations a similar pattern of low IBI scores was observed during July and/or August. Figure 5-37 through Figure 5-40 show the relation of daily mean water temperature and IBI scores for Station 215; a similar relation was observed at Station 214 which is closer to PBAPS. During the first 3 years of study, IBI scores were lower in July and/or August following periods with daily mean water temperature that exceeded 93°F (Figure 5-37 through Figure 5-40). Water temperature that exceeded 93°F for an extended period resulted in lower IBI scores.

Higher IBI scores and recovery of the benthic community were observed in subsequent months after water temperatures decreased. At both Stations 214 and 215 daily mean water temperatures exceeded 93°F during the course of study in July and/or August. Not surprisingly, the greatest number of days exceeding 93°F was observed at Station 214 (Table 5-31). Few days in 2013 at Stations 214 or 215 exceeded a daily mean water temperature of 93°F and both IBI scores and metric values did not indicate a thermal effect. Station 189 also experienced daily mean temperatures greater than 93°F during 2010 and 2011. However, benthos sampling was not initiated at this station until 2012. Daily mean temperature at Station 189 did not exceed 93°F during 2012 or 2013 and both metric values and IBI scores did not indicate thermal effect (Table 5-22 and Table 5-23). Daily mean water temperatures did not exceed 93°F at any of the other stations during the study (Table 5-31).

Interestingly, water temperature at the time of collection was not correlated to IBI scores. IBI score and water temperature pairs were analyzed with simple linear regression for Stations 214 and 215 (2010-2013) with no correlation between pairs ($R^2 \leq 0.03$, $p > 0.1$). Figure 5-41 illustrates the relation of mean water temperature and IBI score at Station 215 for all months

and years combined. IBI scores were variable across month and years with generally higher scores observed in 2013 for most months and highly variable IBI scores observed at the highest water temperatures. A similar result was observed for Station 214. These results support the conclusion that the duration of elevated water temperatures prior to collection was crucial in causing impacts to the benthic community as reflected in the corresponding low IBI scores.

The results observed in 2013 indicate that 5 or 7 days of water temperatures greater than a daily average of 93°F did not result in a benthic effect for Stations 214 and 215, respectively. The actual number of days greater than the threshold temperature of 93°F that would result in benthos impact cannot be determined exactly from the currently available data. However, it is probable that greater than 7 days of elevated water temperatures are required. In 2010-2012 daily mean temperature at Station 215 was greater than 93°F from 21 to 25 days with a corresponding drop in IBI score after the period of elevated temperature for each year. Based on the available data between 7 and 21 days of elevated water temperatures greater than daily mean of 93°F will result in benthic impacts.

A benthic model was developed based on the empirical results discussed above in order to evaluate potential benthic impact of high discharge temperature after implementation of EPU. The constraints of the Benthic Impact Model require a determination of potential impact based on instantaneous rather than mean water temperature. Thus the model was used to determine areas of the near-shore River bottom that experienced instantaneous water temperatures greater than 94°F for both the typical and extreme case. The instantaneous value of 94 °F was selected to be used as a conservative analogue to the 93°F temperature-IBI score metric. Using the instantaneous value of 94°F rather than daily mean of 93°F is more conservative and results in larger areas of potential benthic impact. As indicated in Table 5-32 the conservative instantaneous approach spatially encompasses a greater number of benthos sample stations and thus would predict a larger area of potential benthos impact than was actually observed during this study. Evaluation of potential impacts using the Benthic Impact Model are discussed and illustrated in Section 7.

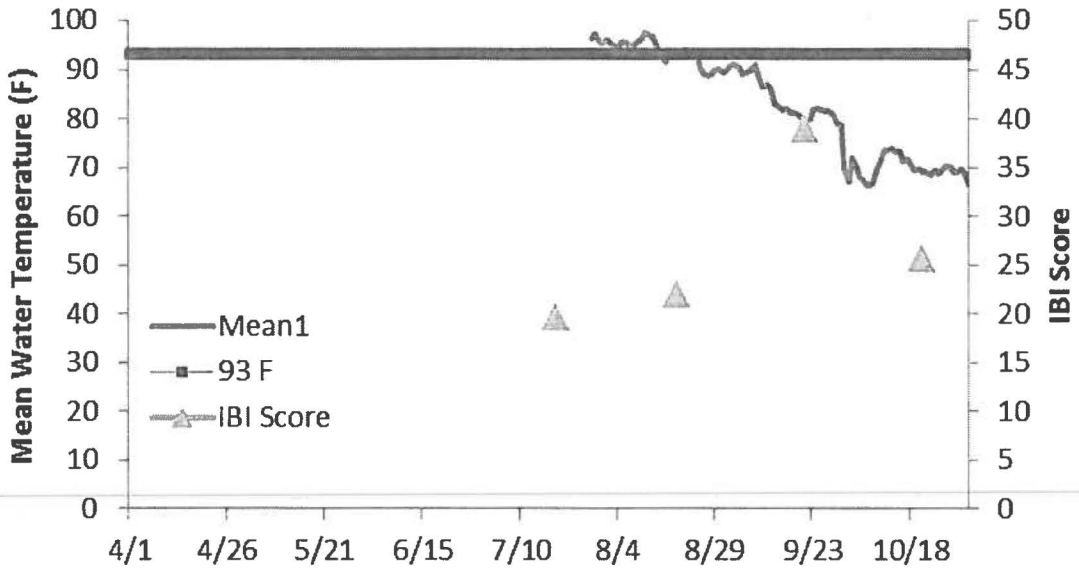



Figure 5-37. Relation of IBI score and water temperature for Station 215 in 2010.

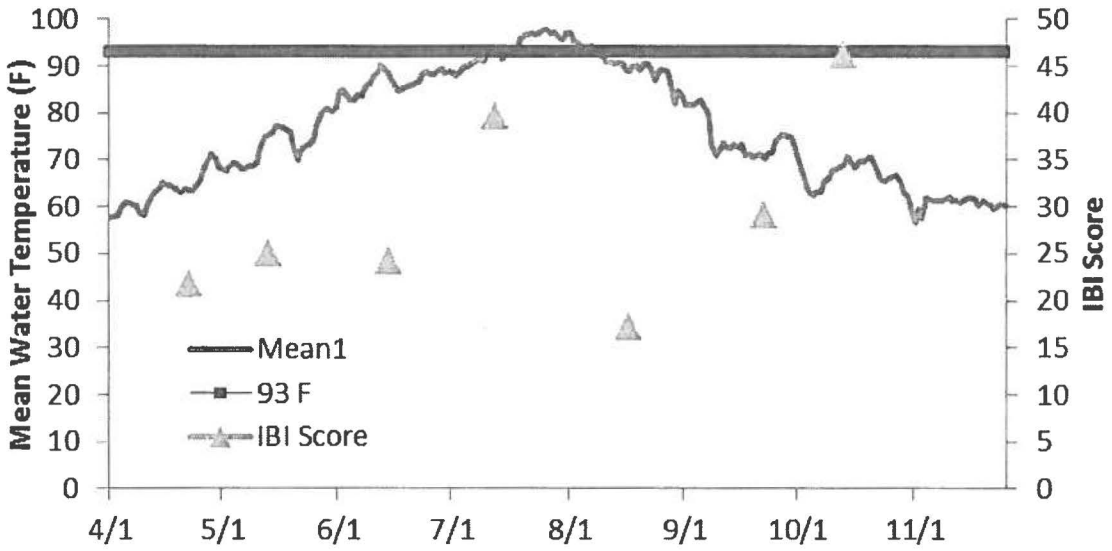



Figure 5-38. Relation of IBI score and water temperature for Station 215 in 2011.

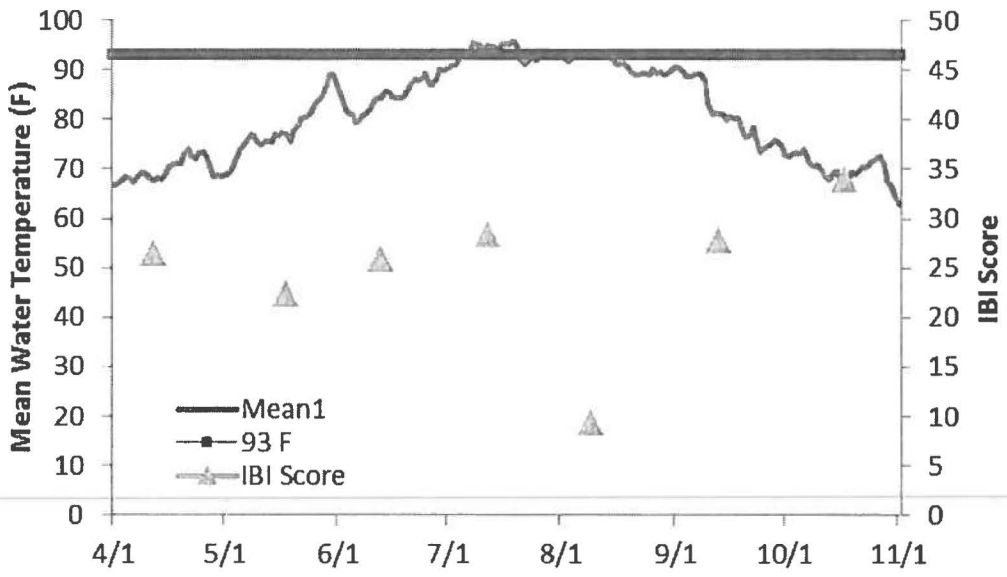



Figure 5-39. Relation of IBI score and water temperature for Station 215 in 2012.

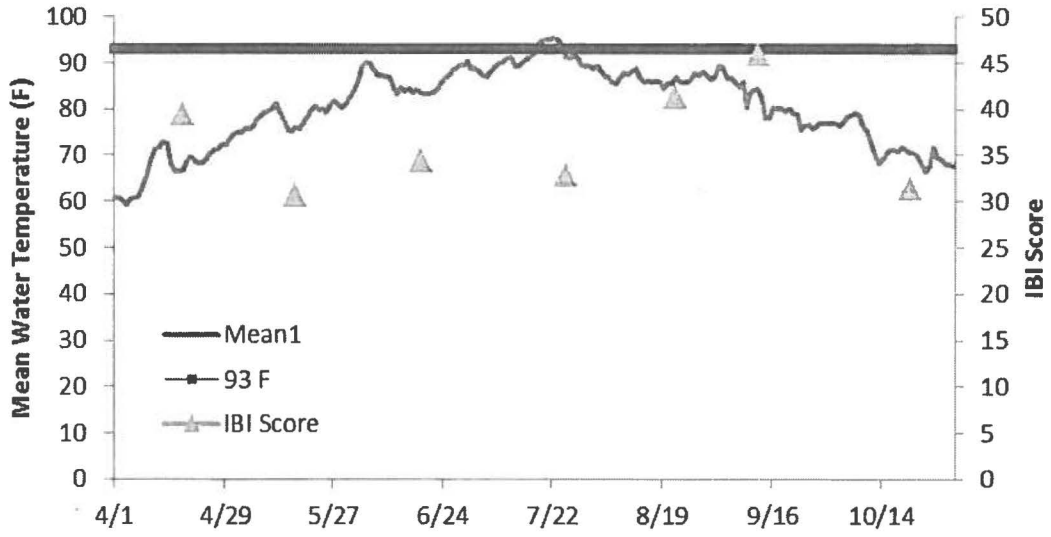



Figure 5-40. Relation of IBI score and water temperature for Station 215 in 2013.

Table 5-31. Number of days each year with daily mean water temperature >93°F for all stations, April 1 to October 31.

| Station | 2010[a] | 2011 | 2012 | 2013 |
|---|---|---|---|---|
| 220 | 0 | 0 | 0 | 0 |
| PBAPS Intake | 0 | 0 | 0 | 0 |
| 208 | 0 | 0 | 0 | 0 |
| 214 | 28 | 36 | 39 | 7 |
| 215 | 25 | 25 | 21 | 5 |
| 189 | 4 | 11 | 0 | 0 |
| 190 | 0 | 0 | 0 | 0 |
| 216 | 0 | 0 | 0 | 0 |
| 217 | 0 | 0 | 0 | 0 |

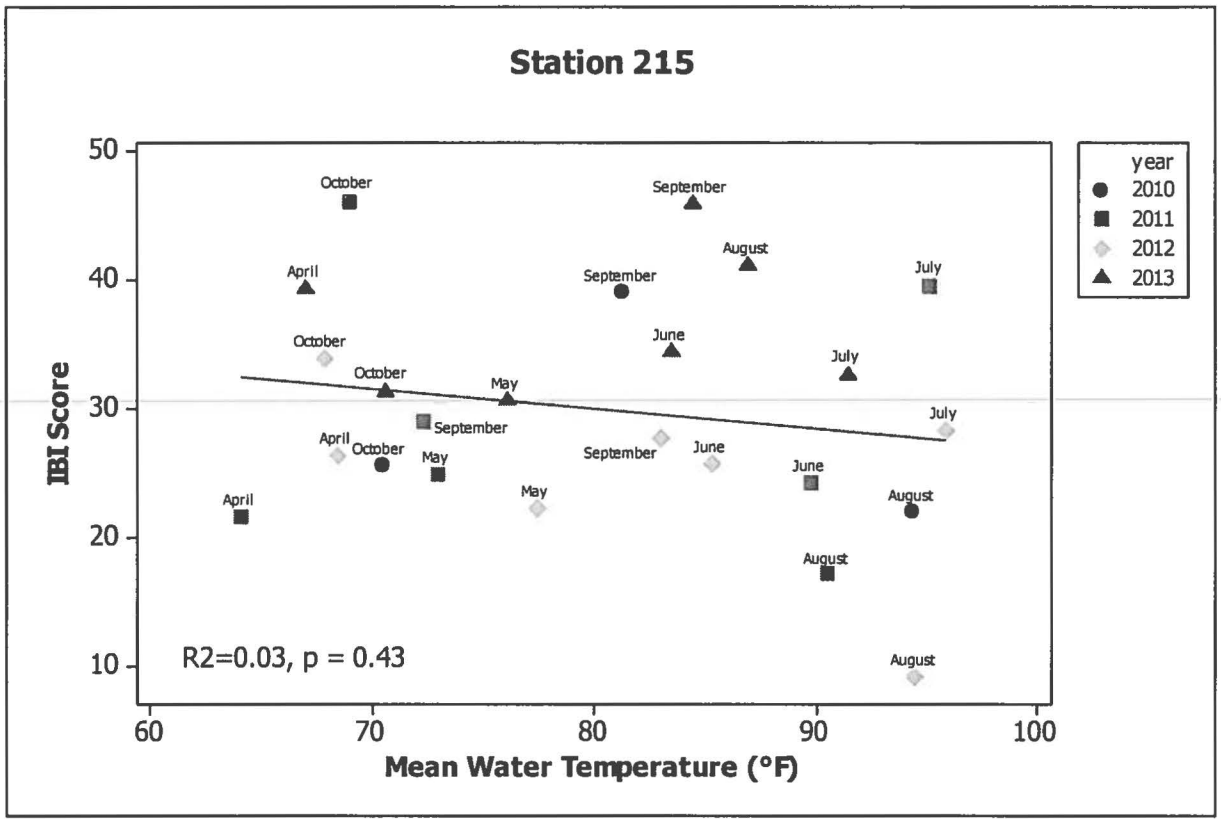
[a]Monitoring did not begin until July 28

Table 5-32. Number of days each year with instantaneous maximum water temperature >94°F for all stations, April 1 to October 31.

| Station | 2010[a] | 2011 | 2012 | 2013 |
|---|---|---|---|---|
| 220 | 0 | 0 | 0 | 0 |
| PBAPS Intake | 0 | 0 | 0 | 0 |
| 208 | 0 | 0 | 0 | 0 |
| 214 | 32 | 39 | 43 | 8 |
| 215 | 28 | 30 | 36 | 8 |
| 189 | 4 | 14 | 5 | 1 |
| 190 | 1 | 8 | 1 | 0 |
| 216 | 0 | 7 | 2 | 0 |
| 217 | 0 | 0 | 1 | 1 |

[a]Monitoring did not begin until July 28

Figure 5-41. Relation of daily mean water temperature and IBI score for Station 215, August-October, 2010 and April-October, 2011-2013.



### *5.6 Fish Community*

The spatial and temporal distribution of fish was evaluated by monthly sampling at both thermally influenced and non-thermally influenced locations in July through October 2010 and April through October 2011-2013. In addition, winter electrofishing events were completed in January, February, or March 2011-2013. 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 of the three sampling gear types. The methods employed in the fisheries study are briefly described below, followed by discussion of the sampling results and analyses for the entire 4-year study. The results from 2010, 2011, and 2012 were reported in three interim annual reports (Normandeau Associates and ERM 2011, 2012 and 2013a).

*Methods*

*Seine*

Seining was conducted at seven shoreline stations (Table 5-12; Figure 5-22) located in areas thermally affected by the plume and in unaffected areas upstream of PBAPS and on the east shore of the Pond. Stations 214 and 215 are considerably influenced by the PBAPS thermal plume as determined by observations of water temperature and velocity of the thermal discharge plume. Data recorded at each station for each collection included weather, date, time, Secchi disc transparency, air and surface water temperatures, dissolved oxygen, and estimated water depth. Appendix 11.2 provides water chemistry data collected during the field collections.

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.

*Electrofishing*

Electrofishing was conducted at night at seven stations located along the shores of Conowingo Pond (Figure 5-23; Table 5-14). Stations 161, 189, 190, and 217 are located sequentially below PBAPS and are influenced by the thermal discharge from PBAPS, with Station 161 being most thermally influenced and Station 217 being the least influenced. 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. Data recorded for each collection included weather, date, time (start and end), air and surface water temperatures, dissolved oxygen, conductivity, voltage, and amperage. Appendix 11.2 provides water chemistry data collected during the field collections.

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.

*Trawl*

Bottom trawl sampling was conducted at five transects (2, 3, 4, 7, and 8) as depicted in Figure 5-24. Each transect was composed of an east shore, mid-pond, and west shore sampling station, except Transect 8 which had two mid-pond stations due to the greater width of the river at this location. Transect Stations 331, 371, 381, and 382 are within the area influenced by PBAPS thermal discharge, but substantial temperature increases do not extend to the bottom of the Pond. Trawl sampling was not performed in 2013.

Table 5-13 provides a description of the location of the trawl stations. Data recorded for each trawl sample include weather, date, time (start and end), Secchi disc transparency, air temperature, and water depth, along with water temperature and dissolved oxygen at the surface, mid-depth, and bottom.

Samples were collected using a 16-ft semi-balloon otter (bottom) trawl with ¼-inch mesh liner in the cod end. The trawl was deployed off the stern of the boat and hauled for 10 minutes in an upstream direction. A minimum of 7 minutes was required for the haul to be considered valid. After the required sampling duration the trawl was retrieved, the boat was returned to the center of the station, and the catch was removed from the net and processed. All specimens in each collection were identified, measured to the nearest mm TL, 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 and an exact count was made of the remainder and released.

*Catch Overview*

This section provides a general summary of the fish catch information produced by the seine, electrofishing and trawl sampling conducted in 2010 through 2013. Table 5-33 provides a list of common and scientific names of fish species observed in Conowingo Pond during the course of this study. This sampling program continued the fish community monitoring that has been performed periodically in Conowingo Pond relative to PBAPS for over 40 years.

The three sampling methods used in this study were deployed in somewhat different habitats and tend to target certain species and sizes of fish, but together they provide a comprehensive understanding of the fish community in the Pond. For example, trawling collects fish on the bottom of the Pond in offshore, generally deep areas, whereas seining and electrofishing are performed at shallow shore-zone sampling stations. In addition, seining collects predominantly

small-bodied fish, often the young of species that attain a large size as adults. Electrofishing is effective for both large and small fish.

Fisheries data from each gear type are expressed as catch (numbers of individuals) per unit effort (CPUE) by station; monthly catches for each gear are expressed as number of individuals for all stations combined. Seine CPUE is expressed as number of each species per collection. The trawl CPUE data are presented as number of each species per 10-minute haul, with electrofishing CPUE expressed as the number of fish captured per 30 minutes of sampling.

Over 90,000 specimens of more than 50 species were collected in this study at sampling stations in Conowingo Pond (Table 5-34 through Table 5-37). The fish assemblage was comprised of various feeding guilds including piscivores, a filter feeder, omnivores, insectivores, generalists, and invertivores. A list of the trophic designation for common species and RIS collected in Conowingo Pond is provided in Table 5-38. Presence of these various groups and their common occurrence (relatively high abundance) in the Pond indicates multiple trophic levels within the fish community and multiple levels of the food chain that includes forage species and predator species. Various representative trophic groups were observed at both thermally and non-thermally affected stations.

Inter-annual and monthly variation in the relative abundance of the various species as collected by the three sampling methods were often substantial due to variability in spawning success and species-specific preference for and avoidance of the habitats sampled. Gizzard Shad was the most numerous species collected by the three sampling methods combined in 2010 and 2011, Comely Shiner (not an RIS) was most abundant in 2012, and Bluegill was most numerous in 2013. Among the RIS, Spotfin Shiner, Bluegill, and Channel Catfish often ranked among the five most abundant fishes and these individual species usually comprised at least 5% of the combined catch each year. Other RIS such as White Sucker, Largemouth Bass, Chesapeake Logperch, and Walleye were collected in relatively low numbers each year. White Crappie was the least numerous RIS in all years.

Annual summaries of the seine data, with the results grouped by thermally affected and non-thermally affected stations, are presented in Table 5-40, Table 5-43, Table 5-46, and Table 5-49. Sample Stations 214 and 215 were categorized as thermally influenced while the remaining five seine stations were judged to be non-thermally affected, as they were located upstream of PBAPS or on the east shore opposite PBAPS. Spotfin Shiner was the most numerous species taken by seine each year except in 2013 when Bluntnose Minnow was slightly more abundant. Other numerous species in one or more years included Bluntnose Minnow, Banded Killifish, Bluegill, Spottail Shiner, Gizzard Shad, and Comely Shiner. Evaluation of the annual summaries of catches at the two thermally affected as compared to the five non-thermally affected stations is hampered by the disparity of numbers of stations in each group. However, Table 5-40, Table 5-43, Table 5-46, and Table 5-49 provide an annual comparison between thermal and non-thermally affected station based on average CPUE.

In 2010, July and August accounted for half of the months sampled. However, overall the data show similar fish communities at each station, although the fewest number of species was collected at both of the thermally affected stations in 2010 and one of them (Station 215) in

2011, 2012, and 2013. As will be discussed in a following section of this report, the decreased catches at high plume temperatures in July and/or August are an indication that fish are temporarily avoiding the high temperature water. Otherwise, the data show no discernible pattern in number of fish per collection and relative abundance by species relative to thermal influence. That is, collections during the other months do not indicate avoidance at Stations 214 or 215; rather, the community composition and relative abundance are comparable to the other stations outside of the plume.

In the electrofishing catch, Gizzard Shad was by far the most numerous species collected in 2010 and 2011, but in 2012 it was overshadowed by high numbers of Comely Shiner and Bluegill (Table 5-39, Table 5-42, and Table 5-45). In 2013, Gizzard Shad and Bluegill were collected in similarly high numbers. Other common species in the electrofishing catch in one or more years included Channel Catfish, Spotfin Shiner, Bluntnose Minnow, and Smallmouth Bass. A similar number of species was collected at the thermally affected (161, 189 and 190) and non-thermally affected stations (164, 165, and 187) in each year of the study. Overall, due to the similarities in the annual summary data, it is apparent that a BIC is being maintained at the thermally affected and unaffected stations.

As with the other gear types, the trawl data collected in 2010 – 2012 are characterized by high variability between stations and years, with no consistent indication of a thermal impact to the BIC at the thermally affected locations (Table 5-41, Table 5-44, and Table 5-47). Channel Catfish was the most numerous species in 2010 and 2011 and at most sample stations. In 2012, Gizzard Shad was most numerous. Other species taken in relatively high numbers in one or more years include Bluegill, Tessellated Darter, Common Carp, and Spottail Shiner. Spotfin Shiner was uncommon in the bottom trawl collections. Other RIS, such as Walleye, Chesapeake Logperch, Smallmouth Bass and Largemouth Bass, were infrequently collected.

The trawl surveys indicated no impact to the fish community from the PBAPS thermal discharge at the thermally affected locations. Fish abundance and species composition observed at the collection stations closest to the thermal discharge were similar to those observed upstream and farther downstream from the thermal discharge. Trawl collections focus on collecting fishes inhabiting the bottom or near-bottom strata of the water column. The water temperature profile for the PBAPS thermal plume shows that water temperatures are highest at the surface of the water column and that a gradient exists where temperatures decrease as a function of depth in the water column. The primary areas of concern for fish relative to elevated water temperatures are shallow water areas and surface waters in the immediate vicinity of the discharge. Trawl collections do not collect fish from shallow water areas or surface waters. Trawl sampling was suspended, upon consultation with PADEP, after the 2012 field season because the thermal plume is predominantly a surface phenomenon and the temperature data collected during field sampling did not show a substantial temperature rise at the bottom of the Pond.

This high-level overview of the multi-year fish sampling data shows that:

- A diverse fish community exists within Conowingo Pond,
- The fish community has the ability to sustain itself through cyclical seasonal changes,
- Numerous prey species are present and relatively abundant in the fish community,

- Pollution- or heat-tolerant species do not dominate the fish community,
- No benefit was observed in terms of overall fish community composition or relative abundance from reduction in temperature resulting from cooling tower operation, and
- A BIC is being maintained in Conowingo Pond.

Table 5-33. List of common and scientific names of fishes collected in Conowingo Pond, 2010-2013.

| | |
|---|---|
| ***Clupeidae*** | **Herrings** |
| *Alosa pseudoharengus* | Alewife |
| *Alosa sapidissima* | American shad |
| *Dorosoma cepedianum* | Gizzard shad |
| ***Salmonidae*** | **Trouts** |
| *Salmo trutta* | Brown trout |
| ***Cyprinidae*** | **Carps and minnows** |
| *Campostoma anomalum* | Central stoneroller |
| *Clinostomus funduloides* | Rosyside dace |
| *Cyprinella spiloptera* | Spotfin shiner |
| *Cyprinus carpio* | Common carp |
| *Ctenopharyngodon idella* | Grass carp |
| *Exoglossum maxillingua* | Cutlips minnow |
| *Luxilus cornutus* | Common shiner |
| *Nocomis micropogon* | River chub |
| *Notemigonus crysoleucas* | Golden shiner |
| *Notropis amoenus* | Comely shiner |
| *Notropis hudsonius* | Spottail shiner |
| *Notropis procne* | Swallowtail shiner |
| *Notropis rubellus* | Rosyface shiner |
| *Notropis volucellus* | Mimic shiner |
| *Pimephales notatus* | Bluntnose minnow |
| *Rhinichthys atratulus* | Blacknose dace |
| *Semotilus atromaculatus* | Creek chub |
| *Semotilus corporalis* | Fallfish |
| ***Catostomidae*** | **Suckers** |
| *Carpiodes cyprinus* | Quillback |
| *Catostomus commersoni* | White sucker |
| *Hypentelium nigricans* | Northern hog sucker |
| *Moxostoma macrolepidotum* | Shorthead redhorse |
| ***Ictaluridae*** | **Bullhead catfishes** |
| *Ictalurus punctatus* | Channel catfish |
| *Pylodictis olivaris* | Flathead catfish |
| ***Osmeridae*** | **Smelts** |
| *Osmerus mordax* | Rainbow smelt |
| ***Belonidae*** | **Needlefishes** |
| *Strongylura marina* | Atlantic needlefish |
| ***Poeciliidae*** | **Livebearers** |
| *Gambusia holbrooki* | Eastern mosquitofish |
| ***Cyprinodontidae*** | **Killifishes** |
| *Fundulus diaphanus* | Banded killifish |
| ***Percichthyidae*** | **Temperate basses** |
| *Morone americana* | White perch |
| *Morone saxatilis* | Striped bass |
| ***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 |
| *Pomoxis nigromaculatus* | Black crappie |
| ***Esocidae*** | **Pikes** |
| Esox masquinongy | Muskellunge |
| ***Percidae*** | **Perches** |
| *Etheostoma blennioides* | Greenside darter |
| *Etheostoma olmstedi* | Tessellated darter |
| *Etheostoma zonale* | Banded darter |
| *Perca flavescens* | Yellow perch |
| *Percina bimaculata* | Chesapeake logperch |
| *Percina peltata* | Shield darter |
| *Stizostedion vitreum* | Walleye |

Table 5-34. Number and percent (%) composition of fishes collected by all gear types in Conowingo Pond, July through October 2010. Species in bold are designated as RIS for this study.

| | July | August | September | October | Total | % |
|---|---|---|---|---|---|---|
| **Gizzard shad** | **2,867** | **538** | **2,422** | **78** | **5,905** | **47.4** |
| **Spotfin shiner** | **345** | **223** | **246** | **247** | **1,061** | **8.5** |
| Common carp | 19 | 12 | 34 | 16 | 81 | 0.7 |
| Golden shiner | 6 | 3 | 3 | 5 | 17 | 0.1 |
| Comely shiner | 36 | 22 | 27 | 70 | 155 | 1.2 |
| Spottail shiner | 20 | 41 | 25 | 14 | 100 | 0.8 |
| Swallowtail shiner | 1 | 2 | 3 | * | 6 | + |
| **Bluntnose minnow** | **20** | **33** | **37** | **41** | **131** | **1.1** |
| Creek chub | * | * | 1 | * | 1 | + |
| Fallfish | 1 | * | * | * | 1 | + |
| Quillback | 9 | 1 | 5 | 1 | 16 | 0.1 |
| **White sucker** | **5** | * | * | **1** | **6** | + |
| Northern hogsucker | 5 | 2 | 1 | 6 | 14 | 0.1 |
| Shorthead redhorse | 4 | * | 8 | 29 | 41 | 0.3 |
| **Channel catfish** | **662** | **600** | **237** | **718** | **2,217** | **17.8** |
| Flathead catfish | 5 | 4 | 9 | 3 | 21 | 0.2 |
| Banded killifish | 1 | 3 | 39 | 142 | 185 | 1.5 |
| White perch | 1 | * | * | 4 | 5 | + |
| Rock bass | 44 | 26 | 16 | 68 | 154 | 1.2 |
| Redbreast sunfish | 1 | * | * | * | 1 | + |
| Green sunfish | 32 | 122 | 222 | 221 | 597 | 4.8 |
| Pumpkinseed | * | 1 | * | 1 | 2 | + |
| **Bluegill** | **105** | **215** | **480** | **320** | **1,120** | **9.0** |
| **Smallmouth bass** | **50** | **16** | **40** | **66** | **172** | **1.4** |
| **Largemouth bass** | **4** | **3** | **8** | **46** | **61** | **0.5** |
| **White crappie** | **1** | * | * | **1** | **2** | + |
| Black crappie | * | * | * | 2 | 2 | + |
| Greenside darter | * | 3 | 10 | * | 13 | 0.1 |
| Tessellated darter | 23 | 48 | 31 | 95 | 197 | 1.6 |
| Banded darter | * | 1 | 2 | 2 | 5 | + |
| Yellow perch | * | * | 1 | * | 1 | + |
| **Chesapeake logperch** | **21** | **20** | **11** | **25** | **77** | **0.6** |
| Shield darter | * | 3 | 1 | 5 | 9 | 0.1 |
| **Walleye** | **2** | **3** | **3** | **71** | **79** | **0.6** |
| Overall | 4,290 | 1,945 | 3,922 | 2,298 | 12,455 | 99.7 |
| Number of species | 27 | 25 | 27 | 28 | 34 | |
| Diversity | 1.23 | 1.95 | 1.47 | 2.35 | 1.83 | |

+ Less than 0.05%.

