FINAL STUDY REPORT
IMPACT OF PLANT OPERATION ON MIGRATORY FISH REPRODUCTION
RSP 3.21

CONOWINGO HYDROELECTRIC PROJECT

FERC PROJECT NUMBER 405

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EXECUTIVE SUMMARY

Exelon Generation Company, LLC (Exelon) has initiated with the Federal Energy Regulatory Commission (FERC) the process of relicensing the 573-megawatt Conowingo Hydroelectric Project (Conowingo Project). The current license for the Conowingo Project was issued on August 14, 1980 and expires on September 1, 2014. FERC issued the final study plan determination for the Project on February 4, 2010, approving the revised study plan with certain modifications.

The final study plan determination required Exelon to conduct a study to examine the impact of plant operations on reproduction of the target anadromous fishes: American shad (*Alosa sapidissima*), hickory shad (*A. mediocris*), river herring (blueback herring, *A. aestivalis*, and alewife, *A. psuedoharangus*), striped bass (*Morone saxatilis*), and white perch (*M. americana*) above and below Conowingo Dam by reviewing existing information. This review included: spawning habitat requirements for these species; existing relevant survey data for early life stages of anadromous fishes in Conowingo Pond and the lower Susquehanna River (below) Conowingo Dam; and existing data regarding characterization of the hydraulic conditions below Conowingo Dam. This study complements: (1) an instream flow habitat assessment study (Study 3.16) that models spawning habitat availability and