Table 5-35. Number and percent (%) composition of fishes collected by all gear types in Conowingo Pond, February and April through October 2011.

| | Feb[a] | Apr | May | Jun | Jul | Aug | Sep | Oct | Total | % |
|---|---|---|---|---|---|---|---|---|---|---|
| Alewife | * | 1 | * | * | * | * | * | * | 1 | + |
| American shad | * | * | * | * | * | * | 1 | * | 1 | + |
| **Gizzard shad** | **57** | **372** | **341** | **34** | **2,251** | **7,027** | **95** | **88** | **10,265** | **40.0** |
| **Spotfin shiner** | **5** | **130** | **74** | **311** | **750** | **225** | **202** | **245** | **1,942** | **7.6** |
| Common carp | 8 | 37 | 36 | 39 | 39 | 30 | 26 | 24 | 239 | 0.9 |
| Common shiner | 2 | * | * | * | 4 | * | 1 | * | 7 | + |
| River chub | * | * | 1 | * | * | * | * | * | 1 | + |
| Golden shiner | * | 2 | 1 | 2 | 1 | 6 | 2 | 1 | 15 | 0.1 |
| Comely shiner | 126 | 71 | 31 | 3 | 17 | 142 | 121 | 1,945 | 2,456 | 9.6 |
| Spottail shiner | 3 | 33 | 5 | 14 | 179 | 173 | 314 | 310 | 1,031 | 4.0 |
| Swallowtail shiner | * | 2 | * | * | * | 1 | * | * | 3 | + |
| Mimic shiner | 17 | 2 | * | * | * | 1 | 5 | * | 25 | 0.1 |
| **Bluntnose minnow** | **83** | **36** | **38** | **36** | **49** | **188** | **66** | **49** | **545** | **2.1** |
| Creek chub | 2 | * | * | * | * | | * | 1 | 3 | + |
| Fallfish | 13 | 1 | 1 | * | * | 14 | 3 | 3 | 35 | 0.1 |
| Quillback | * | 1 | 3 | 3 | 63 | 5 | 11 | * | 86 | 0.3 |
| **White sucker** | * | **1** | **1** | **3** | **2** | * | * | * | **7** | + |
| Northern hogsucker | * | * | * | 1 | 12 | 10 | 3 | 1 | 27 | 0.1 |
| Shorthead redhorse | 1 | 6 | 2 | 8 | 13 | 25 | 25 | 24 | 104 | 0.4 |
| **Channel catfish** | **2** | **361** | **166** | **552** | **719** | **2,752** | **393** | **270** | **5,215** | **20.3** |
| Flathead catfish | * | 1 | 4 | 12 | 6 | 11 | 2 | 3 | 39 | 0.2 |
| Rainbow smelt | * | * | * | * | * | * | 1 | * | 1 | + |
| Eastern mosquitofish | * | * | * | * | * | * | * | 1 | 1 | + |
| Banded killifish | * | 7 | 23 | 18 | 7 | 1 | 4 | 28 | 88 | 0.3 |
| White perch | * | * | * | * | 4 | 7 | 9 | 15 | 35 | 0.1 |
| Striped bass | * | * | * | * | * | * | 1 | * | 1 | + |
| Hybrid Striped bass | * | * | * | * | * | * | 4 | 5 | 9 | + |
| Rock bass | 2 | 34 | 38 | 92 | 25 | 29 | 50 | 83 | 353 | 1.4 |
| Redbreast sunfish | 1 | 1 | * | 2 | 1 | | 1 | 2 | 8 | + |
| Green sunfish | 4 | 9 | 39 | 77 | 32 | 586 | 84 | 79 | 910 | 3.5 |
| Pumpkinseed | * | 1 | * | 3 | 1 | 1 | 4 | 1 | 11 | + |
| **Bluegill** | **30** | **16** | **36** | **142** | **163** | **449** | **258** | **301** | **1,395** | **5.4** |
| **Smallmouth bass** | **8** | **21** | **30** | **43** | **60** | **43** | **91** | **85** | **381** | **1.5** |
| **Largemouth bass** | **18** | **3** | **2** | **4** | **19** | **9** | **29** | **24** | **108** | **0.4** |
| **White crappie** | **1** | **1** | **1** | * | * | * | **8** | **7** | **18** | **0.1** |
| Black crappie | 2 | * | * | * | * | * | 1 | * | 3 | + |
| Greenside darter | 1 | * | * | * | * | 5 | * | * | 6 | + |
| Tessellated darter | 1 | 68 | 3 | 1 | 2 | 9 | 6 | 26 | 116 | 0.5 |
| Yellow perch | * | 1 | 3 | * | 1 | 2 | 2 | 5 | 14 | 0.1 |
| **Chesapeake logperch** | * | * | **2** | **7** | **6** | **39** | **6** | **5** | **65** | **0.3** |
| Shield darter | 1 | * | 9 | 1 | 1 | 11 | * | * | 23 | 0.1 |
| **Walleye** | **1** | **35** | **9** | **5** | **2** | **1** | **21** | **23** | **97** | **0.4** |
| Overall | 389 | 1,254 | 899 | 1,413 | 4,429 | 11,802 | 1,850 | 3,654 | 25,690 | 99.8 |
| Number of species | 24 | 28 | 26 | 25 | 28 | 29 | 33 | 28 | 41 | |
| Diversity | 2.11 | 2.08 | 2.15 | 1.98 | 1.60 | 1.32 | 2.46 | 1.82 | 1.99 | |

[a] Sampling in February was limited to electrofishing only.
+ Less than 0.05%.

Table 5-36. Number and percent (%) composition of fishes collected by all gear types in Conowingo Pond, January, February and April through October 2012.

| | Jan[a] | Feb[a] | Apr | May | Jun | Jul | Aug | Sep | Oct | Total | % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Gizzard shad** | **9** | **10** | **561** | **29** | **47** | **2,411** | **3,313** | **847** | **1,161** | **8,388** | **24.4** |
| Rosyside dace | * | * | * | * | 8 | * | * | * | * | 8 | + |
| **Spotfin shiner** | **3** | **1** | **92** | **213** | **121** | **259** | **246** | **67** | **118** | **1,120** | **3.3** |
| Common carp | 4 | 21 | 40 | 15 | 22 | 15 | 37 | 36 | 27 | 217 | 0.6 |
| Cutplis minnow | * | * | * | * | * | * | 1 | * | * | 1 | + |
| Common shiner | * | * | * | 1 | * | * | * | * | * | 1 | + |
| River chub | * | * | * | * | * | * | 2 | * | * | 2 | + |
| Golden shiner | * | 1 | * | * | 18 | 7 | 17 | 2 | 1 | 46 | 0.1 |
| Comely shiner | 1,825 | 3,905 | 709 | 97 | 20 | 206 | 154 | 2,309 | 148 | 9,373 | 27.3 |
| Spottail shiner | 102 | 42 | 114 | 58 | 33 | 81 | 89 | 156 | 35 | 710 | 2.1 |
| Swallowtail shiner | * | * | 2 | * | * | * | * | 1 | 1 | 4 | + |
| Rosyface shiner | * | * | * | * | * | * | 1 | * | * | 1 | + |
| Mimic shiner | * | * | * | * | * | 2 | * | * | 1 | 3 | + |
| **Bluntnose minnow** | **19** | **26** | **93** | **65** | **25** | **15** | **97** | **61** | **41** | **442** | **1.3** |
| Creek chub | * | * | 3 | 16 | * | 1 | * | * | * | 20 | 0.1 |
| Fallfish | * | * | 2 | 7 | 3 | * | 1 | 1 | * | 14 | + |
| Quillback | * | * | 2 | * | 7 | 2 | 2 | 2 | 3 | 18 | 0.1 |
| **White sucker** | * | * | **5** | **11** | **8** | **1** | **2** | **1** | **3** | **31** | **0.1** |
| Northern hogsucker | * | * | * | 1 | 1 | 6 | 15 | 7 | 2 | 32 | 0.1 |
| Shorthead redhorse | 1 | 4 | 3 | 15 | 21 | 31 | 40 | 70 | 62 | 247 | 0.7 |
| **Channel catfish** | **8** | **2** | **263** | **197** | **233** | **591** | **661** | **414** | **380** | **2,749** | **8.0** |
| Flathead catfish | 3 | 1 | * | 8 | 6 | 12 | 4 | 10 | * | 44 | 0.1 |
| Tiger Muskellunge | 1 | * | * | * | * | * | * | * | * | 1 | + |
| Atlantic needlefish | * | * | * | * | * | * | * | * | 5 | 5 | + |
| Banded killifish | * | * | * | 16 | 5 | * | * | 20 | 24 | 65 | 0.2 |
| White perch | * | 1 | * | * | * | 28 | 2 | 9 | 22 | 62 | 0.2 |
| Striped bass | * | * | * | 1 | * | * | * | * | * | 1 | + |
| Hybrid Striped bass | 2 | * | 4 | 1 | * | * | * | * | 23 | 30 | 0.1 |
| Rock bass | 7 | 8 | 42 | 81 | 22 | 34 | 23 | 45 | 41 | 303 | 0.9 |
| Redbreast sunfish | * | * | 1 | 2 | 1 | 4 | 1 | * | 2 | 11 | + |
| Green sunfish | 5 | 17 | 41 | 29 | 48 | 79 | 676 | 171 | 220 | 1,286 | 3.7 |
| Pumpkinseed | * | * | * | 5 | 1 | * | 1 | 1 | 2 | 10 | + |
| **Bluegill** | **19** | **20** | **150** | **189** | **117** | **196** | **3847** | **2881** | **721** | **8,140** | **23.7** |
| **Smallmouth bass** | **10** | **12** | **36** | **57** | **44** | **54** | **32** | **79** | **63** | **387** | **1.1** |
| **Largemouth bass** | **13** | **12** | **21** | **11** | **7** | **6** | **4** | **51** | **23** | **148** | **0.4** |
| **White crappie** | **1** | * | **3** | * | * | * | * | **5** | **3** | **12** | + |
| Black crappie | * | 2 | * | 1 | * | * | * | 2 | 2 | 7 | + |
| Greenside darter | * | * | * | * | * | 2 | 1 | * | * | 3 | + |
| Tessellated darter | 2 | * | 14 | 15 | 22 | 13 | 49 | 23 | 52 | 190 | 0.6 |
| Yellow perch | * | * | 6 | 3 | 1 | * | 1 | 4 | 8 | 23 | 0.1 |
| **Chesapeake logperch** | * | * | **6** | **9** | **6** | **15** | **19** | **13** | **12** | **80** | **0.2** |
| **Walleye** | **7** | **4** | **6** | **1** | **2** | **3** | **4** | **7** | **87** | **121** | **0.4** |
| Overall | 2,041 | 4,089 | 2,219 | 1,125 | 794 | 4,074 | 9,342 | 7,295 | 3,293 | 34,356 | 99.8 |
| Number of species | 17 | 18 | 24 | 28 | 27 | 26 | 30 | 29 | 30 | 40 | |
| Diversity | 0.79 | 0.42 | 2.96 | 3.69 | 3.74 | 2.22 | 2.21 | 2.42 | 3.07 | 2.82 | |

[a] Sampling in January and February was limited to electrofishing only.

+ Less than 0.05%.

Table 5-37. Number and percent (%) composition of fishes collected by boat electrofishing and seining in Conowingo Pond, January, March and April through October 2013.

| | Jan[a] | Mar[a] | Apr | May | Jun | Jul | Aug | Sep | Oct | Total | % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Gizzard shad** | **83** | **125** | **1049** | **1369** | **24** | **63** | **138** | **140** | **55** | **3046** | **16.6** |
| **Spotfin shiner** | **15** | **1** | **56** | **284** | **404** | **275** | **136** | **107** | **112** | **1390** | **7.6** |
| Central stoneroller | * | * | * | * | 1 | 4 | 1 | * | * | 6 | + |
| Grass carp | * | * | * | * | * | * | * | 1 | * | 1 | + |
| Common carp | * | 33 | 28 | 5 | 5 | 3 | 10 | 6 | 17 | 107 | 0.6 |
| Golden shiner | 1 | * | 1 | * | 1 | 1 | 8 | * | 8 | 20 | 0.1 |
| Comely shiner | 200 | 693 | 219 | 88 | 37 | 33 | 145 | 373 | 165 | 1953 | 10.6 |
| Common shiner | * | * | * | * | 1 | * | * | * | * | 1 | + |
| Spottail shiner | 95 | 58 | 89 | 20 | 38 | 69 | 176 | 132 | 69 | 746 | 4.1 |
| Swallowtail shiner | * | * | 1 | 1 | * | * | * | 2 | * | 4 | + |
| Mimic shiner | * | 2 | * | * | * | * | * | * | * | 2 | + |
| **Bluntnose minnow** | **346** | **39** | **234** | **176** | **141** | **103** | **127** | **204** | **118** | **1488** | **8.1** |
| Blacknose dace | * | * | * | * | * | * | 1 | * | * | 1 | + |
| Creek chub | * | 1 | 8 | 3 | * | * | * | * | * | 12 | 0.1 |
| Fallfish | * | * | 4 | * | * | * | * | * | * | 4 | + |
| Quillback | * | 1 | * | * | 22 | 2 | * | 1 | * | 26 | 0.1 |
| **White sucker** | * | * | * | * | **69** | **2** | **30** | * | **1** | **102** | **0.6** |
| Northern hogsucker | * | * | * | * | 2 | 4 | 4 | * | * | 10 | 0.1 |
| Shorthead redhorse | 2 | 8 | 27 | 29 | 57 | 30 | 44 | 65 | 38 | 300 | 1.6 |
| **Channel catfish** | **1** | **14** | **83** | **99** | **104** | **174** | **205** | **168** | **83** | **931** | **5.1** |
| Flathead catfish | * | * | 2 | 3 | 7 | 2 | 14 | 11 | 1 | 40 | 0.2 |
| Muskellunge | * | 1 | * | * | * | * | * | * | * | 1 | + |
| Brown trout | 1 | 1 | * | * | * | * | * | * | * | 2 | + |
| Banded killifish | 5 | 6 | 20 | 113 | 57 | 3 | 20 | 43 | 433 | 700 | 3.8 |
| White perch | * | * | 4 | 17 | 1 | * | 4 | 1 | 22 | 49 | 0.3 |
| Hybrid Striped bass | * | 4 | * | * | * | * | * | * | 1 | 5 | + |
| Rock bass | 3 | 2 | 89 | 59 | 30 | 23 | 22 | 38 | 151 | 417 | 2.3 |
| Redbreast sunfish | 1 | 1 | * | 2 | 4 | * | * | 3 | 2 | 13 | 0.1 |
| Green sunfish | 83 | 15 | 142 | 203 | 157 | 135 | 243 | 362 | 338 | 1678 | 9.1 |
| Pumpkinseed | * | * | * | 2 | 2 | 1 | * | 6 | 8 | 19 | 0.1 |
| **Bluegill** | **210** | **60** | **160** | **371** | **218** | **158** | **334** | **781** | **954** | **3246** | **17.7** |
| **Smallmouth bass** | **18** | **5** | **55** | **71** | **157** | **217** | **125** | **171** | **305** | **1124** | **6.1** |
| **Largemouth bass** | **29** | **20** | **15** | **8** | **9** | **9** | **27** | **12** | **20** | **149** | **0.8** |
| **White crappie** | **5** | * | * | **1** | * | **2** | **4** | **5** | **5** | **22** | **0.1** |
| Black crappie | 5 | 2 | * | * | * | 1 | * | * | 1 | 9 | + |
| Greenside darter | 3 | * | * | * | * | 2 | 2 | 15 | 5 | 27 | 0.1 |
| Tessellated darter | 22 | * | 35 | 19 | 15 | 4 | 12 | 13 | 22 | 142 | 0.8 |
| Yellow perch | * | * | 11 | 22 | 5 | 8 | 5 | 15 | 37 | 103 | 0.6 |
| **Chesapeake logperch** | **2** | * | **2** | **3** | **9** | **37** | **78** | **153** | **53** | **337** | **1.8** |
| Shield darter | * | * | * | * | 1 | 2 | 7 | 17 | 12 | 39 | 0.2 |
| **Walleye** | 10 | 13 | 12 | 1 | 2 | 2 | 22 | 8 | 39 | 109 | **0.6** |
| Overall | 1140 | 1105 | 2346 | 2969 | 1580 | 1369 | 1944 | 2853 | 3075 | 18381 | 99.8 |
| Number of species | 22 | 23 | 24 | 25 | 29 | 29 | 28 | 28 | 29 | 41 | |
| Diversity | 2.96 | 2.16 | 2.97 | 2.80 | 3.54 | 3.47 | 3.80 | 3.48 | 3.42 | 3.70 | |

[a] Sampling in January and March was limited to electrofishing only.
+ Less than 0.05%.

Table 5-38. Trophic designation of common species and RIS collected in Conowingo Pond, 2010-2013. Trophic designation assigned based on Barbour *et al.* 1999 and Roth *et al.* 2000.

| Species | Trophic Designation |
|---|---|
| Banded darter | IS |
| Banded killifish | IV |
| Black crappie | GE |
| Bluegill | IV |
| Bluntnose minnow | OM |
| Channel catfish | OM |
| Chesapeake logperch | IS |
| Comely shiner | IV |
| Common carp | OM |
| Common shiner | IV |
| Creek chub | GE |
| Flathead catfish | P |
| Gizzard shad | FF |
| Golden shiner | OM |
| Green sunfish | GE |
| Greenside darter | IS |
| Largemouth bass | P |
| Northern hog sucker | IV |
| Pumpkinseed | IV |
| Quillback | OM |
| Rock bass | GE |
| Shield darter | IS |
| Shorthead redhorse | OM |
| Smallmouth bass | P |
| Spotfin shiner | IV |
| Spottail shiner | OM |
| Swallowtail shiner | IV |
| Tessellated darter | IV |
| Walleye | P |
| White crappie | P |
| White perch | IV |
| White sucker | OM |
| Yellow perch | GE |

P=Piscivore
H=Herbivore
OM=Omnivore
IS=Insectivore (including specialized insectivores)
FF=Filter feeder
GE=Generalist feeder
IV=Invertivore

Table 5-39. Summary of fisheries data collected by boat electrofisher, July through October 2010.

| | Non-thermally Affected | | | Total | Number/ | Thermally Affected | | | Total | Number/ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Taxon | 164 | 165 | 187 | Number | Collection | 161 | 189 | 190 | Number | Collection | Total | % |
| **Gizzard shad** | **721** | **48** | **79** | **848** | **70.7** | **2,333** | **2,123** | **503** | **4,959** | **413.3** | **5,807** | **67.5%** |
| **Spotfin shiner** | **62** | **21** | **44** | **127** | **10.6** | **14** | **29** | **30** | **73** | **6.1** | **200** | **2.3%** |
| Common carp | 13 | 9 | 17 | 39 | 3.3 | 7 | 1 | 5 | 13 | 1.1 | 52 | 0.6% |
| Golden shiner | * | * | 1 | 1 | 0.1 | * | 3 | 13 | 16 | 1.3 | 17 | 0.2% |
| Comely shiner | 14 | 24 | 24 | 62 | 5.2 | * | 12 | 32 | 44 | 3.7 | 106 | 1.2% |
| Spottail shiner | 9 | 12 | 16 | 37 | 3.1 | 2 | 3 | 1 | 6 | 0.5 | 43 | 0.5% |
| **Bluntnose minnow** | **7** | **10** | **12** | **29** | **2.4** | **3** | **3** | **5** | **11** | **0.9** | **40** | **0.5%** |
| Quillback | * | 1 | 3 | 4 | 0.3 | 1 | | 1 | 2 | 0.2 | 6 | 0.1% |
| **White sucker** | * | * | **1** | **1** | **0.1** | * | * | * | **0** | **0.0** | **1** | **0.0%** |
| Northern hog sucker | * | 1 | 6 | 7 | 0.6 | * | * | * | 0 | 0.0 | 7 | 0.1% |
| Shorthead redhorse | * | 1 | 6 | 7 | 0.6 | 11 | 8 | 5 | 24 | 2.0 | 31 | 0.4% |
| **Channel catfish** | **93** | **144** | **69** | **306** | **25.5** | **51** | **58** | **69** | **178** | **14.8** | **484** | **5.6%** |
| Flathead catfish | 5 | 4 | * | 9 | 0.8 | 4 | 3 | * | 7 | 0.6 | 16 | 0.2% |
| Banded killifish | * | 1 | * | 1 | 0.1 | * | * | * | 0 | 0.0 | 1 | + |
| White perch | * | * | 2 | 2 | 0.2 | 1 | * | * | 1 | 0.1 | 3 | + |
| Rock bass | 16 | 58 | 51 | 125 | 10.4 | 3 | 14 | 5 | 22 | 1.8 | 147 | 1.7% |
| Redbreast sunfish | * | * | * | 0 | 0.0 | 1 | * | | 1 | 0.1 | 1 | + |
| Green sunfish | 64 | 105 | 11 | 180 | 15.0 | 30 | 75 | 263 | 368 | 30.7 | 548 | 6.4% |
| Pumpkinseed | * | * | 1 | 1 | 0.1 | * | * | * | 0 | 0.0 | 1 | + |
| **Bluegill** | **60** | **136** | **35** | **231** | **19.3** | **35** | **105** | **330** | **470** | **39.2** | **701** | **8.1%** |
| **Smallmouth bass** | **31** | **29** | **18** | **78** | **6.5** | **50** | **9** | **26** | **85** | **7.1** | **163** | **1.9%** |
| **Largemouth bass** | * | **1** | **1** | **2** | **0.2** | **11** | **10** | **34** | **55** | **4.6** | **57** | **0.7%** |
| **White crappie** | * | * | **1** | **1** | **0.1** | * | * | * | **0** | **0.0** | **1** | **+** |
| Black crappie | 1 | * | 1 | 2 | 0.2 | * | * | * | 0 | 0.0 | 2 | + |
| Greenside darter | * | * | 1 | 1 | 0.1 | * | * | * | 0 | 0.0 | 1 | + |
| Tessellated darter | 8 | 5 | 14 | 27 | 2.3 | * | 1 | * | 1 | 0.1 | 28 | 0.3% |
| Banded darter | * | 1 | * | 1 | 0.1 | * | * | * | 0 | 0.0 | 1 | + |
| Yellow perch | * | 1 | * | 1 | 0.1 | * | * | * | 0 | 0.0 | 1 | + |
| **Chesapeake logperch** | **5** | **25** | **19** | **49** | **4.1** | **2** | **2** | **5** | **9** | **0.8** | **58** | **0.7%** |
| Shield darter | * | 5 | 3 | 8 | 0.7 | * | * | 1 | 1 | 0.1 | 9 | 0.1% |
| **Walleye** | **21** | **11** | **15** | **47** | **3.9** | **17** | **10** | **2** | **29** | **2.4** | **76** | **0.9%** |
| No. of Fish | 1,130 | 653 | 451 | 2,234 | 186.2 | 2,576 | 2,469 | 1,330 | 6,375 | 531.3 | 8,609 | 99.9% |
| No. of Species | 16 | 23 | 26 | 30 | | 18 | 18 | 18 | 22 | | 31 | |
| No. of Collections | 4 | 4 | 4 | 12 | | 4 | 4 | 4 | 12 | | 24 | |
| No. of Fish/Collection | 282.5 | 163.3 | 112.8 | 186.2 | | 644.0 | 617.3 | 332.5 | 531.3 | | 358.7 | |
| Diversity Index | 1.47 | 2.30 | 2.63 | | | 0.52 | 0.69 | 1.71 | | | | |
| Evenness Index | 0.53 | 0.73 | 0.81 | | | 0.18 | 0.24 | 0.59 | | | | |

Table 5-40. Summary of fisheries data collected by 10' seine in Conowingo Pond, July through October 2010.

| | Non-thermally Affected | | | | | Total | Number/ | Thermally Affected | | Total | Number/ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Taxon | 203 | 202 | 208 | 221 | 220 | Number | Collection | 214 | 215 | Number | Collection | Total | % |
| **Gizzard shad** | **4** | **2** | **15** | **3** | **3** | **27** | **1.4** | **4** | **5** | **9** | **1.1** | **36** | **2.0%** |
| **Spotfin shiner** | **22** | **43** | **275** | **25** | **268** | **633** | **31.7** | **56** | **171** | **227** | **28.4** | **860** | **47.0%** |
| Comely shiner | * | 7 | * | 1 | 9 | 17 | 0.9 | 25 | 7 | 32 | 4.0 | 49 | 2.7% |
| Spottail shiner | 20 | 14 | * | 1 | 13 | 48 | 2.4 | 1 | 2 | 3 | 0.4 | 51 | 2.8% |
| Swallowtail shiner | 3 | 2 | * | * | 1 | 6 | 0.3 | * | * | 0 | 0.0 | 6 | 0.3% |
| **Bluntnose minnow** | **8** | **20** | **9** | **1** | **23** | **61** | **3.1** | **5** | **25** | **30** | **3.8** | **91** | **5.0%** |
| Creek chub | 1 | * | * | * | * | 1 | 0.1 | * | * | 0 | 0.0 | 1 | 0.1% |
| Fallfish | 1 | * | * | * | * | 1 | 0.1 | * | * | 0 | 0.0 | 1 | 0.1% |
| Quillback | * | 2 | 3 | 2 | * | 7 | 0.4 | * | * | 0 | 0.0 | 7 | 0.4% |
| **White Sucker** | * | * | * | **5** | * | **5** | **0.3** | * | * | **0** | **0.0** | **5** | **0.3%** |
| Northern hog sucker | * | * | * | 4 | 2 | 6 | 0.3 | * | * | 0 | 0.0 | 6 | 0.3% |
| Shorthead redhorse | 1 | 1 | * | 1 | 2 | 5 | 0.3 | * | * | 0 | 0.0 | 5 | 0.3% |
| **Channel catfish** | **1** | **1** | * | * | * | **2** | **0.1** | * | * | **0** | **0.0** | **2** | **0.1%** |
| Flathead catfish | * | 1 | * | * | * | 1 | 0.1 | * | * | 0 | 0.0 | 1 | 0.1% |
| Banded killifish | 42 | 25 | 95 | 8 | 8 | 178 | 8.9 | 6 | * | 6 | 0.8 | 184 | 10.1% |
| Rock bass | * | 3 | * | 2 | 1 | 6 | 0.3 | * | * | 0 | 0.0 | 6 | 0.3% |
| Green sunfish | 2 | 19 | 1 | * | 1 | 23 | 1.2 | 4 | 22 | 26 | 3.3 | 49 | 2.7% |
| Pumpkinseed | * | * | 1 | * | * | 1 | 0.1 | * | * | 0 | 0.0 | 1 | 0.1% |
| **Bluegill** | **12** | **194** | **3** | * | **74** | **283** | **14.2** | **10** | **48** | **58** | **7.3** | **341** | **18.7%** |
| **Smallmouth bass** | * | **1** | * | **4** | **2** | **7** | **0.4** | * | * | **0** | **0.0** | **7** | **0.4%** |
| **Largemouth bass** | * | * | **2** | * | * | **2** | **0.1** | * | **1** | **1** | **0.1** | **3** | **0.2%** |
| Greenside darter | 1 | 5 | 1 | * | 5 | 12 | 0.6 | * | * | 0 | 0.0 | 12 | 0.7% |
| Tessellated darter | 9 | 34 | 3 | 34 | * | 80 | 4.0 | 1 | * | 1 | 0.1 | 81 | 4.4% |
| Banded darter | * | 4 | * | * | * | 4 | 0.2 | * | * | 0 | 0.0 | 4 | 0.2% |
| **Chesapeake logperch** | * | * | **2** | **2** | **15** | **19** | **1.0** | * | * | **0** | **0.0** | **19** | **1.0%** |
| No. of Fish | 127 | 378 | 410 | 93 | 427 | 1,435 | 71.8 | 112 | 281 | 393 | 49.1 | 1,828 | 100.0% |
| No. of Species | 14 | 19 | 12 | 14 | 15 | 25 | | 9 | 8 | 10 | | 25 | |
| No. of Collections | 4 | 4 | 4 | 4 | 4 | 20 | | 4 | 4 | 8 | | 28 | |
| No. of Fish/Collection | 31.8 | 94.5 | 102.5 | 23.3 | 106.8 | 71.8 | | 28.0 | 70.3 | 49.1 | | 65.3 | |
| Diversity Index | 2.00 | 1.78 | 1.02 | 1.91 | 1.34 | | | 1.51 | 1.24 | | | | |
| Evenness Index | 0.76 | 0.6 | 0.41 | 0.72 | 0.49 | | | 0.69 | 0.6 | | | | |

Table 5-41. Summary by station of fisheries data collected by 16' Otter Trawl in Conowingo Pond July through October 2010.

| | McClellan's Rock | | | Below Burkins Run | | | | Below PBAPS | | | Broad Creek | | | PBAPS Intake | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Taxon | 331* | 332 | 333 | 381* | 382* | 383 | 384 | 371* | 372 | 373 | 341 | 342 | 343 | 321 | 322 | 323 | Total | % |
| **Gizzard shad** | **1** | **7** | **4** | * | * | **1** | **1** | * | * | **2** | **12** | **20** | **6** | **8** | * | * | **62** | **3.1%** |
| **Spotfin shiner** | * | **1** | * | * | * | * | * | * | * | * | * | * | * | * | * | * | **1** | + |
| Common carp | * | 3 | 6 | * | 1 | * | 1 | * | 1 | * | 4 | 3 | 7 | 3 | * | * | 29 | 1.4% |
| Spottail shiner | 1 | 3 | 1 | * | * | * | * | * | * | * | 1 | * | * | * | * | * | 6 | 0.3% |
| Quillback | * | * | 2 | * | * | * | * | * | * | * | * | 1 | * | * | * | * | 3 | 0.1% |
| Northern hog sucker | * | 1 | * | * | * | * | * | * | * | * | * | * | * | * | * | * | 1 | + |
| Shorthead redhorse | * | * | 3 | * | * | * | 1 | * | * | * | * | * | 1 | * | * | * | 5 | 0.2% |
| **Channel catfish** | **255** | **473** | **173** | **21** | **41** | **205** | **43** | **3** | * | **2** | **59** | **84** | **310** | **17** | * | **45** | **1,731** | **85.8%** |
| Flathead catfish | * | 1 | 1 | * | 1 | * | * | * | * | * | * | 1 | * | * | * | * | 4 | 0.2% |
| White perch | * | * | * | * | * | * | 1 | * | * | * | * | 1 | * | * | * | * | 2 | 0.1% |
| Rock bass | * | * | 1 | * | * | * | * | * | * | * | * | * | * | * | * | * | 1 | + |
| **Bluegill** | **2** | **17** | **6** | **4** | **1** | **1** | **2** | **3** | **6** | **1** | **16** | **4** | **6** | **4** | * | **5** | **78** | **3.9%** |
| **Smallmouth bass** | * | * | * | * | * | * | **2** | * | * | * | * | * | * | * | * | * | **2** | **0.1%** |
| **Largemouth bass** | * | * | * | * | * | * | **1** | * | * | * | * | * | * | * | * | * | **1** | + |
| **White crappie** | * | * | * | * | * | * | * | * | * | * | * | * | **1** | * | * | * | **1** | + |
| Tessellated darter | 1 | 25 | 8 | 3 | 6 | * | * | 2 | * | 2 | 19 | 1 | 4 | 15 | * | 2 | 88 | 4.4% |
| **Walleye** | * | **1** | **1** | * | * | * | * | * | * | * | * | * | **1** | * | * | * | **3** | **0.1%** |
| No. of Fish | 260 | 532 | 206 | 28 | 50 | 207 | 52 | 8 | 7 | 7 | 111 | 115 | 336 | 47 | 0 | 52 | 2,018 | 99.8% |
| No. of Species | 5 | 10 | 11 | 3 | 5 | 3 | 8 | 3 | 2 | 4 | 6 | 8 | 8 | 5 | 0 | 3 | 17 | |
| No. of Collections | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 64 | |
| No. of Fish/Collection | 65.0 | 133.0 | 51.5 | 7.0 | 12.5 | 51.8 | 13.0 | 2.0 | 1.8 | 1.8 | 27.8 | 28.8 | 84.0 | 11.8 | 0.0 | 13.0 | 31.5 | |
| Fish/10 minute haul | 65.0 | 133.0 | 51.5 | 7.2 | 12.5 | 55.9 | 13.0 | 2.2 | 1.8 | 1.8 | 27.8 | 28.8 | 84.0 | 11.8 | 0.0 | 13.0 | 32.0 | |
| Diversity Index | 0.12 | 0.52 | 0.77 | 0.73 | 0.65 | 0.06 | 0.79 | 1.08 | 0.41 | 1.35 | 1.32 | 0.91 | 0.40 | 1.42 | 0.00 | 0.48 | 0.66 | |
| Evenness Index | 0.07 | 0.23 | 0.32 | 0.66 | 0.40 | 0.05 | 0.38 | 0.98 | 0.59 | 0.97 | 0.74 | 0.44 | 0.19 | 0.91 | 0.00 | 0.49 | 0.23 | |

* Located within the influence of PBAPS thermal effluent.
+ Less than 0.05%.

Table 5-42. Summary of fisheries data by station collected by boat electrofisher in February and April through October 2011.

| | Non-thermally Affected | | | Total | Number/ | Thermally Affected | | | | Total | Number/ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Taxon | 164 | 165 | 187 | Number | Collection | 161 | 189 | 190 | 217 | Number | Collection | Total | % |
| American shad | * | * | * | 0 | 0.0 | * | * | * | 1 | 1 | 0.0 | 1 | + |
| **Gizzard shad** | **2,136** | **109** | **1,127** | **3,372** | **140.5** | **1,697** | **821** | **1,089** | **3,118** | **6,725** | **231.9** | **10,097** | **55.7%** |
| **Spotfin shiner** | **193** | **20** | **588** | **801** | **33.4** | **75** | **120** | **67** | **55** | **317** | **10.9** | **1,118** | **6.2%** |
| Common carp | * | 6 | 41 | 47 | 2.0 | 59 | 20 | 22 | 11 | 112 | 3.9 | 159 | 0.9% |
| Common shiner | * | * | * | 0 | 0.0 | * | * | 2 | * | 2 | 0.1 | 2 | + |
| River chub | * | 1 | * | 1 | 0.0 | * | * | * | * | 0 | 0.0 | 1 | + |
| Golden shiner | * | * | 2 | 2 | 0.1 | * | 1 | 6 | 2 | 9 | 0.3 | 11 | 0.1% |
| Comely shiner | 262 | 84 | 1,225 | 1,571 | 65.5 | 157 | 288 | 292 | 47 | 784 | 27.0 | 2,355 | 13.0% |
| Spottail shiner | 29 | 34 | 40 | 103 | 4.3 | 38 | 15 | 22 | 32 | 107 | 3.7 | 210 | 1.2% |
| Swallowtail shiner | * | 1 | * | 1 | 0.0 | * | * | * | * | 0 | 0.0 | 1 | + |
| Mimic shiner | 8 | 2 | 6 | 16 | 0.7 | 1 | 2 | * | * | 3 | 0.1 | 19 | 0.1% |
| **Bluntnose minnow** | **18** | **20** | **73** | **111** | **4.6** | **20** | **100** | **29** | **9** | **158** | **5.4** | **269** | **1.5%** |
| Creek chub | * | * | 1 | 1 | 0.0 | * | 1 | * | 1 | 2 | 0.1 | 3 | + |
| Fallfish | 1 | 7 | 1 | 9 | 0.4 | * | 5 | 1 | * | 6 | 0.2 | 15 | 0.1% |
| Quillback | 1 | 1 | 5 | 7 | 0.3 | 10 | 2 | * | 2 | 14 | 0.5 | 21 | 0.1% |
| **White sucker** | * | **1** | **3** | **4** | **0.2** | * | * | * | **1** | **1** | **0.0** | **5** | **0.0%** |
| Northern hog sucker | * | 2 | * | 2 | 0.1 | * | * | * | 1 | 1 | 0.0 | 3 | + |
| Shorthead redhorse | 5 | 7 | 15 | 27 | 1.1 | 14 | 5 | 5 | 17 | 41 | 1.4 | 68 | 0.4% |
| **Channel catfish** | **133** | **125** | **113** | **371** | **15.5** | **176** | **109** | **101** | **94** | **480** | **16.6** | **851** | **4.7%** |
| Flathead catfish | 4 | 5 | 2 | 11 | 0.5 | 10 | 8 | 3 | 2 | 23 | 0.8 | 34 | 0.2% |
| Banded killifish | 1 | 1 | 1 | 3 | 0.1 | * | * | 1 | * | 1 | 0.0 | 4 | + |
| White perch | * | 1 | 19 | 20 | 0.8 | 2 | * | * | 3 | 5 | 0.2 | 25 | 0.1% |
| Striped bass | * | * | * | 0 | 0.0 | * | * | * | 1 | 1 | 0.0 | 1 | + |
| Hybrid Striped bass | * | * | 4 | 4 | 0.2 | * | * | * | 1 | 1 | 0.0 | 5 | + |
| Rock bass | 76 | 93 | 93 | 262 | 10.9 | 6 | 20 | 19 | 37 | 82 | 2.8 | 344 | 1.9% |
| Redbreast sunfish | * | * | * | 0 | 0.0 | * | 1 | 3 | 3 | 7 | 0.2 | 7 | + |
| Green sunfish | 75 | 42 | 13 | 130 | 5.4 | 129 | 55 | 223 | 358 | 765 | 26.4 | 895 | 4.9% |
| Pumpkinseed | * | * | * | 0 | 0.0 | 1 | * | * | 7 | 8 | 0.3 | 8 | + |
| **Bluegill** | **65** | **86** | **86** | **237** | **9.9** | **77** | **127** | **193** | **334** | **731** | **25.2** | **968** | **5.3%** |
| **Smallmouth bass** | **115** | **56** | **42** | **213** | **8.9** | **44** | **25** | **40** | **23** | **132** | **4.6** | **345** | **1.9%** |
| **Largemouth bass** | **4** | * | **6** | **10** | **0.4** | **18** | **18** | **4** | **38** | **78** | **2.7** | **88** | **0.5%** |
| **White crappie** | **1** | * | **2** | **3** | **0.1** | **2** | **1** | **4** | **1** | **8** | **0.3** | **11** | **0.1%** |
| Black crappie | * | * | * | 0 | 0.0 | 2 | * | * | * | 2 | 0.1 | 2 | + |
| Greenside darter | * | 2 | * | 2 | 0.1 | 1 | * | * | 2 | 3 | 0.1 | 5 | + |
| Tessellated darter | 2 | 2 | 2 | 6 | 0.3 | * | 2 | 3 | 1 | 6 | 0.2 | 12 | 0.1% |
| Yellow perch | 1 | 2 | 3 | 6 | 0.3 | * | * | * | 2 | 2 | 0.1 | 8 | + |
| **Chesapeake logperch** | **1** | **20** | **14** | **35** | **1.5** | **1** | **1** | **2** | **17** | **21** | **0.7** | **56** | **0.3%** |
| Shield darter | * | 10 | 1 | 11 | 0.5 | * | * | * | * | 0 | 0.0 | 11 | 0.1% |
| **Walleye** | **11** | **9** | **20** | **40** | **1.7** | **18** | **7** | **19** | **8** | **52** | **1.8** | **92** | **0.5%** |
| No. of Fish | 3,142 | 749 | 3,548 | 7,439 | 310.0 | 2,558 | 1,754 | 2,150 | 4,229 | 10,691 | 368.7 | 18,130 | 99.7% |
| No. of Species | 22 | 28 | 28 | 36 | | 23 | 24 | 23 | 30 | 29 | | 38 | |
| No. of Collections | 8 | 8 | 8 | 24 | | 8 | 8 | 8 | 5 | 29 | | 53 | |
| No. of Fish/Collection | 392.8 | 93.6 | 443.5 | 310.0 | | 319.8 | 219.3 | 268.8 | 845.8 | 368.7 | | 342.1 | |
| Diversity Index | 1.31 | 2.52 | 1.76 | | | 1.43 | 1.85 | 1.73 | 1.11 | | | | |
| Evenness Index | 0.42 | 0.76 | 0.53 | | | 0.46 | 0.58 | 0.55 | 0.33 | | | | |

+ Less than 0.05%.

Table 5-43. Summary of fisheries data collected by 10' seine in Conowingo Pond, April through October 2011.

| | Non-thermally Affected | | | | | Total | Number/ | Thermally Affected | | Total | Number/ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Taxon | 203 | 202 | 208 | 221 | 220 | Number | Collection | 214 | 215 | Number | Collection | Total | % |
| **Gizzard shad** | **3** | * | **12** | **13** | **3** | **31** | **0.9** | **7** | **4** | **11** | **0.8** | **42** | **2.6%** |
| **Spotfin shiner** | **77** | **75** | **71** | **34** | **224** | **481** | **13.7** | **134** | **197** | **331** | **23.6** | **812** | **50.6%** |
| Common carp | * | * | * | * | * | 0 | 0.0 | 2 | * | 2 | 0.1 | 2 | 0.1% |
| Common shiner | * | 4 | * | * | * | 4 | 0.1 | * | * | 0 | 0.0 | 4 | 0.2% |
| Golden shiner | * | * | 2 | * | * | 2 | 0.1 | 1 | * | 1 | 0.1 | 3 | 0.2% |
| Comely shiner | 5 | 19 | 2 | 29 | 1 | 56 | 1.6 | 4 | 2 | 6 | 0.4 | 62 | 3.9% |
| Spottail shiner | 11 | 22 | 7 | 11 | 4 | 55 | 1.6 | 2 | * | 2 | 0.1 | 57 | 3.6% |
| Mimic shiner | * | 1 | * | * | 4 | 5 | 0.1 | 1 | * | 1 | 0.1 | 6 | 0.4% |
| **Bluntnose minnow** | **105** | **28** | **23** | **22** | **15** | **193** | **5.5** | **34** | **8** | **42** | **3.0** | **235** | **14.7%** |
| Fallfish | 5 | 2 | * | * | 12 | 19 | 0.5 | 1 | * | 1 | 0.1 | 20 | 1.2% |
| Quillback | 2 | 51 | 1 | 7 | 1 | 62 | 1.8 | * | * | 0 | 0.0 | 62 | 3.9% |
| Northern hog sucker | * | * | 1 | 15 | 7 | 23 | 0.7 | * | * | 0 | 0.0 | 23 | 1.4% |
| Shorthead redhorse | * | * | 1 | 5 | 2 | 8 | 0.2 | * | * | 0 | 0.0 | 8 | 0.5% |
| **Channel catfish** | **2** | * | **1** | **1** | * | **4** | **0.1** | **6** | * | **6** | **0.4** | **10** | **0.6%** |
| Eastern mosquitofish | * | * | 1 | * | * | 1 | 0.0 | * | * | 0 | 0.0 | 1 | 0.1% |
| Banded killifish | * | 1 | 8 | 24 | 4 | 37 | 1.1 | 47 | * | 47 | 3.4 | 84 | 5.2% |
| Hybrid Striped bass | * | * | * | * | * | 0 | 0.0 | 1 | 1 | 2 | 0.1 | 2 | 0.1% |
| Rock bass | * | 1 | * | 1 | 3 | 5 | 0.1 | 4 | * | 4 | 0.3 | 9 | 0.6% |
| Green sunfish | 1 | * | 5 | * | 4 | 10 | 0.3 | 4 | * | 4 | 0.3 | 14 | 0.9% |
| **Bluegill** | **24** | **30** | **2** | **4** | **12** | **72** | **2.1** | **8** | **7** | **15** | **1.1** | **87** | **5.4%** |
| **Smallmouth bass** | * | **2** | **4** | * | **4** | **10** | **0.3** | * | **1** | **1** | **0.1** | **11** | **0.7%** |
| **Largemouth bass** | **8** | * | * | * | * | **8** | **0.2** | **1** | * | **1** | **0.1** | **9** | **0.6%** |
| Greenside darter | * | * | 1 | * | * | 1 | 0.0 | * | * | 0 | 0.0 | 1 | 0.1% |
| Tessellated darter | 4 | 3 | 9 | 9 | 2 | 27 | 0.8 | 3 | 1 | 4 | 0.3 | 31 | 1.9% |
| Yellow perch | * | * | * | 1 | * | 1 | 0.0 | * | * | 0 | 0.0 | 1 | 0.1% |
| **Chesapeake logperch** | * | * | **4** | * | **2** | **6** | **0.2** | * | **1** | **1** | **0.1** | **7** | **0.4%** |
| Shield darter | * | * | 1 | * | * | 1 | 0.0 | * | * | 0 | 0.0 | 1 | 0.1% |
| No. of Fish | 247 | 239 | 156 | 176 | 304 | 1,122 | 32.1 | 260 | 222 | 482 | 34.4 | 1,604 | 100.0% |
| No. of Species | 12 | 13 | 19 | 14 | 17 | 24 | | 16 | 8 | 18 | | 26 | |
| No. of Collections | 7 | 7 | 7 | 7 | 7 | 35 | | 7 | 7 | 14 | | 49 | |
| No. of Fish/Collection | 35.3 | 34.1 | 22.3 | 25.1 | 43.4 | 32.1 | | 37.1 | 31.7 | 34.4 | | 32.7 | |
| Diversity Index | 1.58 | 1.90 | 1.99 | 2.28 | 1.23 | | | 1.63 | 0.55 | | | | |
| Evenness Index | 0.64 | 0.74 | 0.67 | 0.86 | 0.43 | | | 0.59 | 0.26 | | | | |

Table 5-44. Summary by station of fisheries data collected by 16' Otter Trawl in Conowingo Pond April through October 2011.

| | McClellan's Rock | | | Below Burkins Run | | | | Below PBAPS | | | Broad Creek | | | PBAPS Intake | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Taxon | 331* | 332 | 333 | 381* | 382* | 383 | 384 | 371* | 372 | 373 | 341 | 342 | 343 | 321 | 322 | 323 | Total | % |
| Alewife | * | * | * | * | * | * | * | * | * | * | * | * | * | 1 | * | * | 1 | + |
| **Gizzard shad** | **2** | * | **11** | * | **1** | **16** | **7** | * | **5** | * | **82** | **1** | * | * | **1** | * | **126** | **2.1%** |
| **Spotfin shiner** | **1** | **1** | * | * | **1** | * | **2** | * | * | **2** | **5** | * | * | * | * | * | **12** | **0.2%** |
| Common carp | 4 | 4 | 3 | 1 | 9 | 6 | 7 | 2 | 4 | 1 | 22 | 3 | 4 | 1 | 2 | 5 | 78 | 1.3% |
| Common shiner | * | * | * | * | 1 | * | * | * | * | * | * | * | * | * | * | * | 1 | + |
| Golden shiner | * | * | * | * | * | * | 1 | * | * | * | * | * | * | * | * | * | 1 | + |
| Comely shiner | * | * | 1 | * | 3 | * | 3 | * | 1 | 3 | 7 | * | * | * | 21 | * | 39 | 0.7% |
| Spottail shiner | 25 | 23 | 7 | 48 | 137 | 2 | 164 | 5 | 71 | 82 | 94 | 6 | 1 | 20 | 29 | 50 | 764 | 12.8% |
| Swallowtail shiner | * | * | * | * | * | * | * | * | 2 | * | * | * | * | * | * | * | 2 | + |
| **Bluntnose minnow** | * | **1** | * | * | * | * | **37** | * | * | **1** | **2** | * | * | * | * | * | **41** | **0.7%** |
| Quillback | * | * | * | * | * | * | * | * | * | * | 2 | * | 1 | * | * | * | 3 | 0.1% |
| **White sucker** | * | * | * | * | **1** | * | **1** | * | * | * | * | * | * | * | * | * | **2** | **+** |
| Northern hog sucker | 1 | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | 1 | + |
| Shorthead redhorse | 2 | * | * | 2 | 9 | 1 | 7 | 1 | 1 | * | 5 | * | * | * | * | * | 28 | 0.5% |
| **Channel catfish** | **186** | **139** | **326** | **983** | **629** | **343** | **9** | **29** | **583** | **16** | **112** | **309** | **120** | **449** | **86** | **35** | **4,354** | **73.1%** |
| Flathead catfish | 1 | * | * | * | * | * | * | * | * | * | 3 | * | 1 | * | * | * | 5 | 0.1% |
| Rainbow smelt | * | * | * | * | * | * | * | * | * | 1 | * | * | * | * | * | * | 1 | + |
| White perch | * | * | * | * | 1 | 1 | * | * | 5 | * | * | * | * | 2 | 1 | * | 10 | 0.2% |
| Hybrid Striped bass | * | * | * | * | * | * | * | * | 1 | * | 1 | * | * | * | * | * | 2 | + |
| Redbreast sunfish | * | * | * | * | * | * | * | * | * | * | 1 | * | * | * | * | * | 1 | + |
| Green sunfish | * | * | * | * | * | * | * | * | * | * | 1 | * | * | * | * | * | 1 | + |
| Pumpkinseed | * | * | * | * | * | * | 2 | * | * | * | 1 | * | * | * | * | * | 3 | 0.1% |
| **Bluegill** | * | **1** | **1** | **3** | **7** | **3** | **132** | **1** | **5** | **18** | **149** | **1** | **4** | **6** | * | **9** | **340** | **5.7%** |
| **Smallmouth bass** | * | * | * | **1** | **4** | * | **1** | **1** | **1** | **8** | **4** | * | * | **2** | * | **3** | **25** | **0.4%** |
| **Largemouth bass** | * | * | * | * | * | * | **8** | * | * | **1** | **2** | * | * | * | * | * | **11** | **0.2%** |
| **White crappie** | * | * | * | * | * | * | * | * | * | * | **7** | * | * | * | * | * | **7** | **0.1%** |
| Black crappie | * | * | * | * | * | * | * | * | * | * | 1 | * | * | * | * | * | 1 | + |
| Tessellated darter | 1 | 3 | 1 | 13 | 8 | 1 | 14 | * | 10 | 8 | 6 | 1 | * | 4 | 1 | 2 | 73 | 1.2% |
| Yellow perch | * | * | * | * | * | * | 2 | * | * | 1 | * | 1 | * | * | 1 | * | 5 | 0.1% |
| **Chesapeake logperch** | * | * | * | * | * | * | * | * | * | 1 | * | * | * | * | 1 | * | **2** | **+** |
| Shield darter | * | 1 | 1 | 1 | 3 | * | 1 | * | * | 3 | 1 | * | * | * | * | * | 11 | 0.2% |
| **Walleye** | * | * | * | * | * | **1** | **2** | **1** | * | * | **1** | * | * | * | * | * | **5** | **0.1%** |
| No. of Fish | 223 | 173 | 351 | 1,052 | 814 | 374 | 400 | 40 | 689 | 146 | 509 | 322 | 131 | 485 | 143 | 104 | 5,956 | 99.7% |
| No. of Species | 9 | 8 | 8 | 8 | 14 | 9 | 18 | 7 | 11 | 14 | 21 | 7 | 6 | 8 | 9 | 6 | 31 | |
| No. of Collections | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 112 | |
| No. of Fish/Collection | 31.9 | 24.7 | 50.1 | 150.3 | 116.3 | 53.4 | 57.1 | 5.7 | 98.4 | 20.9 | 72.7 | 46.0 | 18.7 | 69.3 | 20.4 | 14.9 | 53.2 | |
| Fish/10 minute haul | 31.9 | 24.7 | 50.1 | 150.3 | 116.3 | 55.0 | 57.1 | 6.1 | 98.4 | 21.5 | 76.0 | 46.0 | 18.7 | 71.3 | 20.4 | 14.9 | 53.8 | |
| Diversity Index | 0.65 | 0.72 | 0.36 | 0.31 | 0.79 | 0.41 | 1.65 | 1.01 | 0.63 | 1.57 | 1.92 | 0.23 | 0.41 | 0.37 | 1.14 | 1.26 | 1.07 | |
| Evenness Index | 0.30 | 0.35 | 0.18 | 0.15 | 0.30 | 0.19 | 0.57 | 0.52 | 0.26 | 0.59 | 0.63 | 0.12 | 0.23 | 0.18 | 0.52 | 0.70 | 0.31 | |

* Located within the influence of PBAPS thermal effluent.
\+ Less than 0.05%.

Table 5-45. Summary of fisheries data by station collected by boat electrofisher in January, February, and April through October 2012.

| | Non-thermally Affected | | | Total | Number/ | Thermally Affected | | | | Total | Number/ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Taxon | 164 | 165 | 187 | Number | Collection | 161 | 189 | 190 | 217 | Number | Collection | Total | % |
| **Gizzard shad** | **1,160** | **326** | **875** | **2,361** | **87.4** | **1,585** | **386** | **110** | **956** | **3,037** | **84.4** | **5,398** | **20.6%** |
| **Spotfin shiner** | **70** | **12** | **31** | **113** | **4.2** | **101** | **35** | **39** | **16** | **191** | **5.3** | **304** | **1.2%** |
| Common carp | 1 | 14 | 33 | 48 | 1.8 | 38 | 17 | 19 | 20 | 94 | 2.6 | 142 | 0.5% |
| Common shiner | * | * | 1 | 1 | 0.0 | * | * | * | * | 0 | 0.0 | 1 | + |
| Golden shiner | * | 1 | 1 | 2 | 0.1 | 4 | 4 | 14 | 22 | 44 | 1.2 | 46 | 0.2% |
| Comely shiner | 3,486 | 762 | 214 | 4,462 | 165.3 | 58 | 2,215 | 2,338 | 211 | 4,822 | 133.9 | 9,284 | 35.5% |
| Spottail shiner | 10 | 68 | 101 | 179 | 6.6 | 13 | 38 | 25 | 8 | 84 | 2.3 | 263 | 1.0% |
| Rosyface shiner | * | * | * | 0 | 0.0 | 1 | * | * | * | 1 | 0.0 | 1 | + |
| Mimic shiner | * | 3 | * | 3 | 0.1 | * | * | * | * | 0 | 0.0 | 3 | + |
| **Bluntnose minnow** | **9** | **26** | **55** | **90** | **3.3** | **8** | **21** | **45** | **26** | **100** | **2.8** | **190** | **0.7%** |
| Creek chub | 5 | 1 | 3 | 9 | 0.3 | * | 2 | 4 | 3 | 9 | 0.3 | 18 | 0.1% |
| Fallfish | 1 | * | 1 | 2 | 0.1 | * | 3 | 2 | * | 5 | 0.1 | 7 | + |
| Quillback | 1 | * | 2 | 3 | 0.1 | 5 | 1 | * | * | 6 | 0.2 | 9 | + |
| **White sucker** | * | **1** | **8** | **9** | **0.3** | **1** | **4** | **1** | **5** | **11** | **0.3** | **20** | **0.1%** |
| Northern hog sucker | 1 | 2 | 5 | 8 | 0.3 | * | 1 | 1 | 8 | 10 | 0.3 | 18 | 0.1% |
| Shorthead redhorse | 2 | 11 | 101 | 114 | 4.2 | 26 | 9 | * | 79 | 114 | 3.2 | 228 | 0.9% |
| **Channel catfish** | **88** | **140** | **132** | **360** | **13.3** | **199** | **118** | **165** | **173** | **655** | **18.2** | **1,015** | **3.9%** |
| Flathead catfish | 5 | 3 | 8 | 16 | 0.6 | 4 | 5 | 7 | 3 | 19 | 0.5 | 35 | 0.1% |
| Tiger Muskellunge | * | * | * | 0 | 0.0 | 1 | * | * | * | 1 | 0.0 | 1 | + |
| Atlantic needlefish | * | * | * | 0 | 0.0 | 5 | * | * | * | 5 | 0.1 | 5 | + |
| White perch | * | * | 4 | 4 | 0.1 | 19 | 1 | * | * | 20 | 0.6 | 24 | 0.1% |
| Striped bass | * | * | * | 0 | 0.0 | 1 | * | * | * | 1 | 0.0 | 1 | + |
| Hybrid Striped bass | * | * | * | 0 | 0.0 | 26 | 3 | * | * | 29 | 0.8 | 29 | 0.1% |
| Rock bass | 76 | 91 | 65 | 232 | 8.6 | 13 | 26 | 2 | 24 | 65 | 1.8 | 297 | 1.1% |
| Redbreast sunfish | 5 | 1 | 1 | 7 | 0.3 | * | * | 1 | 2 | 3 | 0.1 | 10 | + |
| Green sunfish | 92 | 99 | 11 | 202 | 7.5 | 90 | 48 | 275 | 650 | 1,063 | 29.5 | 1,265 | 4.8% |
| Pumpkinseed | 2 | 2 | 1 | 5 | 0.2 | * | 1 | 1 | 2 | 4 | 0.1 | 9 | + |
| **Bluegill** | **166** | **153** | **110** | **429** | **15.9** | **282** | **157** | **1,467** | **4,443** | **6,349** | **176.4** | **6,778** | **25.9%** |
| **Smallmouth bass** | **101** | **72** | **33** | **206** | **7.6** | **98** | **10** | **28** | **32** | **168** | **4.7** | **374** | **1.4%** |
| **Largemouth bass** | **10** | **2** | **10** | **22** | **0.8** | **21** | **9** | **27** | **66** | **123** | **3.4** | **145** | **0.6%** |
| **White crappie** | **1** | * | * | **1** | **0.0** | **1** | **7** | **1** | **1** | **10** | **0.3** | **11** | + |
| Black crappie | * | 1 | * | 1 | 0.0 | 2 | 1 | * | 3 | 6 | 0.2 | 7 | + |
| Greenside darter | * | * | 1 | 1 | 0.0 | * | * | * | 1 | 1 | 0.0 | 2 | + |
| Tessellated darter | 1 | * | 5 | 6 | 0.2 | * | 3 | 3 | 1 | 7 | 0.2 | 13 | + |
| Yellow perch | * | 1 | 12 | 13 | 0.5 | * | 1 | 4 | 2 | 7 | 0.2 | 20 | 0.1% |
| **Chesapeake logperch** | * | **6** | **15** | **21** | **0.8** | **1** | **2** | **9** | **37** | **49** | **1.4** | **70** | **0.3%** |
| **Walleye** | **13** | **23** | **17** | **53** | **2.0** | **37** | **17** | **4** | **4** | **62** | **1.7** | **115** | **0.4%** |
| No. of Fish | 5,306 | 1,821 | 1,856 | 8,983 | 332.7 | 2,640 | 3,145 | 4,592 | 6,798 | 17,175 | 477.1 | 26,158 | 99.7% |
| No. of Species | 23 | 25 | 29 | 30 | | 25 | 28 | 25 | 27 | 32 | | 35 | |
| No. of Collections | 9 | 9 | 9 | 27 | | 9 | 9 | 9 | 9 | 36 | | 63 | |
| No. of Fish/Collection | 589.6 | 202.3 | 206.2 | 332.7 | | 293.3 | 349.4 | 510.2 | 755.3 | 477.1 | | 415.2 | |
| Diversity Index | 1.63 | 2.80 | 2.91 | | | 2.32 | 1.75 | 1.97 | 1.83 | | | | |
| Evenness Index | 0.36 | 0.60 | 0.60 | | | 0.49 | 0.36 | 0.42 | 0.38 | | | | |

+ Less than 0.05%.

Table 5-46. Summary of fisheries data collected by 10' seine in Conowingo Pond, April through October 2012.

| | Non-thermally Affected | | | | | Total | Number/ | Thermally Affected | | Total | Number/ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Taxon | 203 | 202 | 208 | 221 | 220 | Number | Collection | 214 | 215 | Number | Collection | Total | % |
| **Gizzard shad** | **3** | * | * | * | **1** | **4** | **0.1** | * | * | **0** | **0.0** | **8** | **0.3%** |
| Rosyside dace | * | * | * | * | * | 0 | 0.0 | **8** | * | 8 | 0.6 | 8 | 0.3% |
| **Spotfin shiner** | **64** | **55** | **83** | **11** | **170** | **383** | **10.9** | **279** | **138** | **417** | **29.8** | **1,194** | **41.9%** |
| Cutlips minnow | * | * | * | * | 1 | 1 | 0.0 | * | * | 0 | 0.0 | 2 | 0.1% |
| River chub | 2 | * | * | * | * | 2 | 0.1 | * | * | 0 | 0.0 | 4 | 0.1% |
| Comely shiner | 6 | 10 | 3 | 15 | 23 | 57 | 1.6 | 15 | 11 | 26 | 1.9 | 142 | 5.0% |
| Spottail shiner | 80 | 32 | 8 | 46 | 47 | 213 | 6.1 | 7 | 12 | 19 | 1.4 | 451 | 15.8% |
| Swallowtail shiner | 1 | * | * | * | * | 1 | 0.0 | * | * | 0 | 0.0 | 2 | 0.1% |
| **Bluntnose minnow** | **15** | **26** | **6** | **69** | **77** | **193** | **5.5** | **19** | **25** | **44** | **3.1** | **436** | **15.3%** |
| Creek chub | * | * | * | * | * | 0 | 0.0 | 2 | * | 2 | 0.1 | 2 | 0.1% |
| Fallfish | * | 2 | * | * | 1 | 3 | 0.1 | 3 | 1 | 4 | 0.3 | 10 | 0.4% |
| Quillback | 6 | 1 | * | * | * | 7 | 0.2 | * | * | 0 | 0.0 | 14 | 0.5% |
| **White sucker** | * | * | * | **3** | **1** | **4** | **0.1** | * | * | **0** | **0.0** | **8** | **0.3%** |
| Northern hog sucker | 2 | 1 | 2 | 1 | 8 | 14 | 0.4 | * | * | 0 | 0.0 | 28 | 1.0% |
| Shorthead redhorse | 1 | * | * | * | 1 | 2 | 0.1 | * | * | 0 | 0.0 | 4 | 0.1% |
| Banded killifish | * | * | 22 | 41 | 2 | 65 | 1.9 | * | * | 0 | 0.0 | 132 | 4.6% |
| Hybrid striped bass | * | * | * | * | * | 0 | 0.0 | 1 | * | 1 | 0.1 | 1 | 0.0% |
| Rock bass | * | * | 1 | * | 5 | 6 | 0.2 | * | * | 0 | 0.0 | 12 | 0.4% |
| Redbreast sunfish | * | * | * | * | * | 0 | 0.0 | 1 | * | 1 | 0.1 | 1 | 0.0% |
| Green sunfish | * | * | 3 | * | 3 | 6 | 0.2 | 3 | 9 | 12 | 0.9 | 24 | 0.8% |
| **Bluegill** | * | **9** | **11** | **2** | **27** | **49** | **1.4** | **8** | **51** | **59** | **4.2** | **158** | **5.6%** |
| **Smallmouth bass** | **1** | **1** | * | * | **2** | **4** | **0.1** | * | **1** | **1** | **0.1** | **9** | **0.3%** |
| Greenside darter | * | * | 1 | * | * | 1 | 0.0 | * | * | 0 | 0.0 | 2 | 0.1% |
| Tessellated darter | 12 | 25 | 21 | 22 | 4 | 84 | 2.4 | 10 | * | 10 | 0.7 | 180 | 6.3% |
| **Chesapeake logperch** | * | * | * | **4** | **4** | **8** | **0.2** | * | **1** | **1** | **0.1** | **17** | **0.6%** |
| No. of Fish | 193 | 162 | 161 | 214 | 377 | 1,107 | 31.6 | 356 | 249 | 605 | 43.2 | 2,851 | 100.0% |
| No. of Species | 12 | 10 | 11 | 10 | 17 | 20 | | 11 | 9 | 13 | | 24 | |
| No. of Collections | 7 | 7 | 7 | 7 | 7 | 35 | | 7 | 7 | 14 | | 49 | |
| No. of Fish/Collection | 27.6 | 23.1 | 23.0 | 30.6 | 53.9 | 31.6 | | 50.9 | 35.6 | 43.2 | | 58.2 | |
| Diversity Index | 2.25 | 2.52 | 2.31 | 2.58 | 2.47 | | | 1.40 | 1.95 | | | | |
| Evenness | 0.63 | 0.76 | 0.67 | 0.78 | 0.60 | | | 0.39 | 0.62 | | | | |

Table 5-47. Summary by station of fisheries data collected by 16' Otter Trawl in Conowingo Pond April through October 2012.

| | McClellan's Rock | | | Below Burkins Run | | | | Below PBAPS | | | Broad Creek | | | PBAPS Intake | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Taxon | 331* | 332 | 333 | 381* | 382* | 383 | 384 | 371* | 372 | 373 | 341 | 342 | 343 | 321 | 322 | 323 | Total | % |
| **Gizzard shad** | **3** | **1,088** | **84** | **8** | **170** | **274** | **125** | * | **93** | **950** | **29** | **15** | **102** | **28** | **6** | **11** | **2,986** | **46.0%** |
| **Spotfin shiner** | * | * | * | **1** | * | * | * | **3** | * | * | * | * | * | * | **12** | * | **16** | **0.2%** |
| Common carp | 1 | 9 | 17 | 8 | 5 | 1 | * | 1 | 5 | 6 | 3 | 1 | 3 | 4 | 4 | 7 | 75 | 1.2% |
| Comely shiner | * | * | * | * | * | * | 3 | * | * | 1 | 2 | * | * | * | * | * | 6 | 0.1% |
| Spottail shiner | * | 4 | * | * | 40 | 1 | 26 | 1 | 16 | 10 | 95 | 1 | * | 13 | 6 | 2 | 215 | 3.3% |
| Swallowtail shiner | * | * | * | * | 2 | * | * | * | 1 | * | * | * | * | * | * | * | 3 | + |
| **Bluntnose minnow** | * | * | * | * | * | * | **8** | * | **5** | **1** | **1** | * | * | * | * | * | **15** | **0.2%** |
| Quillback | * | * | * | * | * | * | * | 1 | * | * | 1 | * | * | * | * | * | 2 | + |
| **White sucker** | * | * | * | * | * | * | * | * | **1** | **3** | **3** | * | * | * | * | * | **7** | **0.1%** |
| Shorthead redhorse | * | 1 | 1 | * | 3 | * | 2 | * | 4 | 1 | 2 | * | * | 3 | * | * | 17 | 0.3% |
| **Channel catfish** | **45** | **361** | **219** | **367** | **103** | **34** | **52** | **90** | **56** | **28** | **24** | **42** | **169** | **94** | **36** | **14** | **1,734** | **26.7%** |
| Flathead catfish | 2 | 1 | 2 | * | * | * | * | * | * | 1 | 2 | 1 | * | * | * | * | 9 | 0.1% |
| White perch | * | 3 | 1 | * | * | 1 | * | * | 30 | * | * | * | 2 | 1 | * | * | 38 | 0.6% |
| Green sunfish | * | * | * | * | * | * | * | * | * | * | 3 | * | * | * | * | * | 3 | + |
| Pumpkinseed | * | * | * | * | * | * | 1 | * | * | * | * | * | * | * | * | * | 1 | + |
| **Bluegill** | * | * | **58** | **64** | **10** | **12** | **439** | **5** | **45** | **166** | **416** | **10** | **6** | **8** | **10** | **5** | **1,254** | **19.3%** |
| **Smallmouth bass** | * | * | * | * | **1** | * | **4** | * | * | **1** | **2** | * | * | * | * | * | **8** | **0.1%** |
| **Largemouth bass** | * | * | * | * | * | * | **1** | * | * | * | **2** | * | * | * | * | * | **3** | + |
| **White crappie** | * | * | **1** | * | * | * | * | * | * | * | * | * | * | * | * | * | **1** | + |
| Tessellated darter | 3 | 8 | 1 | 2 | 9 | 6 | 4 | 3 | 19 | 1 | 8 | 9 | * | 2 | * | 8 | 83 | 1.3% |
| Yellow perch | * | * | * | * | * | * | 2 | * | * | * | 1 | * | * | * | * | * | 3 | + |
| **Chesapeake logperch** | * | * | * | * | * | * | * | * | * | * | * | 1 | * | * | * | * | 1 | + |
| **Walleye** | * | * | **1** | * | * | **1** | * | * | * | * | * | * | * | **1** | **1** | **2** | **6** | **0.1%** |
| No. of Fish | 54 | 1,475 | 385 | 450 | 343 | 330 | 667 | 104 | 275 | 1,169 | 594 | 80 | 282 | 154 | 75 | 49 | 6,486 | 99.7% |
| No. of Species | 5 | 8 | 10 | 6 | 9 | 8 | 12 | 7 | 11 | 12 | 16 | 8 | 5 | 9 | 7 | 7 | 23 | |
| No. of Collections | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 112 | |
| No. of Fish/Collection | 7.7 | 210.7 | 55.0 | 64.3 | 49.0 | 47.1 | 95.3 | 14.9 | 39.3 | 167.0 | 84.9 | 11.4 | 40.3 | 22.0 | 10.7 | 7.0 | 57.9 | |
| Fish/10 minute haul | 7.7 | 216.9 | 55.0 | 64.3 | 49.0 | 47.1 | 95.3 | 17.0 | 39.3 | 167.0 | 84.9 | 11.4 | 40.3 | 23.3 | 11.0 | 7.0 | 58.8 | |
| Diversity Index | 0.97 | 0.96 | 1.70 | 0.90 | 2.14 | 0.94 | 1.60 | 0.88 | 2.64 | 0.94 | 1.57 | 1.99 | 1.21 | 1.83 | 2.21 | 2.54 | 1.99 | |
| Evenness Index | 0.42 | 0.32 | 0.51 | 0.35 | 0.67 | 0.31 | 0.45 | 0.31 | 0.76 | 0.26 | 0.39 | 0.66 | 0.52 | 0.58 | 0.79 | 0.91 | 0.44 | |

* Located within the influence of PBAPS thermal effluent.
+ Less than 0.05%.

Table 5-48. Summary of fisheries data by station collected by boat electrofisher in January, March, and April through October 2013

| | Non-thermally Affected | | | Total | Number/ | Thermally Affected | | | | Total | Number/ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Taxon | 164 | 165 | 187 | Number | Collection | 161 | 189 | 190 | 217 | Number | Collection | Total | % |
| **Gizzard shad** | **85** | **55** | **116** | **256** | **9.5** | **1,988** | **92** | **165** | **539** | **2,784** | **77.3** | **3,040** | **19.6%** |
| **Spotfin shiner** | **121** | **16** | **158** | **295** | **10.9** | **253** | **119** | **110** | **17** | **499** | **13.9** | **794** | **5.1%** |
| Grass carp | * | * | * | 0 | 0.0 | 1 | * | * | * | 1 | 0.0 | 1 | + |
| Common carp | 2 | 6 | 13 | 21 | 0.8 | 67 | 6 | 9 | 4 | 86 | 2.4 | 107 | 0.7% |
| Golden shiner | * | 1 | * | 1 | 0.0 | 2 | 2 | 3 | 12 | 19 | 0.5 | 20 | 0.1% |
| Comely shiner | 362 | 212 | 286 | 860 | 31.9 | 325 | 114 | 318 | 199 | 956 | 26.6 | 1,816 | 11.7% |
| Spottail shiner | 26 | 37 | 173 | 236 | 8.7 | 12 | 70 | 14 | 36 | 132 | 3.7 | 368 | 2.4% |
| Swallowtail shiner | * | * | 1 | 1 | 0.0 | * | * | * | 1 | 1 | 0.0 | 2 | + |
| Mimic shiner | * | * | 2 | 2 | 0.1 | * | * | * | * | 0 | 0.0 | 2 | + |
| **Bluntnose minnow** | **67** | **198** | **182** | **447** | **16.6** | **51** | **100** | **279** | **112** | **542** | **15.1** | **989** | **6.4%** |
| Creek chub | 1 | * | 1 | 2 | 0.1 | * | 5 | 4 | * | 9 | 0.3 | 11 | 0.1% |
| Fallfish | * | * | * | 0 | 0.0 | 1 | 2 | * | 1 | 4 | 0.1 | 4 | + |
| Quillback | * | 3 | * | 3 | 0.1 | 1 | * | * | * | 1 | 0.0 | 4 | + |
| **White sucker** | * | * | **1** | **1** | **0.0** | * | * | * | **2** | **2** | **0.1** | **3** | + |
| Northern hogsucker | * | * | 3 | 3 | 0.1 | * | * | * | 1 | 1 | 0.0 | 4 | + |
| Shorthead redhorse | 4 | 12 | 178 | 194 | 7.2 | 32 | 14 | 1 | 52 | 99 | 2.8 | 293 | 1.9% |
| **Channel catfish** | **110** | **129** | **146** | **385** | **14.3** | **94** | **149** | **177** | **122** | **542** | **15.1** | **986** | **6.4%** |
| Flathead catfish | 8 | 5 | 3 | 16 | 0.6 | 13 | 9 | 1 | 1 | 24 | 0.7 | 40 | 0.3% |
| Muskellunge | * | * | * | 0 | 0.0 | * | 1 | * | * | 1 | 0.0 | 1 | + |
| Brown trout | * | 1 | * | 1 | 0.0 | * | 1 | * | * | 1 | 0.0 | 2 | 0.0% |
| Banded killifish | 4 | 4 | 6 | 14 | 0.5 | 1 | 1 | 1 | 1 | 4 | 0.1 | 18 | 0.1% |
| White perch | * | 1 | 19 | 20 | 0.7 | 26 | 2 | * | * | 28 | 0.8 | 48 | 0.3% |
| Striped bass x white bass | * | * | * | 0 | 0.0 | 5 | * | * | * | 5 | 0.1 | 5 | + |
| Rock bass | 95 | 121 | 111 | 327 | 12.1 | 13 | 36 | 3 | 32 | 84 | 2.3 | 411 | 2.6% |
| Redbreast sunfish | 7 | 1 | 1 | 9 | 0.3 | 4 | * | * | * | 4 | 0.1 | 13 | 0.1% |
| Green sunfish | 174 | 172 | 34 | 380 | 14.1 | 279 | 186 | 593 | 221 | 1,279 | 35.5 | 1,659 | 10.7% |
| Pumpkinseed | 5 | 3 | 2 | 10 | 0.4 | 4 | * | 1 | 4 | 9 | 0.3 | 19 | 0.1% |
| **Bluegill** | **226** | **294** | **253** | **773** | **28.6** | **474** | **369** | **492** | **899** | **2,234** | **62.1** | **3,007** | **19.4%** |
| **Smallmouth bass** | **273** | **141** | **142** | **556** | **20.6** | **186** | **67** | **130** | **128** | **511** | **14.2** | **1,067** | **6.9%** |
| **Largemouth bass** | **12** | **2** | **13** | **27** | **1.0** | **37** | **23** | **25** | **34** | **119** | **3.3** | **146** | **0.9%** |
| **White crappie** | * | **3** | **5** | **8** | **0.3** | **5** | **6** | **1** | **2** | **14** | **0.4** | **22** | **0.1%** |
| Black crappie | * | * | * | 0 | 0.0 | 7 | 2 | * | * | 9 | 0.3 | 9 | 0.1% |
| Greenside darter | 1 | 5 | * | 6 | 0.2 | 3 | 1 | 4 | 11 | 19 | 0.5 | 25 | 0.2% |
| Tessellated darter | 5 | 9 | 20 | 34 | 1.3 | 1 | 10 | 15 | 33 | 59 | 1.6 | 93 | 0.6% |
| Yellow perch | 6 | 11 | 60 | 77 | 2.9 | * | 9 | 3 | 9 | 21 | 0.6 | 98 | 0.6% |
| **Chesapeake logperch** | **8** | **70** | **70** | **148** | **5.5** | **16** | **6** | **42** | **95** | **159** | **4.4** | **369** | **2.4%** |
| Shield darter | * | 17 | 2 | 19 | 0.7 | * | 2 | 1 | 11 | 14 | 0.4 | 33 | 0.2% |
| **Walleye** | **15** | **12** | **40** | **67** | **2.5** | **14** | **7** | **14** | **7** | **42** | **1.2** | **109** | **0.7%** |
| No. of Fish | 1,617 | 1,541 | 2,041 | 5,199 | 192.6 | 3,915 | 1,411 | 2,406 | 2,586 | 10,318 | 286.6 | 15,517 | 100.6% |
| No. of Species | 23 | 28 | 29 | 38 | | 29 | 29 | 25 | 28 | 38 | | 38 | |
| No. of collections | 9 | 9 | 9 | 27 | | 9 | 9 | 9 | 9 | 36 | | 63 | |
| No. of fish/Collection | 179.7 | 171.2 | 226.8 | 192.6 | | 435.0 | 156.8 | 267.3 | 287.3 | 286.6 | | 246.3 | |
| Diversity Index | 3.33 | 3.53 | 3.85 | | | 2.61 | 3.48 | 3.11 | 3.09 | | | | |
| Eveness | 0.74 | 0.73 | 0.79 | | | 0.54 | 0.72 | 0.67 | 0.64 | | | | |

+ Less than 0.05%.

Table 5-49. Summary of fisheries data collected by 10' seine in Conowingo Pond, April through October 2013.

| | Non-thermally Affected | | | | | Total | Number/ | Thermally Affected | | Total | Number/ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station No. | 202 | 203 | 208 | 220 | 221 | Number | Collection | 214 | 215 | Number | Collection | Total | % |
| **Gizzard shad** | * | * | * | 4 | * | 4 | 0.1 | * | * | 0 | 0.0 | 4 | 0.1% |
| **Spotfin shiner** | 67 | 50 | 45 | 120 | 12 | 294 | 8.4 | 135 | 151 | 286 | 20.4 | 580 | 20.9% |
| Central stoneroller | * | * | * | * | 1 | 1 | 0.0 | 2 | * | 2 | 0.1 | 3 | 0.1% |
| Comely shiner | 38 | 27 | 4 | 10 | 26 | 105 | 3.0 | 13 | 5 | 18 | 1.3 | 123 | 4.4% |
| Common shiner | * | * | * | * | 1 | 1 | 0.0 | 22 | * | 22 | 1.6 | 23 | 0.8% |
| Spottail shiner | 114 | 82 | 6 | 63 | 92 | 357 | 10.2 | 5 | 15 | 20 | 1.4 | 377 | 13.6% |
| Swallowtail shiner | 2 | * | * | * | * | 2 | 0.1 | * | * | 0 | 0.0 | 2 | 0.1% |
| **Bluntnose minnow** | 66 | 64 | 68 | 79 | 156 | 433 | 12.4 | 42 | 22 | 64 | 4.6 | 497 | 17.9% |
| Blacknose dace | * | * | * | * | * | 0 | 0.0 | 1 | * | 1 | 0.1 | 1 | + |
| Creek chub | * | 1 | * | * | * | 1 | 0.0 | * | * | 0 | 0.0 | 1 | + |
| Quillback | 4 | 11 | 2 | 2 | 3 | 22 | 0.6 | * | * | 0 | 0.0 | 22 | 0.8% |
| **White sucker** | 1 | 2 | 2 | * | 94 | 99 | 2.8 | * | * | 0 | 0.0 | 99 | 3.6% |
| Northern hogsucker | * | 1 | * | 4 | 1 | 6 | 0.2 | * | * | 0 | 0.0 | 6 | 0.2% |
| Shorthead redhorse | 3 | * | * | 1 | * | 4 | 0.1 | * | 1 | 1 | 0.1 | 5 | 0.2% |
| Channel catfish | * | * | * | * | 3 | 3 | 0.1 | * | 1 | 1 | 0.1 | 4 | 0.1% |
| Banded killifish | 9 | 18 | 51 | 3 | 314 | 395 | 11.3 | 218 | * | 218 | 15.6 | 613 | 22.1% |
| White perch | * | * | * | * | * | 0 | 0.0 | 1 | * | 1 | 0.1 | 1 | + |
| Rock bass | 1 | * | 1 | 4 | * | 6 | 0.2 | * | * | 0 | 0.0 | 6 | 0.2% |
| Green sunfish | * | * | 14 | 4 | * | 18 | 0.5 | 1 | * | 1 | 0.1 | 19 | 0.7% |
| **Bluegill** | 117 | 1 | 29 | 69 | 1 | 217 | 6.2 | 19 | 3 | 22 | 1.6 | 239 | 8.6% |
| **Smallmouth bass** | 10 | 6 | 9 | 11 | 3 | 39 | 1.1 | 4 | 14 | 18 | 1.3 | 57 | 2.1% |
| **Largemouth bass** | * | * | 2 | 1 | * | 3 | 0.1 | * | * | 0 | 0.0 | 3 | 0.1% |
| Greenside darter | * | * | 2 | * | * | 2 | 0.1 | * | * | 0 | 0.0 | 2 | 0.1% |
| Tessellated darter | 6 | 5 | 14 | 6 | 10 | 41 | 1.2 | 3 | 3 | 6 | 0.4 | 47 | 1.7% |
| Yellow perch | 3 | 1 | * | 1 | * | 5 | 0.1 | * | * | 0 | 0.0 | 5 | 0.2% |
| **Chesapeake logperch** | 1 | * | 8 | 19 | 1 | 29 | 0.8 | 1 | * | 1 | 0.1 | 30 | 1.1% |
| Shield darter | * | * | 5 | * | 1 | 6 | 0.2 | * | * | 0 | 0.0 | 6 | 0.2% |
| No. of fish | 442 | 269 | 262 | 401 | 719 | 2,093 | | 467 | 215 | 682 | | 2,775 | 100 |
| No. of species | 15 | 13 | 16 | 17 | 16 | 27 | | 14 | 9 | 27 | | 27 | |
| No. of Collections | 7 | 7 | 7 | 7 | 7 | 35 | | 7 | 7 | 14 | | 49 | |
| No. of fish/Collection | 63.1 | 38.4 | 37.4 | 57.3 | 102.7 | 59.8 | | 66.7 | 30.7 | 48.7 | | 56.6 | |
| Diversity Index | 2.71 | 2.82 | 3.04 | 2.79 | 2.30 | | | 1.99 | 1.62 | | | | |
| Eveness | 0.69 | 0.81 | 0.78 | 0.71 | 0.57 | | | 0.54 | 0.54 | | | | |

+ Less than 0.05%.

*Fish Metrics and CPUE*

Comparison of 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. No analysis is provided for the trawl collections; the rationale for this decision was discussed previously.

For this analysis stations are discussed as either non-thermal or thermal 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. Stations that are upstream of the PBAPS thermal discharge that experience natural water temperature conditions are considered non-thermal (Figure 5-22 to Figure 5-24; Table 5-12 to Table 5-14). Electrofishing Stations 161, 189, 190, and 217 are considered thermally influenced and Stations 187, 164, and 165 are considered non-thermal. Seine Stations 214 and 215 are considered thermally influenced and Stations 203, 202, 220, 221, and 208 are considered non-thermal. As previously discussed in Section 5.2, 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.

Monthly metric values were compared among locations to determine if statistical differences existed between individuals stations. A total of five metrics were calculated including overall CPUE, species richness, RIS richness, Shannon diversity, and evenness. Differences in metrics values among stations were assessed using the nonparametric Kruskal-Wallis test. This nonparametric test was selected for these analyses rather than the analogous parametric ANOVA test because not all test groups met the assumptions of equal variances, normal distribution, and equal sample size among the stations. The nonparametric test was used for all analyses to streamline statistical analysis among the test metrics.

Mean CPUE by month is provided for several RIS collected using both seine and electrofishing. Species that were collected in low numbers for a specific gear type were excluded from analysis because insufficient numbers of individuals were collected to make meaningful comparisons among stations or months. Catch results for White Sucker and White Crappie were not included for either gear type because insufficient numbers of individuals were collected to make meaningful comparisons among stations or months for either gear type.

A two-way analysis of variance (ANOVA) was performed on electrofishing data collected from July through October 2010-2013 to detect differences in the CPUE between stations and years. The analysis was conducted on several of the RIS: Gizzard Shad, Spotfin Shiner, Smallmouth Bass, Channel Catfish, and Bluegill. Other designated RIS were collected sporadically throughout the period and, because of sporadic collection, it was judged that statistical analysis

would not provide useful information for them. Data from the seine sampling was similarly treated due to low numbers collected and/or collections where no fish were taken.

Indices of diversity and evenness were calculated to describe fish community structure. Species diversity (D) was calculated by the Shannon-Weaver (1948) method using the formula:

$$D = -\sum_{i=1}^{s} P_i \operatorname{Log}_2 P_i$$

Where:

D is the species diversity index,

S is the total number of species collected, and

$P_i$ is the proportion of a species in the sample.

Since the number of species varies between stations and months, an index of evenness was also calculated using the formula (Pielou 1966):
$E = H'/H'_{max}$

Where:
H' is the diversity and $H'_{max}$ is the log of the number of taxa.

Evenness values have a range from 0 to 1.0, with 1.0 being the maximum equality for a community.

*Electrofishing Results*

Five metrics were calculated to provide a description of the fish community among stations and across monthly collections in Conowingo Pond from April to October 2010-2013. Figure 5-42 through Figure 5-46 provide box plots which illustrate the spread of metric values among stations. Table 5-50 through Table 5-54 provide mean and median values for each metric among the stations. Square root transformed mean CPUE was similar among stations with highest CPUE observed at Station 217 (Table 5-50). Station 217 median CPUE was significantly higher ($p<0.05$) than Station 165 (non-thermal) and Station 189 (thermal). Otherwise, CPUE was similar among stations. Species richness was similar among stations with mean values ≥12 for all stations. Generally the highest richness values were observed at Station 187 (non-thermal) and Station 217 (thermal) with median richness values for several stations significantly different ($p<0.05$) from these two stations (Table 5-51). Similar to species richness, RIS richness was highest at Stations 187 and 217. RIS richness for Stations 187 and 217 was significantly different ($p<0.05$) from several stations (Table 5-52). Shannon diversity values were highest at Station 187 with this station scores being significantly different ($p<0.05$) than Stations 164, 161, 190, and 217. The lowest Shannon diversity mean and median values

were observed at Station 161. Similar to Shannon diversity, evenness values were highest for Station 187 with this station being significantly different ($p<0.05$) than Stations 217 and 161 (Table 5-54). Other significant differences in median evenness values were observed between other non-thermal and thermal stations.

Seasonal Patterns

Figure 5-47 through Figure 5-51 provide box plots which graphically illustrate the spread, central tendency, and distribution of the five metrics by station for each monthly collection. Square root transformed CPUE was variable among stations and months with most catches between 100-900 fish/0.5hr. No obvious patterns were related to location, within or outside of the thermal plume during the course of the field season. Species richness was quite variable depending on month of collection (Figure 5-48). For most stations species richness increased over the course of the season with highest richness observed during September and October. Station 161 richness was lower in July; roughly 5-10 fewer species were observed during this month compared to other months. RIS richness ranged generally from 5 to 9 species per month for all stations. No well-defined seasonal patterns were evident (Figure 5-49). Similar to species richness, RIS richness at Station 161 was lowest in July. Shannon diversity values were quite variable among stations and months (Figure 5-50). Shannon diversity was generally highest from August through October for most stations. Similar to Shannon diversity, evenness was variable among stations and months and generally ranged between 0.5 and 0.9 (Figure 5-51). Station 161 exhibited variable evenness among months with the highest values in June and October, and much lower values in April. During other months evenness was variable at this station.

RIS CPUE

Mean electrofishing CPUE by station and month for the RIS is provided in Table 5-55 through Table 5-63. Mean CPUE for most RIS varied widely between stations and collection month including Gizzard Shad, Spotfin Shiner, Channel Catfish, Bluntnose Minnow, Bluegill, and Smallmouth Bass. CPUE was generally low for Largemouth Bass, Chesapeake Logperch, and Walleye. Gizzard Shad mean CPUE was highest in July and August for most stations. This is likely due to large numbers of YOY growing to sufficient size to be collected with electrofishing gear (recruited to the gear). Gizzard Shad mean CPUE was low for all months at Station 165 (non-thermal) and highest at Station 161 (thermal). Spotfin Shiner catch was lowest for Stations 165 and 217. No seasonal patterns were observed among the stations for this species. Higher catch rates were observed at Station 161 and Station 189 during May and June and Stations 164 and 187 in June and July. CPUE for Bluntnose Minnow showed no distinct patterns among stations or collection months. The highest mean CPUE for this species was observed at Station 190 in May. Channel Catfish CPUE was similar among stations and collection month. No specific patterns were observed for this species. Bluegill CPUE generally was highest during August through October. The highest overall CPUE was observed at Stations 217 and 190, both thermally influenced. Smallmouth Bass CPUE was variable among stations and collection month. CPUE was highest in September and October for Stations 164, 165, and 161 and highest in July for Stations 190 and 217. Largemouth Bass CPUE was generally low for all

stations, and in particular, for the non-thermal stations during April through August. Seasonal patterns in Largemouth Bass distribution were clearly evident with high CPUE observed in September and October for Stations 189, 190, and 217. Chesapeake Logperch CPUE was low for all stations and most months. The highest catch rates occurred at Station 217 in August and September and at Station 187 during August through October. Walleye CPUE was fairly low for most stations from April to August. Seasonal patterns of higher Walleye catch rates were observed during October for all stations except Station 190 which had highest CPUE during April.

The results of the ANOVA performed on the electrofishing CPUE for select RIS showed significant differences ($p < 0.1$) for several species between years, stations, and for station and year interaction. Gizzard Shad CPUE was significantly different across years with low CPUE in 2013 compared to the other years. No significant differences were observed for Gizzard Shad catch among stations or when accounting for station and year interaction. Smallmouth Bass CPUE was significantly different among years with higher catch in 2013 compared to previous years and with significantly different catches observed for several stations. CPUE tended to be higher for Stations 161, 164, 165, and 217. Bluegill CPUE was significantly different among years, stations, and for station and year interaction. Higher Bluegill CPUE was observed during 2012 and 2013 at Stations 190 and 217. Spotfin Shiner and Channel Catfish CPUE were not significantly different among years or stations. Although statistically significant differences were observed, the variation observed between years and stations was likely due to the natural variation inherent in the species' populations and variation in environmental conditions within Conowingo Pond.

Winter Metrics

Winter electrofishing was completed during 2011 through 2013 to document seasonal differences in fish community composition. A total of five collections were completed at each station in January 2011 and 2013, February 2011 and 2012, and March 2013. Five metrics were calculated to characterize fish community during this season. CPUE was variable among months with highest catch observed at non-thermal Station 164 (Table 5-64). Species richness was highest each month for thermally influenced Station 161, where typically five or more additional species were collected as compared to the non-thermal stations (Table 5-65). In addition, for each station more species were collected during March than in the other months. Similar to species richness, RIS richness was high at Station 161 for each month of winter collections (Table 5-66). RIS richness was also high at thermally influenced Station 189 during January and March. Shannon diversity values were highest at Station 161 for each month and also high at Station 189 for January and March (Table 5-67). Low Shannon diversity values were observed at Station 164. Similar to Shannon diversity, evenness was high at Station 161 during each month and low at Station 164 for each month (Table 5-68). Table 5-69 provides winter CPUE of Gizzard Shad. Gizzard Shad catch was low for most stations and months with the highest catch observed at thermal Station 161 in February and March and Station 189 in January.

*Seine Results*

Five metrics were calculated to provide a description of the fish community among stations and across monthly collections in Conowingo Pond from April to October 2010-2013. Figure 5-52 through Figure 5-56 provide box plots which illustrate the spread of metric values among stations. Table 5-70 through Table 5-74 provide mean and median values for each metric among the stations. Square root transformed mean CPUE was similar among stations with highest CPUE observed at Station 220 (Table 5-70). Station 220 median CPUE was significantly higher (p=0.1) than CPUE at Station 221 (non-thermal). Otherwise, CPUE was similar among stations. Species richness was similar among stations with mean values greater than five species for all stations except Station 215 (thermal). Generally the highest richness values were observed at Station 220 (non-thermal) with only thermally affected Station 215 significantly different (p=0.05) from Station 220 (Table 5-71). Similar to species richness, mean RIS richness was highest at Station 220. No significant differences in RIS richness were observed among the stations (Table 5-72). Shannon diversity values were similar for most stations with median values at Station 221 (non-thermal) being significantly different (p = 0.09) than Station 215 (thermal) (Table 5-73). Evenness values were comparable among stations with no significant differences observed (Table 5-74).

Seasonal Patterns

Figure 5-57 through Figure 5-61 provide box plots which graphically illustrate the spread, central tendency, and distribution of the five metrics by station for each monthly collection. Square root transformed CPUE was variable among stations and months with most catches between 16-64 fish/collection. No obvious patterns were observed related to location within or outside of the thermal plume during the course of the field season. Species richness was quite variable depending on month of collection. For most stations species richness showed no distinct pattern over the course of the field season; however, species richness tended to be higher for several stations in August. At thermally influenced Stations 214 and 215 richness was lower in July and/or August when roughly one to three fewer species were observed as compared to other months. RIS richness usually ranged from one to four species per month for all stations with RIS richness typically lowest in April. Shannon diversity values were quite variable among stations and months with widely varied interquartile ranges. Shannon diversity was generally lower at Stations 214 and 215 during June and July compared to other months at these locations. Similar to Shannon diversity, evenness was variable among stations and months and generally ranged between 0.5 and 0.8. The interquartile range varied widely among months and stations.

RIS CPUE

Mean seine CPUE by station and month for select RIS is provided in Table 5-75 through Table 5-79. Many of the RIS are usually not collected using a seine and were not included in this analysis. Spotfin Shiner and Bluntnose Minnow were the most common and consistently collected species among stations and months. Spotfin Shiner mean CPUE was generally the highest for most stations from July through October. Mean CPUE for this species was similar at the thermal stations (Stations 214 and 215) and at the non-thermal stations. No reduction in

Spotfin Shiner CPUE was observed during July or August. Bluntnose Minnow mean CPUE was variable among stations and months. CPUE for Bluntnose Minnow showed no distinct patterns among stations. Additionally, no reduction in CPUE was observed during July or August at the two thermal stations. Bluegill mean CPUE varied widely among stations and months with the highest catches observed during August and September. Smallmouth Bass CPUE was generally low for all stations and months with no discernable pattern related to location or month of collection. Similar to Smallmouth Bass, Chesapeake Logperch CPUE was low for all stations and most months. The highest catch rates occurred at Station 220 in July and August.

*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 and in some years during August. 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. This avoidance was of short duration given that community metrics improved at this station during the subsequent months (August through October). Patterns of avoidance were not readily apparent from the monthly metric values for the other thermally affected electrofishing stations. However, Shannon diversity and evenness values tended to vary more widely at the thermal stations as compared to the non-thermal stations.

On the whole (across all months) the fish community diversity and relative abundance was similar regardless of collection location. Specific locations (i.e. Stations 187 and 217) tended to have greater diversity, likely related to greater habitat diversity or habitat preference. However, the avoidance observed at the near-field station was of short duration followed by greater numbers of species being collected in subsequent months. Community heterogeneity and relative abundance of the RIS was comparable during all months but July and August at Station 161. In fact, community heterogeneity was higher at Station 161 during January through March compared to all other stations. A cyclical pattern was observed, but not a substantial reduction in community heterogeneity at Station 161 as compared to the other stations.

Fewer species were collected by seine than were taken by electrofishing. The RIS CPUE for seine collections did not reveal any apparent patterns among the stations or related to month of collection with the exception of Stations 214 and 215. Several metric values indicated a pattern of lower values during June and July at thermally influenced seine Stations 214 and 215, which experienced elevated water temperatures that are typically highest in July. Species richness, Shannon diversity, and evenness values were lower at these stations during June and/or July indicating potential avoidance of these areas during at least one year of the study.

For both electrofishing and seining collections, metric values and RIS CPUE were useful in evaluating differences in the fish community and relative abundance of RIS 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 in July where for each year of the study five to ten fewer species were collected as compared to other months. Avoidance was also observed at seine Stations 214 and 215 during June and/or July for in at least one year of the study. RIS CPUE for both electrofishing and seining varied widely across stations and months and did not reveal any discernable patterns of lower catches during the summer months at Stations 161, 214, or 215. Although avoidance occurred at these locations, community composition quickly rebounded in subsequent months when water temperatures decreased and fish repopulated these areas. No long-term avoidance or loss of community structure was observed at the electrofishing or seine stations.

In contrast to summer avoidance, winter electrofishing indicated that fish appeared to be attracted to the warmer temperatures at Station 161. High species richness was observed at this station compared to the other thermal and non-thermally influenced locations.

*Gizzard Shad Potential as Nuisance Species*

Gizzard Shad is native to the Atlantic and Gulf slopes and to interior drainages of eastern and central North America (Jenkins and Burkhead 1994). The lower Susquehanna River likely represented the historic northern-most range of this species. In 1972 Gizzard Shad was introduced into Conowingo Pond via the Conowingo Dam Fish Lift. Since 1972 over 30 million individuals have been lifted into the Pond. Gizzard Shad abundance has been increasing in the Chesapeake Bay region since the late 1980's and may be indicative of reduced habitat quality in the Bay (MDDNR 2013). Over the current 4-year study period approximately 3.2 million Gizzard Shad were passed into the Pond via the Conowingo Dam East Fish Lift. These pre-spawn adult fish produced large numbers of young that were observed in the catch data during the summer for this study.

A general concern with Gizzard Shad is the potential for this species to increase to such high numbers that it becomes a nuisance species within Conowingo Pond. The Gizzard Shad is a cold-intolerant species that can experience overwinter mortality at water temperatures less than approximately 4°C (Fetzer *et al.* 2011). The implication is that the PBAPS thermal plume may provide a winter refuge for this species, which leads to a larger population size than would exist without PBAPS. Young Gizzard Shad compete with young of many Centrarchids for zooplankton and may depress their numbers and growth rates in the Pond. Thus a larger population of this species may have an effect on relative abundance of other important recreational fish species. For example, the introduction of Gizzard Shad into the Pond has previously been linked to decline in the White Crappie population (RMC 1994). However, Gizzard Shad at present is common in areas upstream of PBAPS without the influence of thermal discharges (Figure 5-62).

The winter electrofishing catch is provided in Table 5-69 for Gizzard Shad. Gizzard Shad mean CPUE was much lower in the winter for all stations compared to collections from April through October (Table 5-55). The highest catch rates occurred during July and August with generally much lower CPUE in June and during the winter months. One might expect a cold intolerant species to benefit from warm water during winter months particularly when ambient water temperatures decrease below 4°C. The CPUE data at the thermally influenced Stations 161, 189, and 190 did not indicate the presence of large numbers of Gizzard Shad during the winter

months. The winter CPUE results do not support a conclusion that the PBAPS thermal plume is interfering with the fall outmigration of Gizzard Shad or attracting excessively large numbers of this species during the winter months and, thus, providing a thermal refuge. In addition, during the fall large numbers of Gizzard Shad have been observed emigrating from Conowingo Pond downstream past Conowingo Dam. However, the higher winter time water temperature created by PBAPS would likely provide for conditions that are more suitable to this species, particularly during extremely cold winter periods, for those individuals that remain in the Pond. The annual migration (fish lift introductions) of Gizzard Shad from the lower Susquehanna River likely contributes substantially to the total population of this species in the Pond, and these fish did not benefit from overwintering in the Pond within the extent of the PBAPS thermal plume.

A parallel to the increase of the Gizzard Shad population in Conowingo Pond has been observed in many northeastern rivers within the United States. Similar to the Conowingo Pond, Gizzard Shad was first collected in the 1970's from the Hudson River (1974) (Daniels *et al.* 2005). The tidal Hudson River Gizzard Shad numbers have been documented to be increasing in abundance (Daniels *et al.* 2005). Gizzard Shad have been reported in other northern rivers including the Connecticut, Merrimack, and Kennebec rivers, suggesting that this species is expanding its range northward. Gizzard Shad have been present in the Delaware River Estuary since the 1960's and anecdotal evidence indicates the population has been expanding since that time into the Delaware and Schuylkill River drainages in Pennsylvania. The region-wide range expansion in the northeast and range expansion in other northern areas of the United States has been linked to increased water temperature potentially resulting from climate change (VanDeHey *et al.* 2011, Gephard 2005).

*Chesapeake Logperch*

Chesapeake Logperch (*Percina bimaculata*) was recently listed as threatened in Pennsylvania. Its current range includes the Chesapeake Bay watershed in Maryland and Pennsylvania, limited to lower sections of the Susquehanna River and tributaries in Maryland and Pennsylvania, and a few direct tributaries to the Chesapeake Bay (Jenkins and Burkhead 1994). In Pennsylvania, it is restricted to the Susquehanna River above and below Conowingo Dam and the lowermost sections of four tributaries to Conowingo Pond including Fishing Creek, Muddy Creek, Peters Creek and Michaels Run located in Lancaster and York Counties. It is also found in the Octoraro Creek in Chester and Lancaster Counties below Conowingo Dam. In Maryland, this species is known to inhabit the lower reaches of Broad, Conowingo, Deer, and Octoraro creeks.

Although relatively little is known about the Chesapeake Logperch, its habits and biology are likely to be similar to those of other logperches, in particular, the Logperch *Percina caprodes*. Logperch spawning occurs from mid-March to mid-July (initiated at water temperature of 10-15°C) over clean gravel or sand in swift currents of streams and near shores of lakes (Jenkins and Burkhead 1994). It is unclear whether Chesapeake Logperch spawn along the shores of the Conowingo Pond or if spawning is restricted to the lower sections of the six tributary streams of the Pond with documented occurrence of the species (Fishing Creek, Muddy Creek, Michaels Run, Peters Creek in Pennsylvania; Broad and Conowingo Creek in Maryland). Logperch have

been observed to move from shallow areas into deeper water during the winter and migrate back into shallow areas prior to spawning (Winn 1958).

Seasonal and Spatial Distribution

In this study, electrofishing proved more effective in collecting Chesapeake Logperch than seining. Very few Chesapeake Logperch were taken by trawling. Electrofishing catch data indicate that Chesapeake Logperch occurrence in the Pond varies through the year (Table 5-62). Only two Chesapeake Logperch were collected during the winter (January-March 2011-2013) from the Pond. A single individual was collected from both Stations 190 and 217 during 2013. Electrofishing CPUE was low from April to June and increased during the summer months with highest CPUE occurring from August through October. Chesapeake Logperch electrofishing CPUE was variable among collection locations (Table 5-62). The highest CPUE was observed at two non-thermal Stations, 165 (upstream from Peters Creek) and 187 (downstream from Muddy Creek), and one thermally influenced Station, 217 (upstream of Conowingo Creek). Otherwise, catch was lower for most months at the other four electrofishing locations including Station 161 (upstream from Michaels Run) which is the thermally influenced station closest to PBAPS. Few Chesapeake Logperch were collected while seining in Conowingo Pond and overall catch rates were low (Table 5-79). Similar to electrofishing results, the highest CPUE was observed during August. Seine catches were highest at Station 220, which is downstream of Muddy Creek, and Station 208, which is downstream of Peters Creek. Few Chesapeake Logperch were collected at the two thermally influenced seine locations (Stations 214 and 215) or the two most upstream non-thermal locations (Stations 202 and 203).

Discussion

The life cycle of the Chesapeake Logperch in the Pond and its tributaries is not well known. The distribution of this species within the Pond did not seem random, with higher catch rates at several stations and lower catch at most of the other stations. Distribution seems to be, in part, related to proximity to tributary streams and shallow shoreline habitat. CPUE was highest at electrofishing Station 187 and seine Station 220 (both downstream from Muddy Creek), electrofishing Station 164 and seine Station 208 (both near Peters Creek), and electrofishing Station 217 (upstream from Conowingo Creek). Within these shallow shoreline areas, Chesapeake Logperch are likely selecting for a specific habitat composition (e.g., presence of sand, clean gravel, SAV, complex structure, woody debris) for both protective cover and feeding opportunity.

CPUE of Chesapeake Logperch was low at the sampling stations closest to the PBAPS that experience the highest water temperatures, i.e., Stations 161, 214, and 215. Catch at these locations was low throughout most of the sampling season with higher CPUE during September and October. However, the closest tributary to these stations with known Chesapeake Logperch occurrence is Michaels Run which is approximately 1.2 miles downstream from Stations 161 and 215. Similarly, catch was low at several upstream locations including Stations 202, 203, and 164 which are not located along the perimeter of the Pond, rather, adjacent to islands.

It is difficult to ascertain whether Chesapeake Logperch avoided Stations 214, 215, and 161 during summer because of elevated water temperatures or if their preferred habitat was not present, since so little is known about the life history of this species. In any case, the elevated water temperatures observed during July and August at these stations likely would result in this species avoiding the shallow shoreline habitats near these stations (Table 7-12). The highest water temperature at which Chesapeake Logperch was collected (n=4) during this study was 33.9°C at Station 217 in 2011. The shallow shoreline habitat analysis in Section 5.2 determined that approximately 12 acres of shallow shoreline was present within this section of the Pond from the end of PBAPS discharge canal to Station 215. Much of this habitat is in the immediate vicinity of Burkins Run, with limited shallow shoreline areas downstream of Station 215. It is not known, but unlikely, that substantial numbers of Chesapeake Logperch inhabit Burkins Run as it is a fairly small tributary to the Pond.

A habitat mapping study related to water level fluctuation was completed within the Conowingo Pond during 2010 (URS 2011). This study evaluated shoreline sediment class and location of SAV. Several of the locations within the Pond that had the highest catch rates of Chesapeake Logperch were in locations with fairly large areas of shallow shoreline habitat with either sand or gravel sediment present. For example, electrofishing Stations 165 and 217 are in areas with fairly large amounts of shallow habitat adjacent to shoreline. Both these areas have deposits of sediment with a mix of gravel and/or sand as well as fairly substantial beds of SAV (*Hydrilla* sp.). Electrofishing Station 187 has a smaller area of shallow shoreline habitat with gravel sediment present, but minimal SAV. The collection locations with the lowest catch of Chesapeake Logperch were within areas that had limited shallow shoreline habitat that was composed mostly of bedrock with minimal gravel or sand deposits present. These include electrofishing Stations 189, 190, and 216 and seine Stations 202 and 203. But, several of these stations, with the exception of Stations 189 and 190, were also more distant from tributaries known to be inhabited by Chesapeake Logperch than stations with greater catches of the species. Electrofishing Stations 189 and 190 were in close proximity to Michaels Run, known to be populated by Chesapeake Logperch. Catch was low at the stations closest to the end of the discharge canal (these include seine Stations 214 and 215, and electrofishing Station 161) that experience the highest elevated water temperatures. Shallow shoreline areas were present at these locations with sediment composed of gravel.

An entrainment study completed in 2012 (Normandeau 2013c) at PBAPS characterized the fish assemblage being entrained through the cooling water system. No Chesapeake Logperch were collected during this study. Historic icthyoplankton surveys were completed in Conowingo Pond in relation to the PBAPS intake structure during 1975 and 1976 (Anjard 1975, 1976, 1977). Few larval Chesapeake Logperch were collected in this study. Based on these prior studies, as well as the present study, it is likely that most Chesapeake Logperch spawning occurs in the tributaries and tributary mouths and not in Conowingo Pond proper. Additionally, the length-frequency data for this species shows that few individuals less than 50 mm in length were collected within the Pond from 2010 through 2013 (Figure 5-83 through Figure 5-86) and mean length of Chesapeake Logperch was around 70 mm (Table 5-96 through Table 5-99). In Wisconsin young Logperch ranged between 56-69 mm in length at the end of the first growing

season (Lutterbie 1979). Collection of few small individuals also suggests that abundance of Chesapeake Logperch young of the year is low within the Pond.

It is probable that most Chesapeake Logperch spawn in the lower sections and near the mouths of some tributaries to Conowingo Pond in the spring and move into the Pond during summer and fall for feeding and to utilize various preferred habitats. The low numbers collected at shallow shoreline sampling stations directly influenced by the PBAPS thermal discharge may indicate lack of suitable Chesapeake Logperch habitat at these locations. But, the high water temperatures in July and August would still preclude the presence of most Chesapeake Logperch from these locations despite close proximity to potentially suitable stream habitat.

*Conclusions*

- A diverse fish community of over 50 species exists in the Pond;
- CPUEs among species and between stations were variable due to differences in year class strength (i.e. large numbers of young of year of a species being collected at a particular location during given month), habitat preferences, and the constantly changing multitude of environmental variables they experience;
- Metrics used to describe fish community structure show no clear differences in the fish community between thermally influenced and non-thermally influenced;
- Avoidance by selected species was observed at Stations 161/214 and 215 at high water temperatures, mostly during July. This was observed in total richness, RIS richness, diversity, and evenness values; Attraction of fishes to Station 161 was observed during January through March;
- Differences in metric values were not attributable to the proximity of the individual station to the end of the discharge canal, except for the limited avoidance observed in July;
- Gizzard Shad relative abundance in the Pond was high for most years of the study; however, it is unlikely that the population is dependent on the PBAPS thermal plume or has grown markedly because of the it;
- Chesapeake Logperch is a threatened species in Pennsylvania that likely avoids areas of potentially suitable habitat during the summer in locations directly downstream from PBAPS;
- Species richness, diversity, and evenness values observed over the course of study indicate seasonality at all stations with community heterogeneity being similar regardless of location within the Pond;
- Similar fish assemblages were present at non-thermal and thermal stations with no loss of trophic structure.

Table 5-50. Square root transformed mean and median CPUE (no./0.5hr) for all boat electrofishing stations, April to October 2010-2013.

| Station | Mean | Median | Total Samples |
|---|---|---|---|
| st187 | 16.9 | 13 | 25 |
| st164 | 16.7 | 15 | 25 |
| st165 | 13.8 | 13[a] | 25 |
| st161 | 21.1 | 17 | 25 |
| st189 | 15.4 | 13[b] | 25 |
| st190 | 19.3 | 16 | 25 |
| st217 | 26.2 | 21[ab] | 19 |

Kruskal-Wallis test, p=0.037, values followed by same letter were significantly different.

Table 5-51. Mean and median species richness for all boat electrofishing stations, April to October 2010-2013.

| Station | Mean | Median | Total Samples |
|---|---|---|---|
| st187 | 15.7 | 16[cdf] | 25 |
| st164 | 12.2 | 12[ac] | 25 |
| st165 | 13.4 | 14[g] | 25 |
| st161 | 12.6 | 14[ef] | 25 |
| st189 | 13.7 | 14[h] | 25 |
| st190 | 12.3 | 12[bd] | 25 |
| st217 | 16.6 | 16[abegh] | 19 |

Kruskal-Wallis test, p<0.001, values followed by same letter were significantly different.

Table 5-52. Mean and median RIS richness for all boat electrofishing stations, April to October 2010-2013.

| Station | Mean | Median | Total Samples |
|---|---|---|---|
| st187 | 8.0 | $9^{abc}$ | 25 |
| st164 | 6.6 | $7^{be}$ | 25 |
| st165 | 6.6 | $7^{cf}$ | 25 |
| st161 | 6.6 | $7^{ad}$ | 25 |
| st189 | 7.2 | 7 | 25 |
| st190 | 7.3 | 7 | 25 |
| st217 | 8.1 | $8^{def}$ | 19 |

Kruskal-Wallis test, $p<0.001$, values followed by same letter were significantly different.

Table 5-53. Mean and median Shannon diversity values for all boat electrofishing stations, April to October 2010-2013.

| Station | Mean | Median | Total Samples |
|---|---|---|---|
| st187 | 2.9 | $3.2^{abcd}$ | 25 |
| st164 | 2.4 | $2.7^{c}$ | 25 |
| st165 | 2.7 | $2.9^{e}$ | 25 |
| st161 | 2.1 | $2.3^{aef}$ | 25 |
| st189 | 2.7 | $2.9^{f}$ | 25 |
| st190 | 2.4 | $2.7^{b}$ | 25 |
| st217 | 2.3 | $2.5^{d}$ | 19 |

Kruskal-Wallis test, $p<0.001$, values followed by same letter were significantly different.

Table 5-54. Mean and median evenness for all boat electrofishing stations, April to October 2010-2013.

| Station | Mean | Median | Total Samples |
|---|---|---|---|
| st187 | 0.74 | 0.80[ac] | 25 |
| st164 | 0.68 | 0.75 | 25 |
| st165 | 0.74 | 0.79[b] | 25 |
| st161 | 0.58 | 0.71[c] | 25 |
| st189 | 0.71 | 0.78[d] | 25 |
| st190 | 0.67 | 0.71 | 25 |
| st217 | 0.56 | 0.62[abd] | 19 |

Kruskal-Wallis test, p=0.001, values followed by same letter were significantly different.

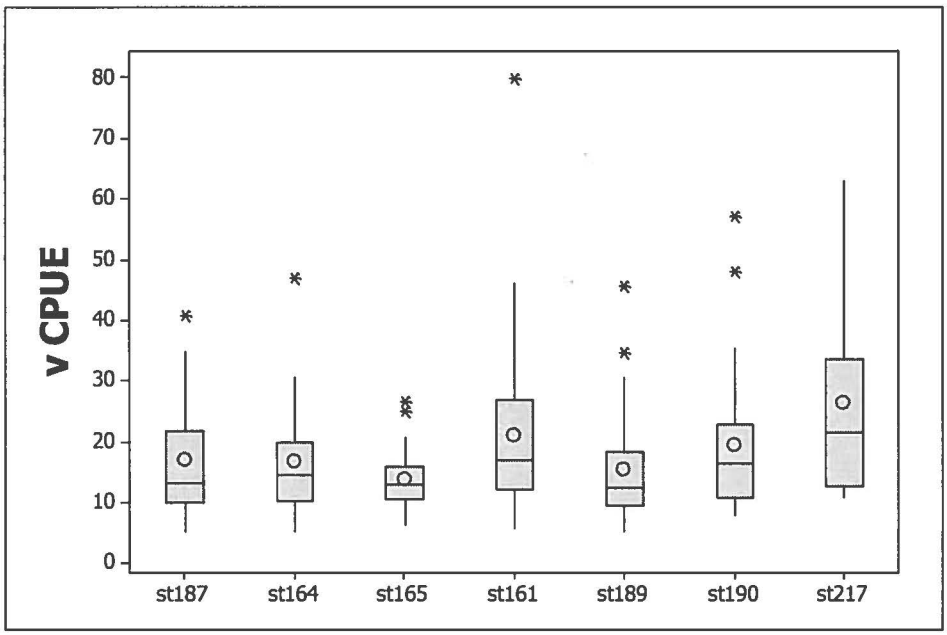



Figure 5-42. Box plot of square root transformed CPUE (no./0.5hr) for all electrofishing stations, April to October 2010-2013. (boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, circle = mean, and asterisk = outlier)

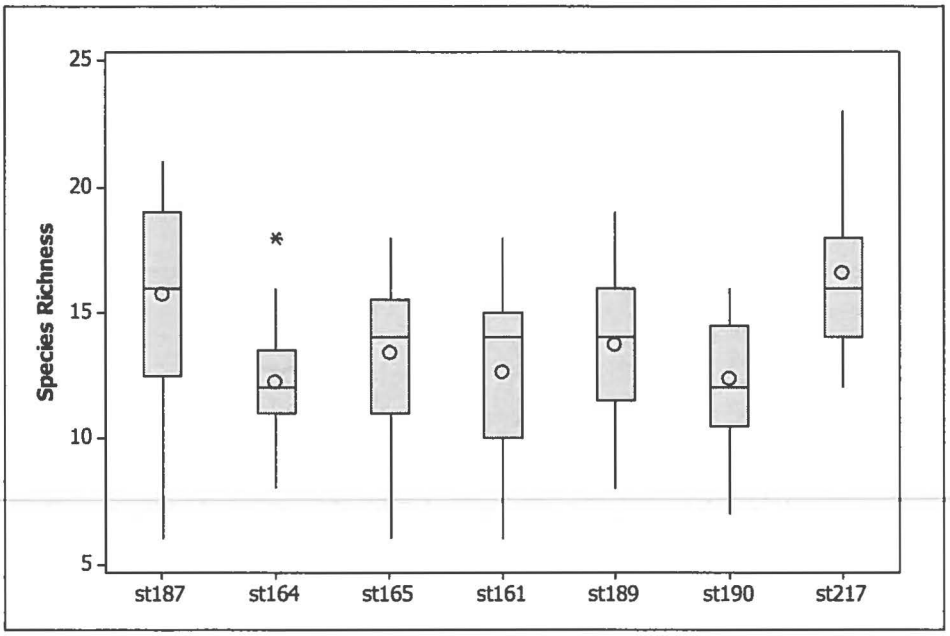



Figure 5-43. Box plot of species richness for all boat electrofishing stations, April to October 2010-2013. (boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, circle = mean, and asterisk = outlier)

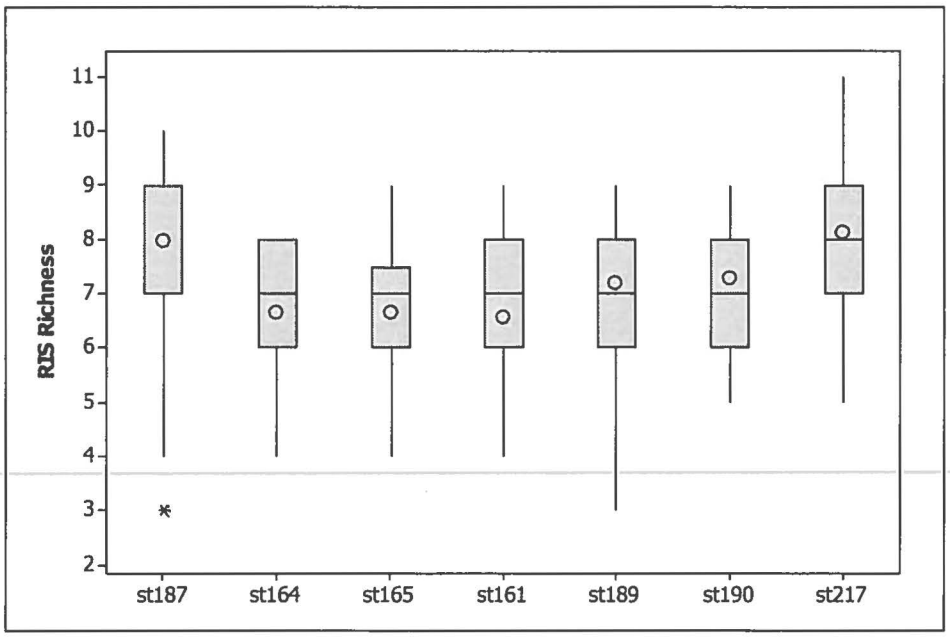



Figure 5-44. Box plot of RIS richness for all boat electrofishing stations, April to October 2010-2013. (boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, circle = mean, and asterisk = outlier)

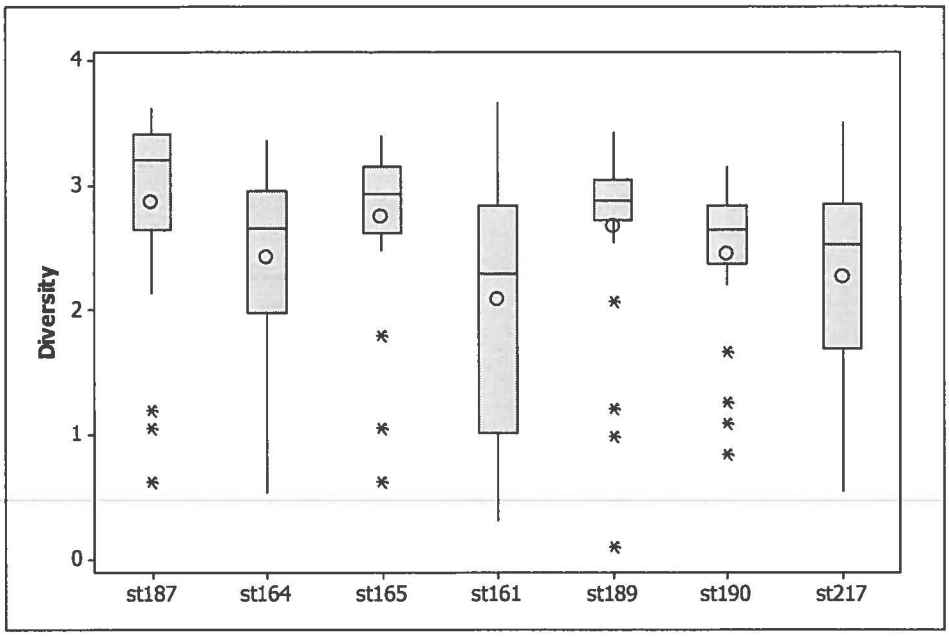



Figure 5-45. Box plot of Shannon diversity values for all boat electrofishing stations, April to October 2010-2013. (boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, circle = mean, and asterisk = outlier)

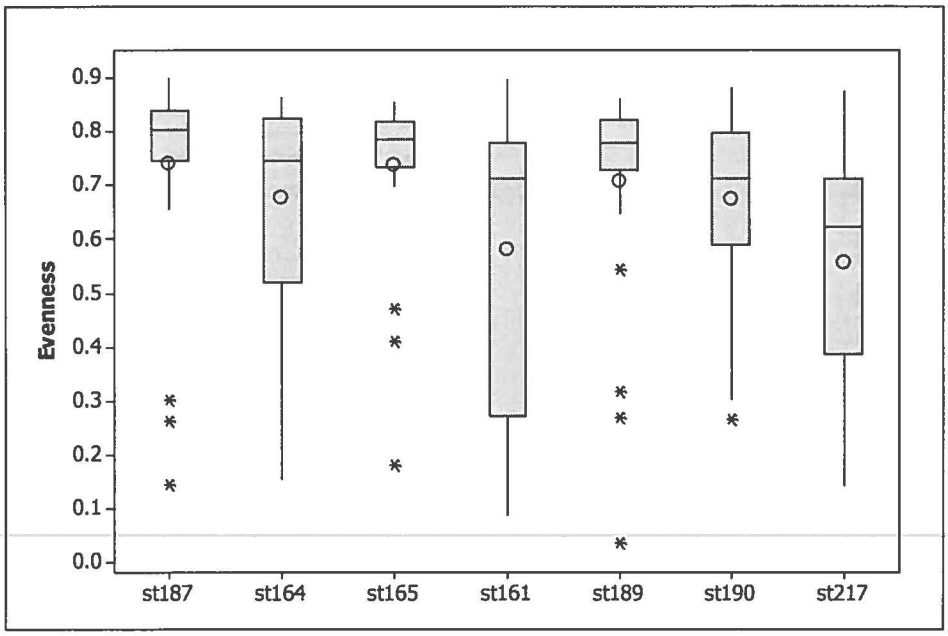



Figure 5-46. Box plot of evenness values for all boat electrofishing stations, April to October 2010-2013. (boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, circle = mean, and asterisk = outlier)

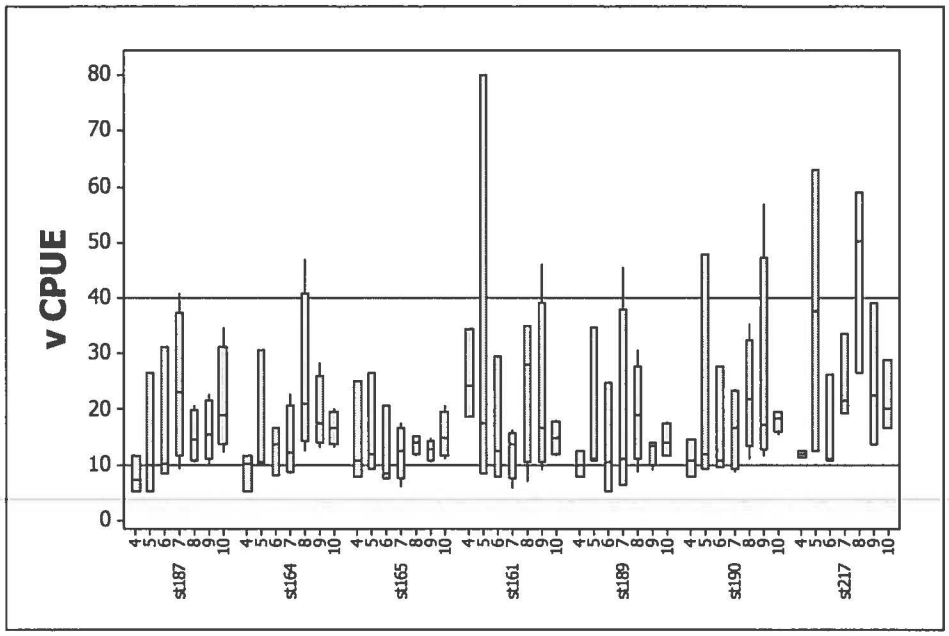



Figure 5-47. Box plot of square root transformed CPUE (no./0.5hr) by month for all electrofishing stations, April to October 2010-2013. (4 = April, 5 = May, 6 = June, etc.) (boxes = interquartile range, line across box = median value, and vertical lines extending from the box = highest and lowest values)

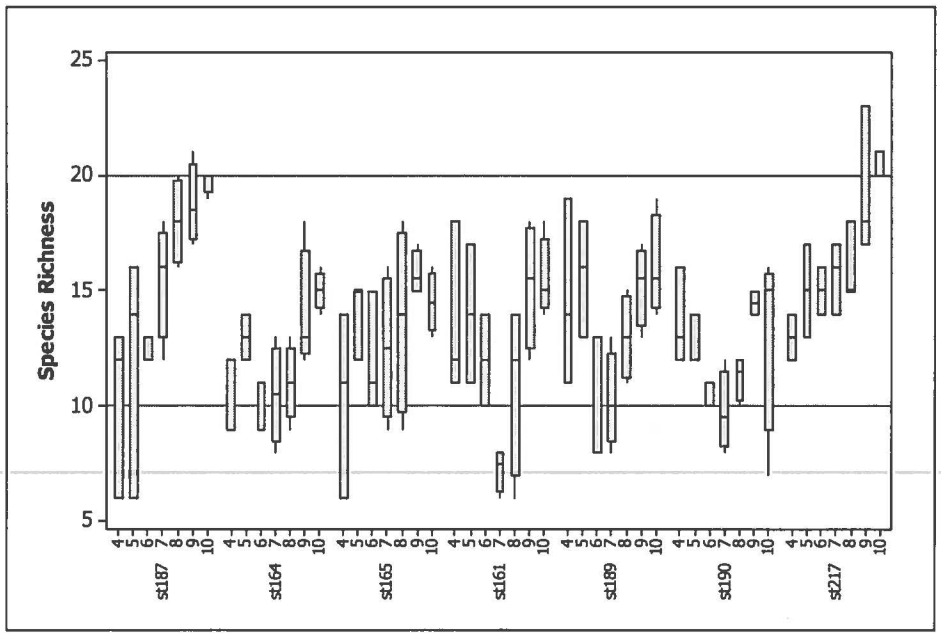



Figure 5-48. Box plot of species richness by month for all boat electrofishing stations, April to October 2010-2013. (4 = April, 5 = May, 6 = June, etc.) (boxes = interquartile range, line across box = median value, and vertical lines extending from the box = highest and lowest values)

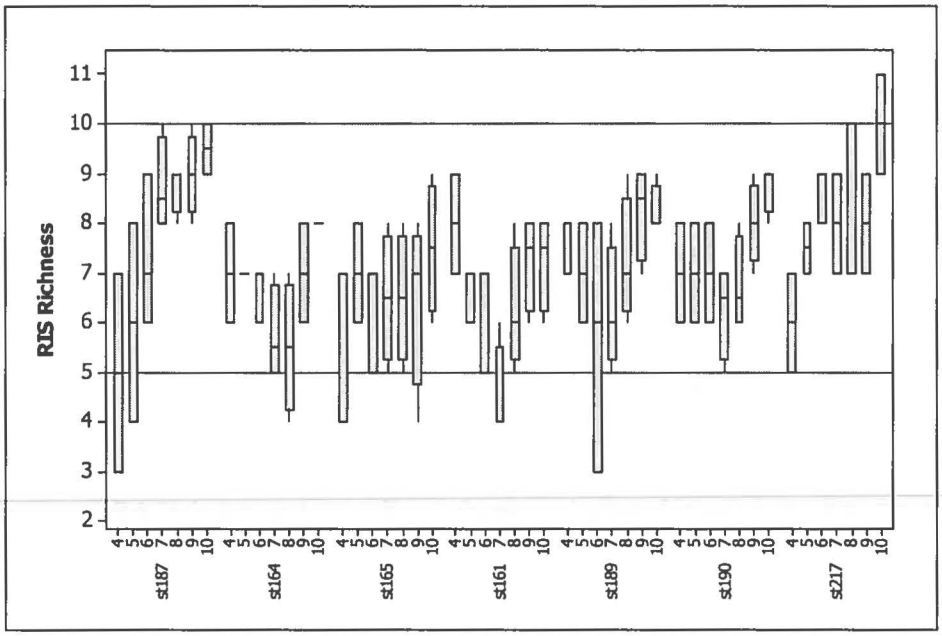



Figure 5-49. Box plot of RIS richness by month for all boat electrofishing stations, April to October 2010-2013. (4 = April, 5 = May, 6 = June, etc.) (boxes = interquartile range, line across box = median value, and vertical lines extending from the box = highest and lowest values)

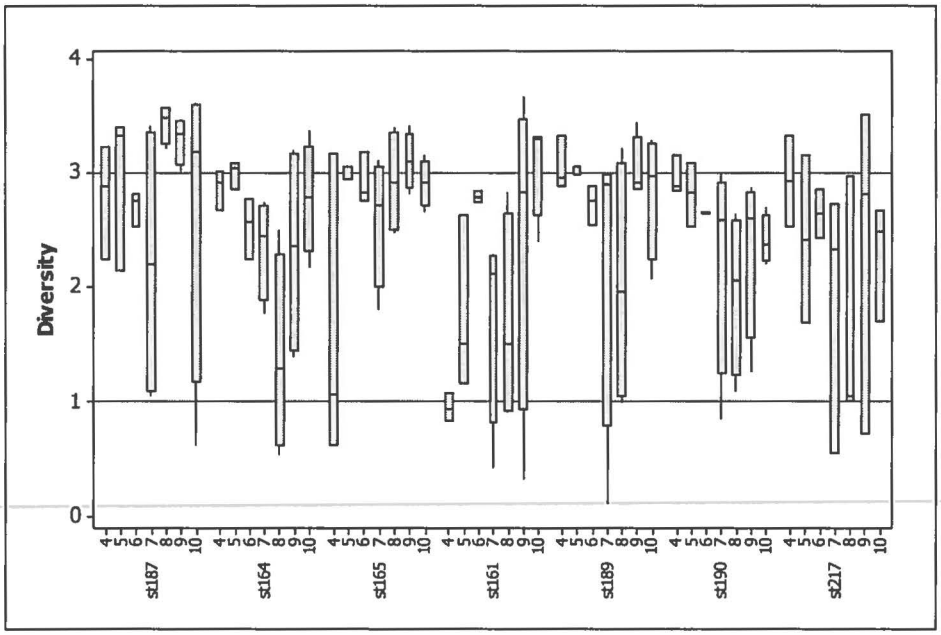



Figure 5-50. Box plot of Shannon diversity by month for all boat electrofishing stations, April to October 2010-2013. (4 = April, 5 = May, 6 = June, etc.) (boxes = interquartile range, line across box = median value, and vertical lines extending from the box = highest and lowest values)

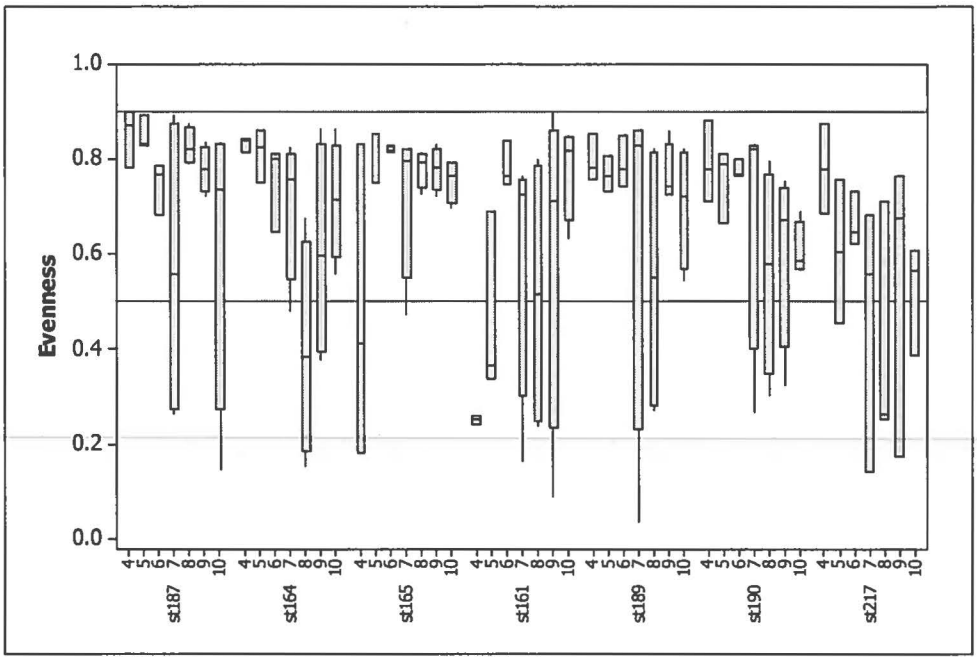



Figure 5-51. Box plot of evenness by month for all boat electrofishing stations, April to October 2010-2013. (4 = April, 5 = May, 6 = June, etc.) (boxes = interquartile range, line across box = median value, and vertical lines extending from the box = highest and lowest values)

Table 5-55. Mean electrofishing CPUE (no./0.5hr) by station for Gizzard Shad collected in Conowingo Pond, April to October 2010-2013.

| Station | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|
| st187 | 6.3 | 4.0 | 7.7 | 424.3 | 35.8 | 25.3 | 50.5 |
| st164 | 3.7 | 17.0 | 3.0 | 102.0 | 658.8 | 222.0 | 17.8 |
| st165 | 19.3 | 11.7 | 2.7 | 63.0 | 21.5 | 3.8 | 15.5 |
| st161 | 601.0 | 351.0 | 1.7 | 67.0 | 525.3 | 527.5 | 25.5 |
| st189 | 8.7 | 25.0 | 0.7 | 515.5 | 272.5 | 26.0 | 7.0 |
| st190 | 4.7 | 33.3 | 4.0 | 125.5 | 273.5 | 18.3 | 9.5 |
| st217 | 24.0 | 206.5 | 9.0 | 441.7 | 696.7 | 37.3 | 198.3 |

Table 5-56. Mean electrofishing CPUE (no./0.5hr) by station for Spotfin Shiner collected in Conowingo Pond, April to October 2010-2013.

| Station | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|
| st187 | 0.0 | 1.7 | 31.7 | 155.3 | 7.0 | 13.3 | 8.8 |
| st164 | 1.0 | 9.3 | 43.0 | 20.0 | 15.3 | 8.3 | 12.0 |
| st165 | 0.3 | 1.0 | 3.7 | 3.5 | 3.8 | 1.8 | 2.0 |
| st161 | 4.0 | 39.3 | 32.3 | 4.3 | 8.0 | 4.8 | 13.5 |
| st189 | 2.7 | 18.3 | 29.3 | 8.8 | 6.8 | 6.0 | 10.5 |
| st190 | 3.0 | 14.7 | 17.0 | 12.0 | 11.3 | 5.3 | 3.8 |
| st217 | 0.0 | 4.0 | 2.7 | 7.3 | 12.3 | 2.0 | 5.3 |

Table 5-57. Mean electrofishing CPUE (no./0.5hr) by station for Bluntnose Minnow collected in Conowingo Pond, April to October 2010-2013.

| Station | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|
| st187 | 7.7 | 9.7 | 11.3 | 3.5 | 17.3 | 15.3 | 7.8 |
| st164 | 3.0 | 12.7 | 2.3 | 8.0 | 0.5 | 3.3 | 6.8 |
| st165 | 2.3 | 6.3 | 3.0 | 1.0 | 1.8 | 1.8 | 5.3 |
| st161 | 8.7 | 3.7 | 6.0 | 8.3 | 13.3 | 5.0 | 2.5 |
| st189 | 10.3 | 13.3 | 6.3 | 2.0 | 4.8 | 2.3 | 7.3 |
| st190 | 11.3 | 32.0 | 14.0 | 5.0 | 3.3 | 3.8 | 7.3 |
| st217 | 13.0 | 8.0 | 1.7 | 1.0 | 1.7 | 1.0 | 11.3 |

Table 5-58. Mean electrofishing CPUE (no./0.5hr) by station for Channel Catfish collected in Conowingo Pond, April to October 2010-2013.

| Station | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|
| st187 | 14.7 | 14.7 | 21.7 | 17.0 | 18.8 | 23.5 | 17.3 |
| st164 | 6.0 | 11.3 | 17.3 | 21.8 | 35.5 | 23.0 | 14.3 |
| st165 | 12.0 | 13.0 | 19.7 | 22.0 | 27.5 | 25.3 | 26.3 |
| st161 | 4.3 | 19.3 | 30.3 | 35.5 | 17.8 | 11.8 | 22.3 |
| st189 | 11.3 | 30.3 | 11.3 | 10.3 | 10.3 | 19.3 | 25.8 |
| st190 | 17.3 | 12.3 | 14.7 | 16.8 | 29.0 | 25.3 | 23.5 |
| st217 | 31.5 | 20.0 | 18.0 | 12.7 | 27.7 | 16.7 | 19.7 |

Table 5-59. Mean electrofishing CPUE (no./0.5hr) by station for Bluegill collected in Conowingo Pond, April to October 2010-2013.

| Station | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|
| st187 | 1.0 | 3.0 | 3.3 | 3.3 | 27.5 | 51.5 | 32.5 |
| st164 | 7.3 | 11.0 | 13.7 | 11.0 | 14.0 | 40.8 | 34.8 |
| st165 | 3.3 | 15.0 | 10.0 | 6.3 | 33.3 | 27.5 | 74.0 |
| st161 | 30.7 | 20.3 | 15.3 | 5.0 | 36.3 | 40.8 | 25.5 |
| st189 | 20.0 | 22.0 | 20.3 | 15.8 | 32.8 | 37.8 | 54.5 |
| st190 | 26.3 | 48.0 | 31.3 | 16.3 | 107.3 | 298.8 | 111.5 |
| st217 | 23.0 | 115.5 | 62.3 | 41.3 | 975.7 | 550.3 | 163.3 |

Table 5-60. Mean electrofishing CPUE (no./0.5hr) by station for Smallmouth Bass collected in Conowingo Pond, April to October 2010-2013.

| Station | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|
| st187 | 7.0 | 3.3 | 13.7 | 10.5 | 8.5 | 6.5 | 15.3 |
| st164 | 14.0 | 21.0 | 7.7 | 7.8 | 7.3 | 30.3 | 52.5 |
| st165 | 5.0 | 14.3 | 9.0 | 10.3 | 6.8 | 17.0 | 19.3 |
| st161 | 3.7 | 5.7 | 17.3 | 7.3 | 9.5 | 21.0 | 24.3 |
| st189 | 3.3 | 2.3 | 6.0 | 5.5 | 5.3 | 3.5 | 4.5 |
| st190 | 3.3 | 3.7 | 6.7 | 22.0 | 5.5 | 9.8 | 8.5 |
| st217 | 1.5 | 3.5 | 9.7 | 23.7 | 9.0 | 8.3 | 6.7 |

Table 5-61. Mean electrofishing CPUE (no./0.5hr) by station for Largemouth Bass collected in Conowingo Pond, April to October 2010-2013.

| Station | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|
| st187 | 0.3 | 0.0 | 0.7 | 2.0 | 1.8 | 1.5 | 1.0 |
| st164 | 3.7 | 2.0 | 1.0 | 0.0 | 0.0 | 0.5 | 0.3 |
| st165 | 0.7 | 0.3 | 0.0 | 0.3 | 0.0 | 0.0 | 0.3 |
| st161 | 2.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 2.5 |
| st189 | 2.0 | 0.7 | 1.3 | 1.0 | 2.5 | 4.0 | 3.5 |
| st190 | 2.0 | 0.7 | 0.7 | 0.8 | 0.8 | 3.5 | 12.3 |
| st217 | 3.0 | 5.0 | 2.7 | 2.3 | 5.3 | 19.0 | 10.3 |

Table 5-62. Mean electrofishing CPUE (no./0.5hr) by station for Chesapeake Logperch collected in Conowingo Pond, April to October 2010-2013.

| Station | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|
| st187 | 0.0 | 0.3 | 0.3 | 3.5 | 6.5 | 12.5 | 6.5 |
| st164 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 1.3 | 2.0 |
| st165 | 0.0 | 0.3 | 0.7 | 4.5 | 7.5 | 9.5 | 8.0 |
| st161 | 0.3 | 0.3 | 0.7 | 0.0 | 0.3 | 1.5 | 2.3 |
| st189 | 0.0 | 0.0 | 0.3 | 0.0 | 0.5 | 1.8 | 0.3 |
| st190 | 0.0 | 1.3 | 1.0 | 3.0 | 2.5 | 5.3 | 1.8 |
| st217 | 1.5 | 2.0 | 3.0 | 7.7 | 16.3 | 17.3 | 2.7 |

Table 5-63. Mean electrofishing CPUE (no./0.5hr) by station for Walleye collected in Conowingo Pond, April to October 2010-2013.

| Station | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|
| st187 | 3.3 | 0.7 | 1.3 | 2.0 | 5.5 | 2.3 | 9.0 |
| st164 | 1.7 | 0.0 | 0.3 | 0.0 | 0.8 | 2.5 | 10.0 |
| st165 | 1.7 | 0.7 | 0.0 | 0.0 | 0.5 | 1.0 | 10.3 |
| st161 | 1.0 | 1.3 | 0.0 | 0.0 | 0.3 | 1.0 | 13.5 |
| st189 | 2.3 | 0.7 | 0.0 | 0.0 | 0.0 | 0.8 | 6.5 |
| st190 | 7.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 3.0 |
| st217 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 1.0 | 3.3 |

Table 5-64. Square root transformed mean CPUE (no./0.5hr) for all boat electrofishing stations, January- March 2011-2013.

| Station | January | February | March |
|---|---|---|---|
| st187 | 8 | 6 | 13 |
| st164 | 30 | 29 | 11 |
| st165 | 13 | 6 | 8 |
| st161 | 12 | 11 | 16 |
| st189 | 9 | 33 | 8 |
| st190 | 12 | 9 | 17 |
| st217 | 8 | 6 | 12 |

Table 5-65. Species richness for all boat electrofishing stations, January- March 2011-2013.

| Station | January | February | March |
|---|---|---|---|
| st187 | 6 | 6 | 10 |
| st164 | 8 | 6 | 7 |
| st165 | 8 | 5 | 4 |
| st161 | 13 | 13 | 15 |
| st189 | 9 | 8 | 13 |
| st190 | 10 | 9 | 10 |
| st217 | 7 | 4 | 7 |

Table 5-66. RIS richness for all boat electrofishing stations, January- March 2011-2013.

| Station | January | February | March |
|---|---|---|---|
| st187 | 3 | 2 | 4 |
| st164 | 4 | 3 | 4 |
| st165 | 3 | 2 | 2 |
| st161 | 6 | 7 | 6 |
| st189 | 6 | 3 | 7 |
| st190 | 5 | 3 | 6 |
| st217 | 2 | 2 | 4 |

Table 5-67. Shannon diversity values for all boat electrofishing stations, January- March 2011-2013.

| Station | January | February | March |
|---|---|---|---|
| st187 | 1.69 | 1.72 | 1.83 |
| st164 | 0.97 | 0.87 | 0.76 |
| st165 | 1.65 | 1.18 | 0.32 |
| st161 | 2.67 | 2.77 | 2.62 |
| st189 | 2.24 | 0.64 | 2.74 |
| st190 | 1.54 | 1.46 | 0.98 |
| st217 | 1.60 | 0.63 | 0.81 |

Table 5-68. Evenness for all boat electrofishing stations, January- March 2011-2013.

| Station | January | February | March |
|---|---|---|---|
| st187 | 0.65 | 0.66 | 0.55 |
| st164 | 0.30 | 0.34 | 0.27 |
| st165 | 0.68 | 0.68 | 0.16 |
| st161 | 0.73 | 0.73 | 0.67 |
| st189 | 0.70 | 0.21 | 0.74 |
| st190 | 0.46 | 0.47 | 0.30 |
| st217 | 0.57 | 0.32 | 0.29 |

Table 5-69. Mean CPUE for Gizzard Shad, January-March 2011-2013.

| Station | January | February | March |
|---|---|---|---|
| st187 | 0 | 0 | 0 |
| st164 | 11 | 0 | 7 |
| st165 | 10.5 | 0 | 1 |
| st161 | 1 | 29.5 | 100 |
| st189 | 13 | 1.5 | 6 |
| st190 | 10.5 | 2.5 | 8 |
| st217 | 0 | 0 | 3 |

Table 5-70. Square root transformed mean and median CPUE (no/collection) for seine stations, April to October 2010-2013.

| Station | Mean | Median | Total Number |
|---|---|---|---|
| st202 | 6.1 | 5.3 | 24 |
| st203 | 5.3 | 5.4[a] | 24 |
| st220 | 7.4 | 7.3[a] | 24 |
| st221 | 6.3 | 5.3 | 24 |
| st208 | 5.7 | 5.1 | 24 |
| st214 | 6.5 | 6.2 | 24 |
| st215 | 6.0 | 5.6 | 24 |

Kruskal-Wallis test, p=0.1, values followed by same letter were significantly different.

Table 5-71. Mean and median species richness for seine stations, April to October 2010-2013.

| Station | Mean | Median | Total Number |
|---|---|---|---|
| st202 | 5.4 | 5 | 24 |
| st203 | 5.3 | 5 | 24 |
| st220 | 6.5 | 5.5[a] | 24 |
| st221 | 5.6 | 5 | 24 |
| st208 | 5.6 | 5 | 24 |
| st214 | 5.1 | 5 | 24 |
| st215 | 3.7 | 4[a] | 24 |

Kruskal-Wallis test, p=0.05, values followed by same letter were significantly different.

Table 5-72. Mean and median RIS richness for seine stations, April to October 2010-2013.

| Station | Mean | Median | Total Number |
|---|---|---|---|
| st202 | 2.4 | 2 | 24 |
| st203 | 2.3 | 2 | 24 |
| st220 | 3.4 | 3 | 24 |
| st221 | 2.5 | 2 | 24 |
| st208 | 2.8 | 3 | 24 |
| st214 | 2.8 | 3 | 24 |
| st215 | 2.7 | 3 | 24 |

Kruskal-Wallis test, p>0.2, no significant differences between stations.

Table 5-73. Mean and median Shannon diversity for seine stations, April to October 2010-2013.

| Station | Mean | Median | Total Number |
|---|---|---|---|
| st202 | 1.6 | 1.5 | 24 |
| st203 | 1.6 | 1.7 | 24 |
| st220 | 1.6 | 1.6 | 24 |
| st221 | 1.7 | 1.6[a] | 24 |
| st208 | 1.7 | 1.6 | 24 |
| st214 | 1.4 | 1.5 | 24 |
| st215 | 1.1 | 1.1[a] | 24 |

Kruskal-Wallis test, p=0.09, values followed by same letter were significantly different.

Table 5-74. Mean and median evenness for seine stations, April to October 2010-2013.

| Station | Mean | Median | Total Number |
|---|---|---|---|
| st202 | 0.7 | 0.7 | 24 |
| st203 | 0.7 | 0.8 | 24 |
| st220 | 0.6 | 0.7 | 24 |
| st221 | 0.7 | 0.7 | 24 |
| st208 | 0.7 | 0.8 | 24 |
| st214 | 0.6 | 0.7 | 24 |
| st215 | 0.6 | 0.7 | 24 |

Kruskal-Wallis test, p=0.16, no significant differences between stations.

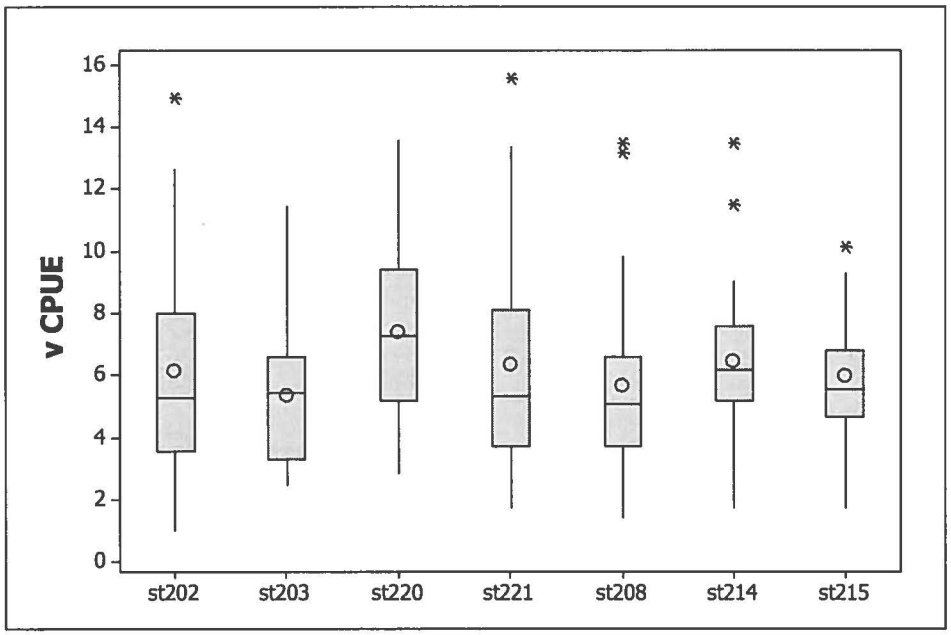



Figure 5-52. Box plot of square root transformed CPUE (no./collection) by station for seine collections, April to October 2010-2013.(boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, circle = mean, and asterisk = outlier)

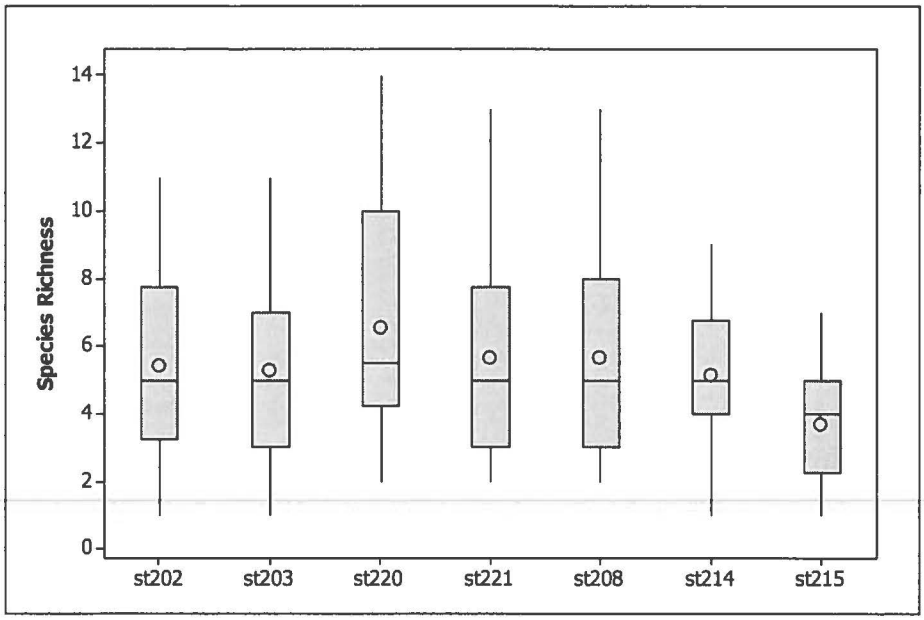



Figure 5-53. Box plot of fish species richness (no./collection) by station for seine collections, April to October 2010-2013. (boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, circle = mean, and asterisk = outlier)

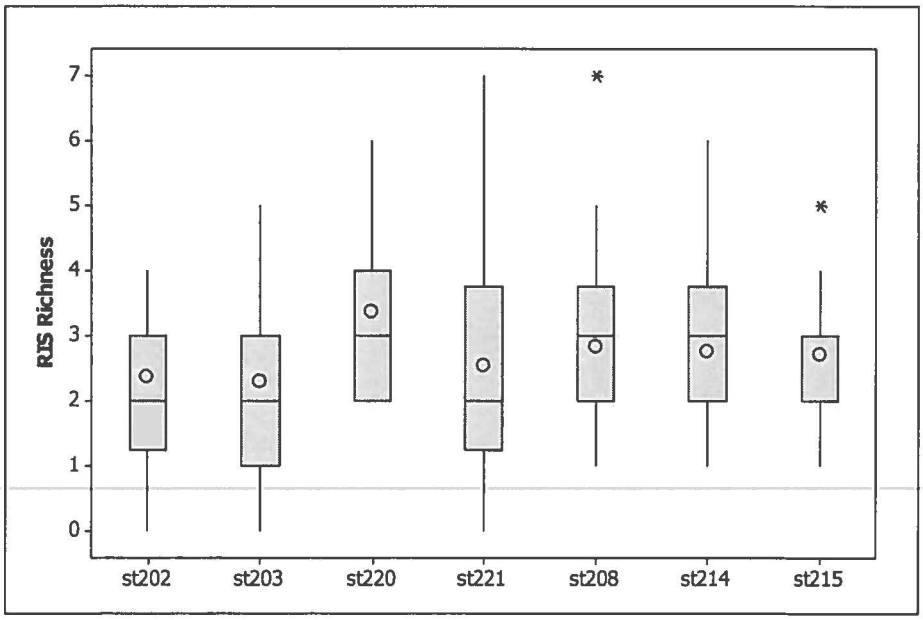



Figure 5-54. Box plot of RIS richness (no./collection) by station for seine collections, April to October 2010-2013. (boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, circle = mean, and asterisk = outlier)

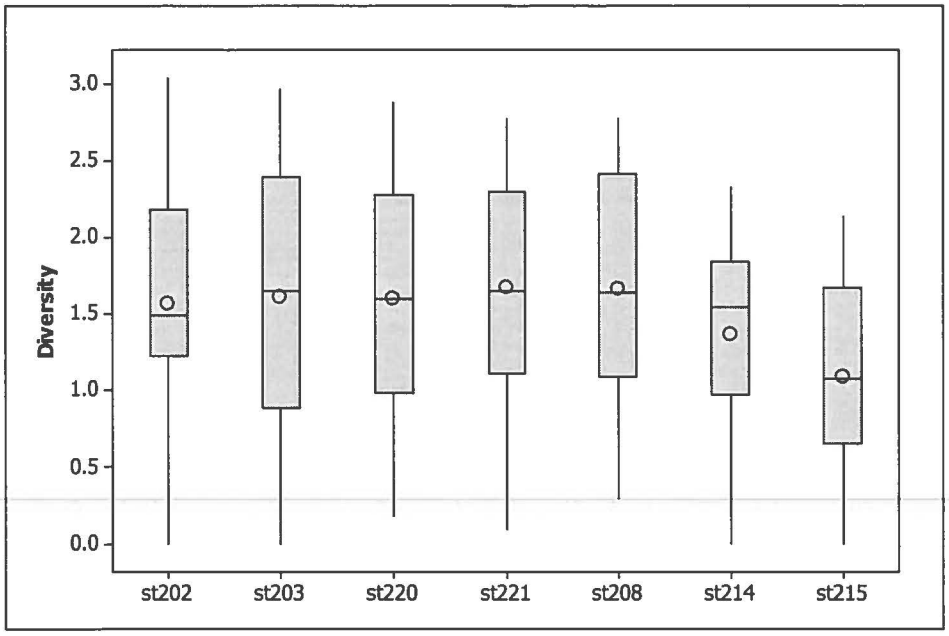



Figure 5-55. Box plot of Shannon diversity values by station for each monthly seine collection, April to October 2010-2013. (boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, circle = mean, and asterisk = outlier)

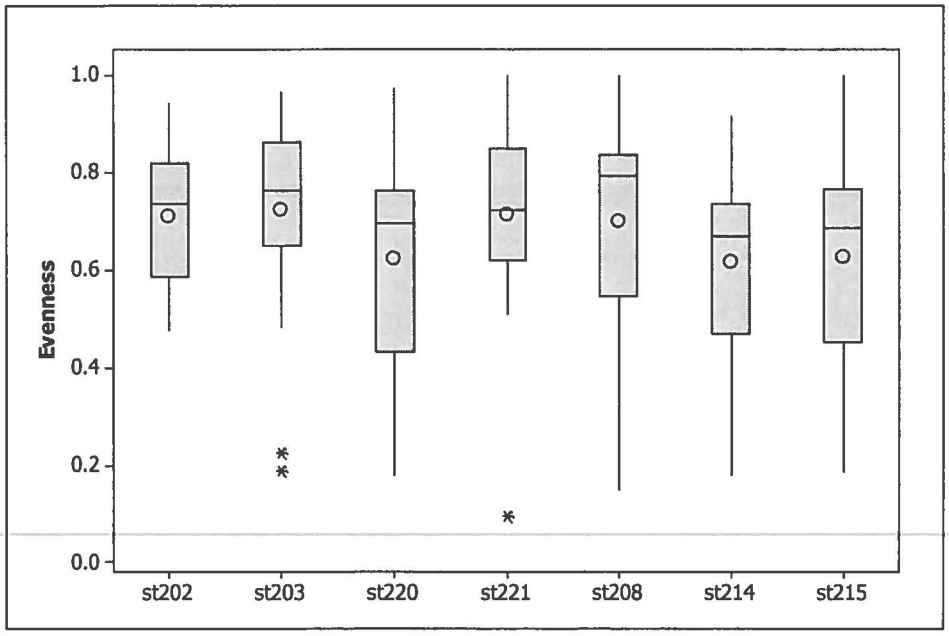



Figure 5-56. Box plot of evenness values by station for each monthly seine collection, April to October 2010-2013. (boxes = interquartile range containing 50% of the values, the line across the box = median value, vertical lines extending from the box = highest and lowest values, circle = mean, and asterisk = outlier)

Table 5-75. Mean seine CPUE (no./collection) by station for Spotfin Shiner collected in Conowingo Pond, April to October 2010-2013.

| Station | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|
| st202 | 3.7 | 4.7 | 13.0 | 7.5 | 14.0 | 11.5 | 3.8 |
| st203 | 6.0 | 5.7 | 7.3 | 5.3 | 4.8 | 13.3 | 3.5 |
| st220 | 31.7 | 7.3 | 18.7 | 16.3 | 29.5 | 38.5 | 44.8 |
| st221 | 13.3 | 5.0 | 7.0 | 6.8 | 8.5 | 1.8 | 3.0 |
| st208 | 2.3 | 6.3 | 5.7 | 47.5 | 6.5 | 9.0 | 25.5 |
| st214 | 11.7 | 9.3 | 19.7 | 15.5 | 13.3 | 17.3 | 9.5 |
| st215 | 13.3 | 11.3 | 15.7 | 36.5 | 31.0 | 21.5 | 16.8 |

Table 5-76. Mean seine CPUE (no./0.5hr) by station for Bluntnose Minnow collected in Conowingo Pond, April to October 2010-2013.

| Station | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|
| st202 | 11.7 | 6.7 | 6.0 | 9.5 | 7.5 | 4.3 | 2.8 |
| st203 | 3.0 | 10.0 | 12.3 | 13.3 | 22.3 | 2.5 | 3.3 |
| st208 | 4.7 | 8.3 | 6.3 | 10.0 | 13.8 | 5.5 | 2.0 |
| st220 | 18.7 | 7.3 | 11.3 | 12.5 | 14.5 | 2.5 | 14.3 |
| st221 | 3.3 | 3.3 | 3.0 | 1.5 | 6.8 | 31.5 | 0.3 |
| st214 | 16.7 | 18.0 | 9.7 | 17.0 | 28.3 | 4.8 | 6.8 |
| st215 | 10.7 | 5.7 | 6.0 | 10.0 | 13.5 | 2.3 | 5.8 |

Table 5-77. Mean seine CPUE (no./collection) by station for Bluegill collected in Conowingo Pond, April to October 2010-2013.

| Station | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|
| st202 | 0.0 | 0.0 | 0.0 | 0.3 | 17.5 | 68.5 | 1.3 |
| st203 | 0.0 | 0.3 | 0.0 | 0.0 | 6.8 | 1.0 | 1.3 |
| st220 | 0.0 | 0.0 | 0.0 | 0.8 | 10.3 | 29.8 | 4.8 |
| st221 | 0.3 | 0.0 | 0.0 | 0.3 | 0.3 | 1.0 | 0.0 |
| st208 | 0.0 | 0.0 | 0.0 | 2.3 | 3.5 | 2.0 | 3.5 |
| st214 | 0.7 | 0.3 | 1.0 | 1.8 | 2.5 | 4.8 | 0.8 |
| st215 | 0.3 | 0.0 | 0.0 | 7.0 | 15.3 | 2.3 | 2.5 |

Table 5-78. Mean seine CPUE (no./collection) by station for Smallmouth Bass collected in Conowingo Pond, April to October 2010-2013.

| Station | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|
| st202 | 0.0 | 0.0 | 2.0 | 1.5 | 0.5 | 0.0 | 0.0 |
| st203 | 0.0 | 0.0 | 1.3 | 0.5 | 0.3 | 0.0 | 0.0 |
| st220 | 0.0 | 0.0 | 1.0 | 2.3 | 1.5 | 0.3 | 0.0 |
| st221 | 0.0 | 0.0 | 0.7 | 0.8 | 0.5 | 0.0 | 0.0 |
| st208 | 0.0 | 0.0 | 0.7 | 1.5 | 0.8 | 0.5 | 0.0 |
| st214 | 0.0 | 0.0 | 1.0 | 0.3 | 0.0 | 0.0 | 0.0 |
| st215 | 0.0 | 0.0 | 2.7 | 1.3 | 0.8 | 0.0 | 0.0 |

Table 5-79. Mean seine CPUE (no./collection) by station for Chesapeake Logperch collected in Conowingo Pond, April to October 2010-2013.

| Station | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|
| st202 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 |
| st203 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| st220 | 0.0 | 0.0 | 0.3 | 2.3 | 6.5 | 0.8 | 0.3 |
| st221 | 1.3 | 0.0 | 0.0 | 0.0 | 0.8 | 0.0 | 0.0 |
| st208 | 0.0 | 0.7 | 1.0 | 0.3 | 1.8 | 0.0 | 0.3 |
| st214 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 |
| st215 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.3 |

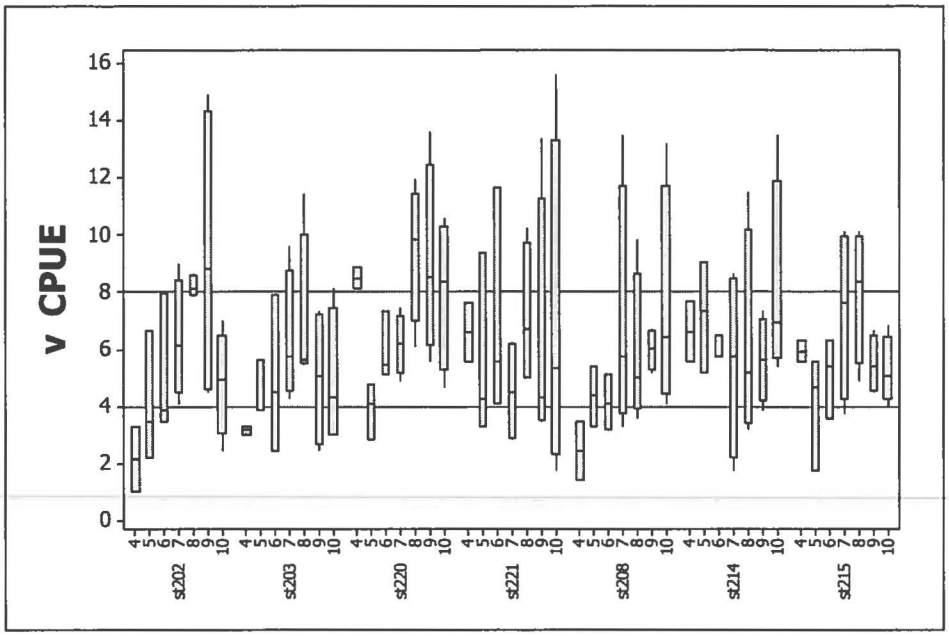



Figure 5-57. Box plot of square root transformed CPUE (no./collection) by month for all seine stations, April to October 2010-2013. (4=April, 5=May, 6=June, etc.) (boxes = interquartile range, line across box = median value, and vertical lines extending from the box = highest and lowest values)

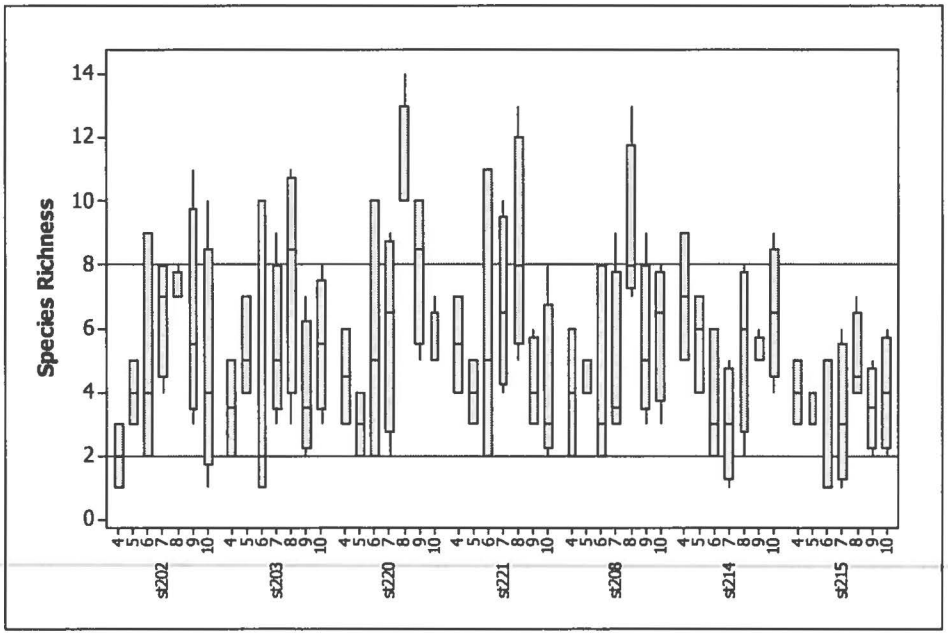



Figure 5-58. Box plot of species richness by month for all seine stations, April to October 2010-2013. (4=April, 5=May, 6=June, etc.) (boxes = interquartile range, line across box = median value, and vertical lines extending from the box = highest and lowest values)

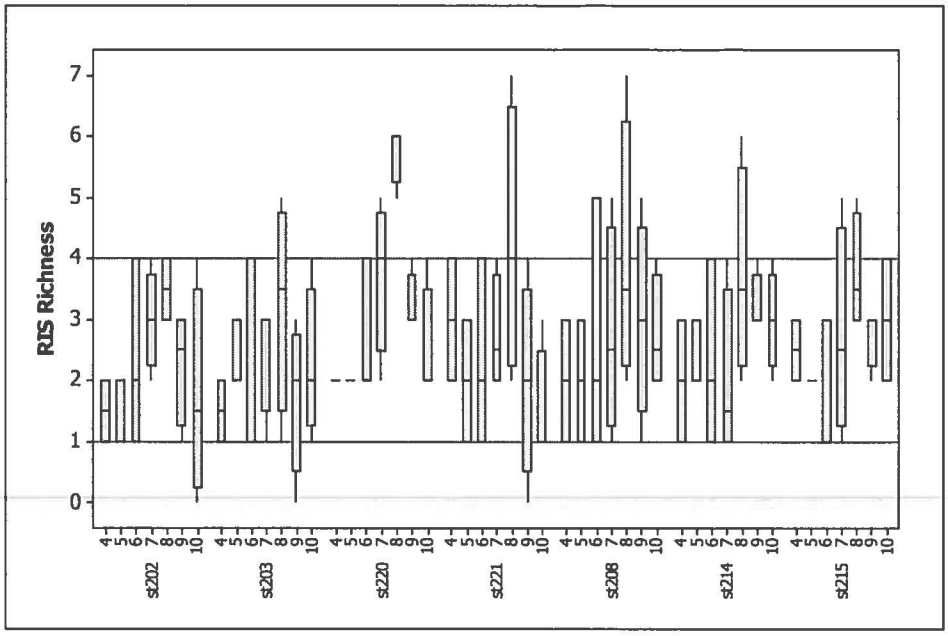



Figure 5-59. Box plot of RIS richness by month for all seine stations, April to October 2010-2013. (4=April, 5=May, 6=June, etc.) (boxes = interquartile range, line across box = median value, and vertical lines extending from the box = highest and lowest values)

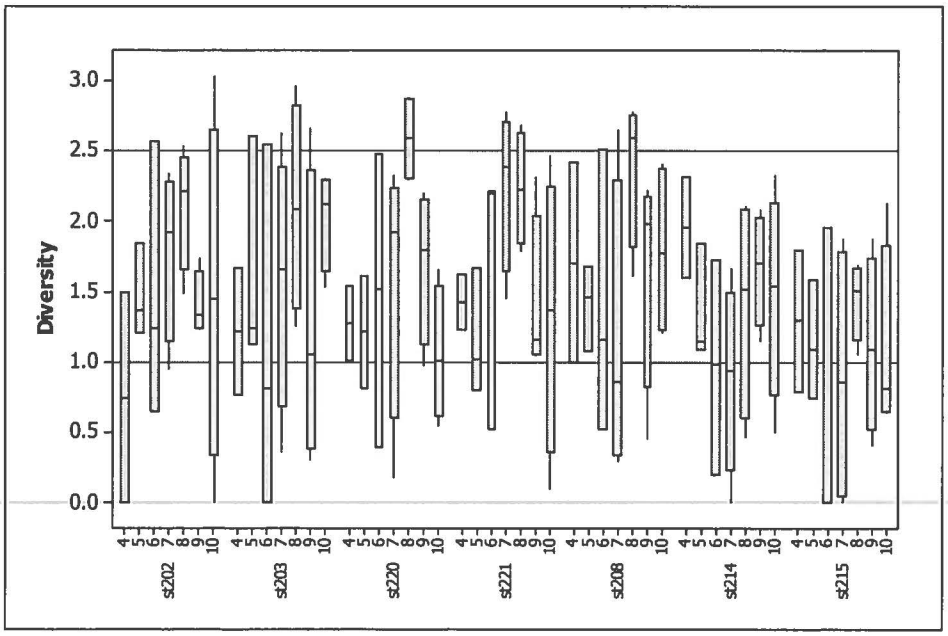



Figure 5-60. Box plot of Shannon diversity values by month for all seine stations, April to October 2010-2013. (4=April, 5=May, 6=June, etc.) (boxes = interquartile range, line across box = median value, and vertical lines extending from the box = highest and lowest values)

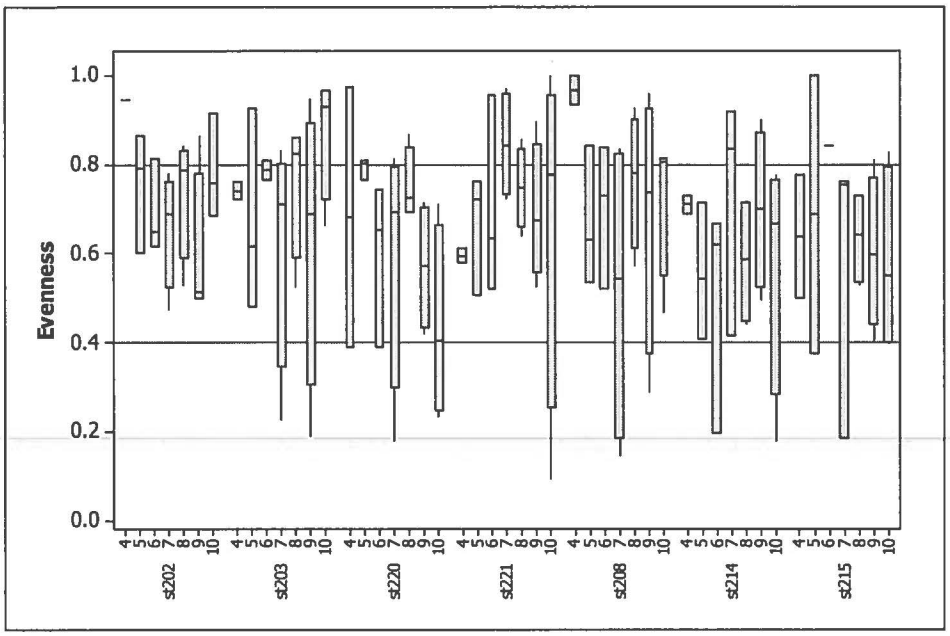



Figure 5-61. Box plot of evenness values by month for all seine stations, April to October 2010-2013. (4=April, 5=May, 6=June, etc.) (boxes = interquartile range, line across box = median value, and vertical lines extending from the box = highest and lowest values)

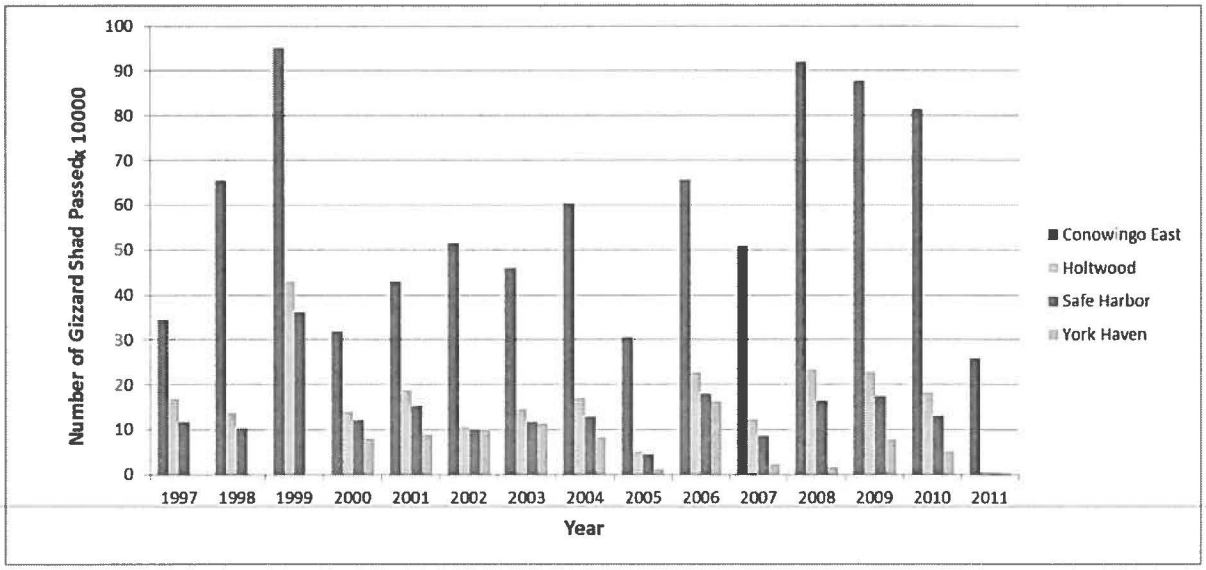



Figure 5-62. Number of Gizzard Shad passed at Conowingo, Holtwood, Safe Harbor, and York Haven Dam, 1997-2011. Data taken from Exelon's annual Cowowingo Dam fish lift reports.

*Fish-Water Temperature Observations*[1]

Fish were collected over a wide range of water temperatures during the course of the four year study. Water temperatures at the time of field collections ranged from 1.5°C (34.7°F) to 36.6°C (97.9°F). Data presented in this section pertains to boat electrofishing and seine collections completed from April to October, 2010-2013. During the course of field collections instantaneous water temperature measurements were completed at each station. Water temperatures were measured within a few feet of the water surface and these temperatures reflect the entire water column at these shallow shoreline seine and electrofishing stations, as the water is fully mixed with no temperature stratification.

To elucidate the relation of fish occurrence to collection water temperature, the total number of each fish species observed at both non-thermally and thermally influenced stations was tabulated. For this analysis stations are discussed as either non-thermal or thermal 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. Stations that are upstream of the PBAPS thermal discharge that experience natural water temperature conditions are considered non-thermal (Figure 5-22 to Figure 5-24; Table 5-12 to Table 5-14). Electrofishing Stations 161, 189, 190, and 217 are considered thermally influenced and Stations 187, 164, and 165 are considered non-thermal. Seine Stations 214 and 215 are considered thermally influenced and Stations 203, 202, 220, 221, and 208 are considered non-thermal. As previously discussed in Section 5.2, 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.

Fish occurrence over a range of water temperatures was determined with particular emphasis on water temperatures >25°C (77°F) which represents ambient water temperatures during the warmer period of the year, roughly from June to September. Time series plots of daily mean and instantaneous maximum water temperature for the monitoring stations are provided previously in Figure 5-1 through Figure 5-9 and show the complete temperature history for each station.

Table 5-80 provides the total number of each fish species collected over a range of water temperatures for the non-thermal stations. Maximum water temperature observed at the non-thermal stations was 32°C (89.6°F). Most of the abundant RIS were collected over a wide range of summer water temperatures up to the near maximum ambient water temperature of 32°C. Table 5-81 provides the total number of each fish species collected over a range of water temperatures for the thermally affected stations. The maximum water temperature observed for

[1] Temperature values are provided in both English (Fahrenheit) and metric (Centigrade) units due to the widespread use of metric units in the scientific literature.

the thermally affected stations was 36.6°C (97.9°F). Water temperatures ≥ 32°C represents water temperatures that were greater than those observed at any of the non-thermal stations. Ten of the RIS were collected at water temperatures ≥ 32°C. The only RIS not collected at elevated water temperatures was Walleye, with few of this species collected at water temperature exceeding 25°C. The highest temperature that Walleye were collected was in the 29-29.9°C (84.2-85.8°F) range for the non-thermal stations (Table 5-80); however, similar to thermal stations, most Walleye were collected at water temperatures ≤ 25°C.

In general, species richness decreased as water temperatures increased above 33°C (91.4°F). For example, 11 species were collected between temperatures of 33-33.9°C (91.4-93.0°F) and only six species were collected at the highest temperatures between 36-36.9°C (96.8-97.9°F). Relatively few individuals were collected at the highest water temperatures for most species except Spotfin Shiner. Spotfin Shiner was collected in fairly large numbers for all water temperature ranges up to and including 36-36.9°C. It should be noted that the comparison here is not standardized for effort, that is, fewer samples were collected at the highest water temperatures. However, comparing absolute numbers of individuals for a given species is useful in showing the approximate delineation where most species begin to avoid locations within the Pond because of elevated water temperatures.

Conclusions

Fish were collected at a wide range of water temperatures during the course of this study. Fish species distribution and community composition were similar between the non-thermal and thermal stations. Each of the 11 RIS was collected at both the non-thermal and thermally influenced stations. No thermally stressed fish were observed, with fish maintaining normal activity prior to collection and after processing and release. Field observations during this study found no indications that fish (4,130 individuals, 2010-2013) collected at water temperatures ≥32°C (89.6°F), which is the maximum ambient water temperature observed, were experiencing thermal stress.

Few fish were collected at water temperatures greater than 36°C (96.8°F). Water temperatures greater than 36°C (96.8°F) observed during fish surveys occurred only during July at the near-field stations (214, 215, and 161). For the thermally influenced locations, ten of the 11 RIS were collected at elevated water temperatures between 30-33°C (86-91.4°F) and eight of the 11 RIS were collected at water temperatures between 33-36°C (91.4-96.8°F). Three of the RIS (Walleye, White Sucker, and White Crappie) were not collected at water temperatures between 33-36°C (91.4-96.8°F). Few individuals of these three species were collected at water temperatures >25°C. Twenty-one species of fish were collected at water temperatures that exceeded 33°C (91.4°F).

The next section provides gear-specific CPUE by station for the observed collection water temperatures during July and August, which is a complementary analysis to this section.

Table 5-80. Number of each species collected using seine and electrofishing gear across a range of water temperature for non-thermally affected locations within Conowingo Pond, April-October, 2010-2013.

| | Water temperature °C | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Taxon | < 25.0 | 25 - 25.9 | 26 - 26.9 | 27 - 27.9 | 28 - 28.9 | 29 - 29.9 | 30 - 30.9 | 31 - 31.9 | 32 - 32.9 |
| **Gizzard shad** | **1,645** | **17** | **2,353** | **469** | **1,256** | **1,052** | **24** | **31** | **5** |
| Central stoneroller | 1 | | | | | | | | |
| Common carp | 88 | 9 | 37 | | 15 | 2 | 3 | | |
| Cutlips minnow | | | | | | 1 | | | |
| River chub | 1 | | | | 2 | | | | |
| Golden shiner | 3 | | 4 | | | | | | |
| Comely shiner | 2,976 | 39 | 115 | 27 | 149 | 8 | 17 | 2 | 1 |
| Common shiner | 1 | 1 | | | 4 | | | | |
| Spottail shiner | 491 | 150 | 110 | 38 | 148 | 12 | 42 | | |
| Swallowtail shiner | 5 | 2 | 2 | 1 | 1 | | | | |
| **Spotfin shiner** | **1,451** | **156** | **207** | **59** | **238** | **646** | **148** | **224** | **4** |
| Mimic shiner | 6 | | | | 2 | | | | |
| **Bluntnose minnow** | **677** | **122** | **249** | **70** | **108** | **33** | **25** | **13** | |
| Semotilus sp | 1 | | | | | | | | |
| Creek chub | 9 | 3 | | | | | | | |
| Fallfish | 10 | 5 | 3 | 7 | 1 | | | | |
| Quillback | 37 | 1 | 2 | 2 | 59 | | 3 | 11 | |
| **White sucker** | **105** | **7** | **1** | **1** | | **2** | **7** | | |
| Northern hogsucker | 29 | 3 | 2 | 3 | 13 | 7 | 5 | 7 | |
| Shorthead redhorse | 217 | 2 | 80 | 3 | 23 | 5 | 28 | 5 | |
| **Channel catfish** | **855** | **76** | **165** | **52** | **127** | **46** | **80** | **12** | **16** |
| Flathead catfish | 22 | 3 | 7 | 3 | 12 | 2 | 1 | | 2 |
| Banded killifish | 675 | 17 | 47 | 8 | | | 1 | 5 | |
| Eastern mosquitofish | 1 | | | | | | | | |
| White perch | 45 | | 1 | | | | | | |
| Striped bass x white bass | 4 | | | | | | | | |
| Rock bass | 738 | 24 | 71 | 11 | 71 | 27 | 12 | 4 | 6 |
| Redbreast sunfish | 8 | 3 | 1 | | 4 | | | | |
| Green sunfish | 646 | 53 | 91 | 52 | 23 | 47 | 18 | 3 | 2 |
| Pumpkinseed | 14 | 1 | 1 | | | 1 | | | |
| **Bluegill** | **1,444** | **305** | **205** | **110** | **78** | **78** | **26** | **1** | **2** |
| **Smallmouth bass** | **845** | **26** | **95** | **6** | **71** | **15** | **47** | **6** | **1** |
| **Largemouth bass** | **39** | **3** | **7** | **9** | **3** | **1** | **5** | **2** | |
| **White crappie** | **11** | | | | | | | | |
| Black crappie | 3 | | | | | | | | |
| Greenside darter | 16 | 1 | 1 | 4 | 4 | | | | |
| Tessellated darter | 171 | 18 | 36 | 15 | 40 | 4 | 9 | 1 | |
| Banded darter | 4 | | | | | 1 | | | |
| Yellow perch | 90 | 3 | 3 | | 1 | | 6 | | |
| **Chesapeake logperch** | **205** | **6** | **23** | **25** | **17** | **22** | **17** | | |
| Shield darter | 25 | 1 | 4 | 13 | | 1 | | | |
| **Walleye** | **185** | **2** | **9** | | **4** | **2** | **2** | | |
| Total number | 13,799 | 1,059 | 3,932 | 988 | 2,475 | 2,015 | 526 | 327 | 39 |
| Total Species | 40 | 30 | 30 | 23 | 27 | 23 | 22 | 15 | 9 |

Table 5-81. Number of each species collected using seine and electrofishing gear across a range of water temperature for thermally affected locations within Conowingo Pond, April-October, 2010-2013.

| | Water temperature °C | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Taxon | < 25.0 | 25 - 25.9 | 26 - 26.9 | 27 - 27.9 | 28 - 28.9 | 29 - 29.9 | 30 - 30.9 | 31 - 31.9 | 32 - 32.9 | 33 - 33.9 | 34 - 34.9 | 35 - 35.9 | 36 - 36.9 |
| American shad | 1 | | | | | | | | | | | | |
| **Gizzard shad** | **3,446** | **51** | **381** | **830** | **3,878** | **2,852** | **2,362** | **1,091** | **1,025** | **1,354** | **4** | **17** | **3** |
| Central stoneroller | | | | | | | | 1 | | 4 | | | |
| Rosyside dace | | | | | | 8 | | | | | | | |
| Grass carp | | | | 1 | | | | | | | | | |
| Common carp | 152 | 5 | 17 | 6 | 15 | 17 | 3 | 17 | 1 | 5 | 4 | | |
| Golden shiner | 20 | 1 | 11 | 12 | 18 | 10 | 10 | 1 | 4 | 1 | | | |
| Comely shiner | 3,156 | 40 | 24 | 161 | 120 | 153 | 94 | 28 | 19 | 11 | | 3 | |
| Spottail shiner | 178 | 1 | 11 | 48 | 17 | 26 | 7 | 18 | 1 | 2 | | | 1 |
| Swallowtail shiner | 1 | | | | | | | | | | | | |
| Rosyface shiner | | | | | | | | | 1 | | | | |
| **Spotfin shiner** | **595** | **99** | **55** | **209** | **175** | **193** | **52** | **187** | **128** | **146** | **270** | **121** | **96** |
| Mimic shiner | 2 | | | | 1 | | | | | | | | |
| **Bluntnose minnow** | **448** | **24** | **14** | **76** | **47** | **27** | **11** | **38** | **10** | **16** | **16** | **13** | |
| Blacknose dace | | | | | | | | 1 | | | | | |
| Creek chub | 12 | 3 | | 4 | | 1 | 1 | | | | | | |
| Fallfish | 7 | 2 | | 2 | | 3 | | | | | | | |
| Quillback | 9 | 1 | 6 | | 1 | | | 2 | 2 | | | 1 | |
| **White sucker** | **8** | | **1** | | **1** | **2** | | **1** | **1** | | | | |
| Northern hogsucker | 4 | | 1 | | 3 | | 3 | 1 | | | | | |
| Shorthead redhorse | 159 | 11 | 27 | 6 | 19 | 7 | 12 | 16 | 5 | 1 | | | |
| **Channel catfish** | **802** | **41** | **208** | **83** | **78** | **131** | **61** | **158** | **89** | **119** | **10** | **57** | |
| Flathead catfish | 19 | 1 | 6 | 12 | 8 | 8 | 2 | 9 | 2 | | 1 | 2 | |
| Atlantic needlefish | 5 | | | | | | | | | | | | |
| Banded killifish | 221 | 38 | | | 5 | 8 | | | | | | 2 | |
| White perch | 35 | | 1 | 17 | | 1 | | | | | | | |
| Striped bass | 1 | | | | | | | | 1 | | | | |
| Striped bass x white bass | 31 | 1 | | | | | | | | | | | |
| Rock bass | 153 | 9 | 22 | 6 | 10 | 16 | 10 | 4 | 6 | 4 | | | |
| Redbreast sunfish | 4 | 1 | 2 | 2 | 1 | 1 | | | | 1 | 1 | | |
| Green sunfish | 1,221 | 100 | 250 | 230 | 712 | 413 | 91 | 245 | 24 | 36 | 31 | 53 | 2 |
| Pumpkinseed | 10 | 2 | 2 | 3 | 1 | 1 | | 1 | | | | 1 | |
| **Bluegill** | **4,731** | **171** | **386** | **275** | **3,006** | **496** | **146** | **135** | **150** | **30** | **92** | **16** | **7** |
| **Smallmouth bass** | **295** | **16** | **73** | **80** | **56** | **53** | **33** | **169** | **39** | **21** | **6** | **22** | **1** |
| **Largemouth bass** | **214** | **11** | **25** | **10** | **10** | **3** | **5** | **2** | **2** | **5** | **3** | | |
| **White crappie** | **21** | | **2** | **2** | | | | | **2** | | | | |
| Black crappie | 4 | | | | | 1 | | | 1 | | | | |
| Greenside darter | 12 | | | 2 | | 2 | 1 | 1 | | | | 1 | |
| Tessellated darter | 69 | 1 | 3 | 3 | 2 | 4 | | | | | | | |
| Yellow perch | 28 | | | | 1 | | | 1 | | | | | |
| **Chesapeake logperch** | **111** | **3** | **43** | **16** | **17** | **12** | **11** | **22** | | **4** | | | |
| Shield darter | 11 | 1 | 2 | | | | | 1 | | | | | |
| **Walleye** | **146** | | **5** | | | **2** | | | | | | | |
| Total number | 16,342 | 634 | 1,578 | 2,096 | 8,202 | 4,451 | 2,915 | 2,150 | 1,513 | 1,760 | 438 | 309 | 110 |
| Total Species | 37 | 25 | 26 | 25 | 25 | 28 | 19 | 25 | 21 | 17 | 11 | 13 | 6 |

*Temperature-CPUE comparison*

This section describes fish catch at the electrofishing and seining locations during July and August and the measured water temperature at the time of collection. July and August are the two months of the year associated with the highest collection waters temperatures at both the non-thermal and thermal stations in the Pond (Figure 5-1 through Figure 5-9). Elevated water temperatures can result in species-specific avoidance and, thus, the following discussion evaluates the difference in CPUE and species richness with specific emphasis on the RIS.

For this analysis stations are discussed as either non-thermal or thermal 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. Stations that are upstream of the PBAPS thermal discharge that experience natural water temperature conditions are considered non-thermal (Figure 5-22 and Figure 5-23). Electrofishing Stations 161, 189, 190, and 217 are considered thermally influenced and Stations 187, 164, and 165 are considered non-thermal. Seine Stations 214 and 215 are considered thermal influenced and Stations 203, 202, 220, 221, and 208 are considered non-thermal. As previously discussed in Section 5.2, 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.

Electrofishing

Table 5-82 through Table 5-84 provide CPUE by species and observed water temperature for the three non-thermal electrofishing stations during July and August, 2010-2013. For Station 187, the most upstream collection location, water temperature varied from 24.2 to 30.9°C (75.6-87.6°F). Station 187 generally had high fish diversity during both months with 12 to 20 species observed. Ten of the 11 RIS were present during most of the collections. CPUE at Station 187 was highly variable among months and years of collection. Similarly, for Station 165, 10 RIS were observed during July and August, 2010-2013. Water temperature at this location ranged from 20.3 to 32°C (68.5-89.6°F). Six RIS were collected during most months (Gizzard Shad, Spotfin Shiner, Chesapeake Logperch, Bluegill, Smallmouth Bass, Channel Catfish); while others were collected less frequently. Species richness ranged from 9 to 18 species. For Station 164, collection water temperature ranged from 24.4 to 31°C (75.9-87.8°F). A total of 8 RIS were collected with most of the RIS observed during each collection. Total species richness varied from 8 to 13 species. Most of the observed RIS at this location were collected during most months with variable CPUE. Few Walleye or Chesapeake Logerch were collected at this location.

Table 5-85 through Table 5-88 provide CPUE by species and observed water temperature for the four thermally affected electrofishing stations during July and August, 2010-2013. Station 161, the location closest to PBAPS, experienced the highest observed water temperatures ranging from 29.2 to 35.2°C (84.6-95.4°F). Species richness ranged from 6 to 14 species. Greater numbers of species were collected at the lowest water temperatures (n=14 in August 2011, temperature 31.2°C; n=14 in August 2013, temperature 29.2°C) during these two months.

Species richness was generally low at water temperatures that exceeded 33°C. Fewer species were observed during July than August for all years with a total of 8 RIS observed. Two RIS, Chesapeake Logperch and Walleye were only observed in August 2013. The other commonly collected RIS had quite variable CPUE. Station 189 observed water temperature range was 27.7°C to 34.2°C (81.9-93.6°F). Total species richness ranged from 8 to 15, with 9 RIS collected. Most the observed RIS were present during each sample month including Gizzard Shad, Spotfin Shiner, Bluntnose Minnow, Channel Catfish, Bluegill, and Smallmouth Bass. No consistent pattern in species richness or CPUE related to collection temperature was observed. For Station 190, collection temperature ranged from 26.5 to 33.9°C (79.7-93°F). Species richness was similar for most months ranging from 8 to 12 species, although the fewest species were collected at the highest observed water temperature (33.9°C) in July 2011. A total of 8 RIS observed during July and August with CPUE varying widely from month to month and year to year. For example in 2013, 66 Smallmouth Bass were collected in July at water temperature of 31.5 °C and only 13 were collected in August at water temperature of 26.5°C. For the most downstream location (Station 217), water temperature ranged from 26.1 to 33.9°C (79-93°F). All 11 RIS were observed at least once during July or August. Monthly species richness ranged from 10 to 18 species and was not well correlated to water temperature. CPUE varied widely for the RIS. Smallmouth Bass CPUE was much higher during July (55/ 0.5hr) and August (21/ 0.5hr) 2013 compared to most other months. Chesapeake Logperch catch was also higher during August 2013 (28/0.5hr) compared to most other collections. Otherwise, there were no well-defined trends in RIS CPUE among years.

Seine

Table 5-89 through Table 5-93 provide CPUE by species and observed water temperature for the five non-thermal seining stations during July and August, 2010-2013. For Stations 202 and 203, the most upstream stations which are both adjacent to islands, water temperature varied from 25.3 to 28.9°C (77.5-84°F). Station 202 species richness ranged from 4 to 8 species and Station 203 species richness ranged from 2 to 10 species. Seven of the 11 RIS were present during at least one collection at these two stations. CPUE was highly variable among months and years of collection with Spotfin and Spottail Shiner present in all collections. For Station 220, collection water temperature ranged from 24.8 to 30.8°C (76.6-87.4°F). Species richness varied from 2 to 14 species with highly variable CPUE. A total of 6 RIS were collected with only Spotfin Shiner and Smallmouth Bass observed during each collection. Spotfin Shiner CPUE was generally high, ranging from 11 to 50 individuals per collection. At Station 221, species richness ranged from 4 to 13 species with .8 RIS observed. Water temperature at this location ranged from 21.2 to 31.2 °C (70.2-88.2°F). The Spotfin Shiner was the only RIS collected in every month at this station; while the other RIS were collected less frequently. For the most downstream location (Station 208) water temperature ranged from 26.5 to 31.7°C (79.7-89.1°F). A total of 7 RIS were collected at this station with species richness ranging from 3 to 13 species. Spotfin Shiner had the highest CPUE and was collected during all months. Most other species were collected infrequently with few individuals in each collection.

Table 5-94 and Table 5-95 provide CPUE by species and observed water temperature for the two thermal seining stations during July and August, 2010-2013. Station 214, the location

closest to PBAPS, experienced the highest observed water temperatures, ranging from 31.4 to 36.6°C (88.5-97.9°F). Species richness ranged from 1 to 7 species. Species richness was low at water temperatures that exceeded 34°C (93.2°F). Only Spotfin Shiner was collected at the highest observed water temperature (36.6°C). Fewer species were observed during July compared to August for all years. A total of 8 RIS were observed across all years. CPUE was low for all species except Spotfin Shiner. Station 215 observed water temperature range was 30.3°C to 36.2°C (86.5-97.2°F). Species richness ranged from 1 to 7, with 7 RIS collected. Only Spotfin Shiner was collected during each month with CPUE for this species being high for most months. Similar to Station 214, fewer species were collected at water temperatures greater than 34°C.

Discussion

The observations of fish community composition at the electrofishing stations during July and August indicated widely varying CPUE for most species and variation in species richness at both thermally affected and non-thermally affected stations. Stations 187 and 165 (non-thermal) and 217 (thermal) had the greatest observed species richness among the electrofishing stations.

Gizzard Shad CPUE was extremely variable and tended to comprise a large percentage of the overall catch for most locations. This is typical for this species which can be collected in large numbers due to presence of a large school within a sample reach. Other RIS were collected frequently at most electrofishing stations during these months including Bluegill, Smallmouth Bass, Channel Catfish, and Spotfin Shiner. Chesapeake Logperch abundance was highest at Stations 187 and 217 with CPUE typically lower at the other locations. This species was collected during each month for all years at these two locations. Several RIS had low CPUE and occurred infrequently during these months including Walleye, White Sucker, and White Crappie. Few White Sucker or White Crappie were collected during the entire four year study regardless of collection month. Relative abundance of these two species is low in the Pond.

CPUE and species richness for most fish species was not related to collection temperature except at Station 161 where fewer species were collected at the highest water temperatures. A pattern of avoidance was observed at Station 161 at the highest water temperatures (>33 °C) with the lowest species richness (n =6) in July and August 2010. Species richness during these periods was lower than the lowest values observed at all other non-thermal or thermal stations. CPUE at this station was also low at the highest water temperatures for the limited number of species observed in July, 2011 and 2013. Figure 5-47, provided previously in Section 5 (Fish Metrics and CPUE) illustrates month to month variation in species richness among station and shows a clear depression in richness during July and in some years August at Station 161. No clear pattern of avoidance at the other thermally affected locations was observed.

The observations of fish community composition at the seining stations during July and August indicated widely varying CPUE for most species and variation in species richness among locations. Stations 220 and 221 (non-thermal) had the greatest observed species richness among the seine stations. The highest observed collection water temperatures were observed at Stations 214 and 215 which are both thermally affected. At the highest water temperatures

few species were present and CPUE was low for the species that were present with the exception of Spotfin Shiner. Spotfin Shiner CPUE was high for some months even at the highest observed water temperatures. Species richness was low at both thermally affected stations with few species observed when water temperature exceeded 34°C, an indication that most fishes avoided these areas. Fish avoidance at Stations 214 and 215 occurred during most July and August collections with the exception of a few collections where species richness was comparable to the non-thermal stations.

Wide variation in CPUE among species and months was observed among the seine stations. Spotfin Shiner had the highest CPUE and was the most commonly collected species among the stations. This species was present at the highest water temperatures, an indication that this species may be more tolerant to higher water temperatures than most other species in the Pond. Most other fishes were collected sporadically with quite variable CPUE. For example, White Sucker CPUE was low for most months and years with exception of Station 221 where 29 individuals were collected in August 2013, more than the combined total for all other stations and months.

In 2013 more species were observed, at both thermal and non-thermal locations for both electrofishing and seining, as compared to previous years' collections in July and August. This general observation was most evident in the electrofishing catch with species richness for the seine collections being more variable. The greater species richness may be related to higher River flows and lower overall water temperatures observed in July and August 2013 compared to previous years. Species preferring these cooler conditions combined with higher overall flows may have moved farther downstream into the mid- and lower-Pond where the field collections occurred. In contrast, during 2010 fewer species were observed at most electrofishing locations compared to the other years.

Besides year to year variation, station differences related to physical habitat and location in the Pond also determine species distribution and occurrence at a given station. The upstream non-thermal stations at the upper part of the Pond are influenced more by flows from Holtwood Dam (free-flowing riverine environment) and the lower portions of the Pond are more characteristic of impoundment, with little direct influence from Holtwood Dam releases. Thus the stations are located on a gradient of influence from upstream to downstream that likely, in part, shapes the characteristics of the fish community present at a given location.

Observed collection water temperature is a useful means to determine the instantaneous water temperature-fish occurrence relationship. However, the recent water temperature history at a station is also likely to be quite important in determining the fish community present at a given location in the Pond. Instantaneous water temperature, although related, does not account for the days or weeks leading up to the collection. Water temperatures at a given location, particularly at the thermally influenced stations, could have been quite different from the observed instantaneous water temperatures based on the highly variable nature of River flow and ambient water temperature in the Pond. As discussed previously in Section 3.4, flow and ambient water temperature are strong predictors of the spatial characteristics of the PBAPS thermal plume.

Table 5-82. CPUE (number/0.5hr) and water temperature for fishes collected with a boat electrofisher at Station 187, July and August 2010-2013.

| | 2010 | | 2011 | | 2012 | | 2013 | |
|---|---|---|---|---|---|---|---|---|
| | July | August | July | August | July | August | July | August |
| Collection water temperature (°C) | 28.5 | 26.8 | 29.2 | 26 | 28.1 | 26.1 | 30.9 | 24.2 |
| **Gizzard shad** | **6** | **21** | **1,051** | **34** | **623** | **39** | **17** | **49** |
| Common carp | 5 | 6 | 2 | 10 | | 12 | 3 | 5 |
| Golden shiner | | | | 2 | | | | |
| Comely shiner | 7 | 3 | 4 | 9 | 20 | 15 | 2 | 20 |
| Spottail shiner | | 11 | | 22 | | 1 | | 1 |
| **Spotfin shiner** | **12** | **9** | **562** | **12** | **5** | | **47** | **5** |
| **Bluntnose minnow** | **5** | **2** | | **60** | | **2** | **4** | **7** |
| Quillback | | | | 1 | 2 | | | |
| **White sucker** | | | **2** | | | | **1** | |
| Northern hogsucker | | | | | 3 | 1 | 2 | 1 |
| Shorthead redhorse | | | 3 | 10 | 18 | 19 | 26 | 27 |
| **Channel catfish** | **13** | **7** | **9** | **30** | **20** | **15** | **26** | **23** |
| Flathead catfish | | | 2 | | 4 | | 1 | 1 |
| White perch | | | | 1 | | | | 3 |
| Rock bass | 19 | 11 | 12 | 8 | 10 | 7 | 10 | 9 |
| Green sunfish | 2 | 2 | 1 | 8 | 3 | | 4 | 5 |
| Pumpkinseed | | | | | | 1 | | |
| **Bluegill** | **2** | **15** | **2** | **72** | **2** | **7** | **7** | **16** |
| **Smallmouth bass** | **11** | **1** | **10** | **11** | **5** | **4** | **16** | **18** |
| **Largemouth bass** | | **1** | **1** | **2** | **2** | **3** | **5** | **1** |
| Greenside darter | | 1 | | | 1 | | | |
| Tessellated darter | | 6 | 1 | 1 | | | | |
| Yellow perch | | | | 1 | | 1 | 6 | 4 |
| **Chesapeake logperch** | **3** | **7** | **1** | **11** | **4** | **2** | **6** | **6** |
| Shield darter | | 2 | | | | | | |
| **Walleye** | **1** | **2** | **2** | **1** | **3** | **4** | **2** | **15** |
| Total CPUE | 86 | 107 | 1,665 | 306 | 725 | 133 | 185 | 216 |
| Total species | 12 | 17 | 16 | 20 | 16 | 16 | 18 | 19 |

Table 5-83. CPUE (number/0.5hr) and water temperature for fishes collected with a boat electrofisher at Station 164, July and August 2010-2013.

| | 2010 | | 2011 | | 2012 | | 2013 | |
|---|---|---|---|---|---|---|---|---|
| | July | August | July | August | July | August | July | August |
| Collection water temperature (°C) | 28.5 | 27 | 31 | 26.3 | 28.2 | 26.5 | 30.4 | 24.4 |
| **Gizzard shad** | **20** | **451** | **31** | **2,061** | **354** | **108** | **3** | **15** |
| Common carp | 2 | | | | | | | 1 |
| Comely shiner | 5 | 5 | 1 | 27 | 53 | 18 | 5 | 12 |
| Spottail shiner | | | | | 4 | 1 | 3 | |
| **Spotfin shiner** | **21** | **16** | **17** | **40** | **30** | | **39** | **4** |
| **Bluntnose minnow** | | | | **1** | **3** | **1** | **2** | **1** |
| Fallfish | | | | | | 1 | | |
| Northern hogsucker | | | | | | 1 | | |
| Shorthead redhorse | | | | 1 | 1 | | | |
| **Channel catfish** | **26** | **24** | **12** | **18** | **22** | **7** | **27** | **34** |
| Flathead catfish | 3 | 1 | | 1 | 2 | 2 | | 3 |
| Rock bass | 1 | 2 | 2 | 5 | 8 | | 2 | 3 |
| Redbreast sunfish | | | | | 3 | | | |
| Green sunfish | 5 | 12 | 3 | 31 | 3 | 4 | 6 | 11 |
| **Bluegill** | **3** | **10** | **1** | **15** | **29** | **6** | **11** | **25** |
| **Smallmouth bass** | **10** | | **6** | **8** | **6** | **5** | **9** | **16** |
| Tessellated darter | | 1 | | | | | | |
| Yellow perch | | | | | | | | 1 |
| **Chesapeake logperch** | | | | | | | **1** | |
| **Walleye** | | | | | | | | **3** |
| Total CPUE | 96 | 522 | 73 | 2,208 | 518 | 154 | 108 | 129 |
| Total species | 10 | 9 | 8 | 11 | 13 | 11 | 11 | 13 |

Table 5-84. CPUE (number/0.5hr) and water temperature for fishes collected with a boat electrofisher at Station 165, July and August 2010-2013.

| | 2010 | | 2011 | | 2012 | | 2013 | |
|---|---|---|---|---|---|---|---|---|
| | July | August | July | August | July | August | July | August |
| Collection water temperature (°C) | 28 | 29 | 32 | 27 | 28.8 | 26.2 | 30.6 | 20.3 |
| **Gizzard shad** | **35** | | **5** | **16** | **210** | **57** | **2** | **13** |
| Common carp | 5 | | | | 3 | 3 | | 2 |
| Comely shiner | 9 | 2 | 1 | 22 | 42 | 7 | 6 | 9 |
| Spottail shiner | 1 | | | 27 | 6 | | | |
| Swallowtail shiner | | | | 1 | | | | |
| **Spotfin shiner** | **3** | **9** | **4** | **5** | **2** | | **6** | **1** |
| Mimic shiner | | | | | 2 | | | |
| **Bluntnose minnow** | **1** | **3** | | **4** | **1** | | **1** | |
| Quillback | 1 | | | | | | 1 | |
| Northern hogsucker | | | | 1 | | | | |
| Shorthead redhorse | | | | 1 | | | 1 | |
| **Channel catfish** | **26** | **37** | **16** | **28** | **19** | **17** | **27** | **28** |
| Flathead catfish | 2 | | 2 | 2 | 1 | | | 2 |
| White perch | | | | | | | | 1 |
| Rock bass | 22 | 11 | 6 | 9 | 5 | 7 | | 4 |
| Redbreast sunfish | | | | | 1 | | | |
| Green sunfish | 1 | 44 | 2 | 25 | 4 | 25 | 8 | 18 |
| **Bluegill** | **6** | **51** | **2** | **54** | **9** | **14** | **8** | **14** |
| **Smallmouth bass** | **16** | **3** | **1** | **3** | **6** | **5** | **18** | **16** |
| **Largemouth bass** | **1** | | | | | | | |
| **White crappie** | | | | | | | | **1** |
| Greenside darter | | | | 2 | | | | |
| Tessellated darter | 1 | 1 | | 1 | | | | 1 |
| Banded darter | | 1 | | | | | | |
| **Chesapeake logperch** | **8** | **8** | | **17** | | **1** | **10** | **4** |
| Shield darter | | 1 | | 10 | | | | 1 |
| **Walleye** | | | | | | | | **2** |
| Total CPUE | 138 | 171 | 39 | 228 | 311 | 136 | 88 | 117 |
| Total species | 16 | 12 | 9 | 18 | 14 | 9 | 11 | 16 |

Table 5-85. CPUE (number/0.5hr) and water temperature for fishes collected with a boat electrofisher at Station 161, July and August 2010-2013.

| | 2010 | | 2011 | | 2012 | | 2013 | |
|---|---|---|---|---|---|---|---|---|
| | July | August | July | August | July | August | July | August |
| Collection water temperature (°C) | 33.5 | 35 | 35.2 | 31.2 | 33.9 | 32.1 | 35.2 | 29.2 |
| **Gizzard shad** | **249** | **17** | | **1,050** | **19** | **1,012** | | **22** |
| Common carp | | | | 1 | | | | 2 |
| Golden shiner | | | | | | 1 | | |
| Comely shiner | | | | 1 | | 9 | | 74 |
| Spottail shiner | | | | 13 | 1 | | | 3 |
| Rosyface shiner | | | | | | 1 | | |
| **Spotfin shiner** | **3** | **4** | **3** | **17** | **33** | **46** | **7** | **10** |
| **Bluntnose minnow** | | | | **3** | **4** | **1** | | **4** |
| Quillback | | | 1 | 1 | | | | |
| Shorthead redhorse | | | | 1 | | | | 2 |
| **Channel catfish** | **10** | **13** | **17** | **32** | **89** | **15** | **26** | **11** |
| Flathead catfish | | | 1 | 1 | | | 1 | 1 |
| Redbreast sunfish | 1 | | | | | | | |
| Green sunfish | 1 | 12 | 8 | 97 | 19 | 14 | 30 | 29 |
| Pumpkinseed | | | | 1 | | | 1 | |
| **Bluegill** | **1** | **1** | **2** | **5** | **10** | **88** | **7** | **51** |
| **Smallmouth bass** | | **1** | **1** | **4** | **8** | **9** | **20** | **24** |
| Greenside darter | | | | | | | 1 | |
| **Chesapeake logperch** | | | | | | | | **1** |
| **Walleye** | | | | | | | | **1** |
| Total CPUE | 265 | 48 | 33 | 1,227 | 183 | 1,196 | 93 | 235 |
| Total species | 6 | 6 | 7 | 14 | 8 | 10 | 8 | 14 |

Table 5-86. CPUE (number/0.5hr) and water temperature for fishes collected with a boat electrofisher at Station 189, July and August 2010-2013.

| | 2010 | | 2011 | | 2012 | | 2013 | |
|---|---|---|---|---|---|---|---|---|
| | July | August | July | August | July | August | July | August |
| Collection water temperature (°C) | 30.8 | 30.1 | 34.2 | 28.8 | 31 | 29.8 | 32.7 | 27.7 |
| **Gizzard shad** | **2,054** | **18** | | **754** | **3** | **313** | **5** | **5** |
| Common carp | | | 4 | 1 | 3 | 2 | | |
| Golden shiner | | 1 | | | | 3 | | |
| Comely shiner | 1 | | | 47 | 4 | 5 | 2 | 10 |
| Spottail shiner | | 1 | | | | | 1 | 15 |
| **Spotfin shiner** | **3** | **2** | **12** | **19** | **1** | **3** | **19** | **5** |
| Mimic shiner | | | | 1 | | | | |
| **Bluntnose minnow** | | **2** | **1** | **3** | **1** | **1** | **6** | **11** |
| Shorthead redhorse | | | | 1 | | | | 2 |
| **Channel catfish** | **1** | **8** | **10** | **11** | **8** | **6** | **22** | **16** |
| Flathead catfish | | | 1 | 3 | | 1 | | 5 |
| Rock bass | 1 | 1 | | 2 | 2 | 4 | 4 | 3 |
| Redbreast sunfish | | | 1 | | | | | |
| Green sunfish | 2 | 17 | 3 | 33 | 6 | 8 | 5 | 37 |
| **Bluegill** | **14** | **18** | **8** | **50** | **11** | **15** | **30** | **48** |
| **Smallmouth bass** | **1** | **5** | **6** | **5** | **2** | **2** | **13** | **9** |
| **Largemouth bass** | | **1** | **2** | **2** | | | **2** | **7** |
| **White crappie** | | | | | | | **2** | **1** |
| Black crappie | | | | | | | 1 | |
| **Chesapeake logperch** | | | | | | | | **2** |
| Total CPUE | 2,077 | 74 | 48 | 932 | 41 | 363 | 112 | 176 |
| Total species | 8 | 11 | 10 | 14 | 10 | 12 | 13 | 15 |

Table 5-87. CPUE (number/0.5hr) and water temperature for fishes collected with a boat electrofisher at Station 190, July and August 2010-2013.

| | 2010 | | 2011 | | 2012 | | 2013 | |
|---|---|---|---|---|---|---|---|---|
| | July | August | July | August | July | August | July | August |
| Collection water temperature (°C) | 29.5 | 30 | 33.9 | 28.7 | 30.1 | 29.3 | 31.5 | 26.5 |
| **Gizzard shad** | **445** | **19** | **26** | **1,045** | **12** | **22** | **19** | **8** |
| Common carp | | | | 2 | | 3 | | |
| Golden shiner | 6 | 2 | 1 | 4 | | | | |
| Comely shiner | 14 | 5 | 9 | 20 | 25 | 39 | 11 | 7 |
| Spottail shiner | | 1 | | 3 | | | 3 | |
| **Spotfin shiner** | **7** | **7** | **15** | **31** | **1** | **2** | **26** | **6** |
| **Bluntnose minnow** | | **2** | | **7** | | **1** | **19** | **2** |
| **Channel catfish** | **6** | **17** | **13** | **18** | **12** | **22** | **36** | **59** |
| Flathead catfish | | | | | 1 | | | 1 |
| Rock bass | | | | 1 | | | | |
| Green sunfish | 6 | 28 | 4 | 77 | 31 | 44 | 67 | 106 |
| **Bluegill** | **14** | **39** | **1** | **46** | **26** | **286** | **24** | **58** |
| **Smallmouth bass** | **5** | **4** | **6** | **3** | **11** | **2** | **66** | **13** |
| **Largemouth bass** | | | | | **3** | | | **3** |
| Greenside darter | | | | | | | 1 | |
| Tessellated darter | | | | | | 1 | | 1 |
| Yellow perch | | | | | | | 1 | |
| **Chesapeake logperch** | **1** | | | | **1** | **1** | **10** | **9** |
| Total CPUE | 504 | 124 | 75 | 1,257 | 123 | 423 | 283 | 273 |
| Total species | 9 | 10 | 8 | 12 | 10 | 11 | 12 | 12 |

Table 5-88. CPUE (number/0.5hr) and water temperature for fishes collected with a boat electrofisher at Station 217, July and August 2010-2013.

| | 2011 | | 2012 | | 2013 | |
|---|---|---|---|---|---|---|
| | July | August | July | August | July | August |
| Collection water temperature (°C) | 33.9 | 29.8 | 30.5 | 28.4 | 31.5 | 26.1 |
| **Gizzard shad** | **1,051** | **2,050** | **259** | **18** | **15** | **22** |
| Common carp | 3 | 1 | 3 | 5 | | |
| Golden shiner | | 13 | 7 | 13 | 1 | 8 |
| Comely shiner | 2 | 14 | 61 | 47 | 4 | |
| Spottail shiner | 1 | 14 | | | 2 | 2 |
| **Spotfin shiner** | 12 | 26 | | | **7** | **2** |
| **Bluntnose minnow** | **2** | | **3** | **9** | **1** | **5** |
| Creek chub | | | 1 | | | |
| **White sucker** | | | | **1** | **1** | |
| Northern hogsucker | | | 3 | 3 | 1 | |
| Shorthead redhorse | 1 | 4 | 11 | 15 | | 9 |
| **Channel catfish** | **6** | **31** | **23** | **20** | **9** | **32** |
| Flathead catfish | | 2 | 1 | | | 1 |
| Rock bass | 4 | 3 | 8 | 1 | 1 | 3 |
| Redbreast sunfish | | | | 1 | | |
| Green sunfish | 11 | 305 | 13 | 562 | 13 | 25 |
| **Bluegill** | **16** | **55** | **47** | **2,767** | **61** | **108** |
| **Smallmouth bass** | **6** | **3** | **10** | **3** | **55** | **21** |
| **Largemouth bass** | **4** | 1 | **1** | | **2** | **15** |
| **White crappie** | | | | | | **2** |
| Greenside darter | | 2 | 1 | | | |
| Tessellated darter | | | | | | 2 |
| **Chesapeake logperch** | **4** | **9** | **10** | **12** | **9** | **28** |
| Shield darter | | | | | 1 | 2 |
| **Walleye** | | | | | | **1** |
| Total CPUE | 1,123 | 2,520 | 462 | 3,474 | 183 | 288 |
| Total species | 13 | 11 | 14 | 10 | 16 | 18 |

Table 5-89. CPUE (number/collection) and water temperature for fishes collected with a seine at Station 202, July and August 2010-2013.

| | 2010 | | 2011 | | 2012 | | 2013 | |
|---|---|---|---|---|---|---|---|---|
| | July | August | July | August | July | August | July | August |
| Collection water temperature (°C) | 28.5 | 27.0 | 28.4 | 26.6 | 28.7 | 28.8 | 28.7 | 25.3 |
| **Gizzard shad** | | **1** | | | | | | |
| Comely shiner | | | | 2 | | 3 | 1 | |
| Common shiner | | | 4 | | | | | |
| Spottail shiner | 6 | 8 | 4 | 11 | 1 | 6 | 18 | 45 |
| **Spotfin shiner** | **13** | **17** | **11** | **12** | **14** | **8** | **6** | **8** |
| **Bluntnose minnow** | | **6** | **9** | **12** | | **19** | **15** | **4** |
| Fallfish | | | | 2 | | | | |
| Quillback | 2 | | 51 | | | 1 | 1 | |
| Northern hogsucker | | | | | | 1 | | |
| Shorthead redhorse | 1 | | | | | | 1 | 2 |
| **Channel catfish** | **1** | | | | | | | |
| Banded killifish | | 1 | | | | | | |
| Rock bass | | | | 1 | | | 1 | |
| **Bluegill** | **1** | **31** | | **30** | | **9** | | |
| **Smallmouth bass** | **1** | | **2** | | **1** | | **2** | **2** |
| Tessellated darter | 6 | 11 | | | 1 | 15 | | 1 |
| **Chesapeake logperch** | | | | | | | | **1** |
| Total CPUE | 31 | 75 | 81 | 70 | 17 | 62 | 45 | 63 |
| Total species | 8 | 7 | 6 | 7 | 4 | 8 | 8 | 7 |

Table 5-90. CPUE (number/collection) and water temperature for fishes collected with a seine at Station 203, July and August 2010-2013.

| | 2010 | | 2011 | | 2012 | | 2013 | |
|---|---|---|---|---|---|---|---|---|
| | July | August | July | August | July | August | July | August |
| Collection water temperature (°C) | 28 | 26.5 | 27.6 | 25.3 | 28 | 28.9 | 28 | 25.4 |
| **Gizzard shad** | **1** | **2** | | **3** | | **3** | | |
| River chub | | | | | | 2 | | |
| Comely shiner | | | | | | 1 | 1 | 5 |
| Spottail shiner | 7 | 11 | 1 | 3 | 35 | 8 | 41 | 20 |
| Swallowtail shiner | 1 | 2 | | | | | | |
| **Spotfin shiner** | **4** | **9** | **3** | **4** | **1** | **3** | **14** | **5** |
| **Bluntnose minnow** | **1** | | **16** | **86** | | **1** | **35** | |
| Fallfish | 1 | | | 5 | | | | |
| Quillback | | | 1 | 1 | | 1 | | |
| Northern hogsucker | | | | | | 2 | | |
| Shorthead redhorse | 1 | | | | | 1 | | |
| **Channel catfish** | | | | **2** | | | | |
| Banded killifish | | 1 | | | | | | |
| Green sunfish | | | | 1 | | | | |
| **Bluegill** | | **4** | | **23** | | | | |
| **Smallmouth bass** | | | | | | **1** | **2** | |
| **Largemouth bass** | | | **8** | | | | | |
| Total CPUE | 16 | 33 | 29 | 131 | 37 | 31 | 93 | 30 |
| Total species | 7 | 6 | 5 | 9 | 2 | 10 | 5 | 3 |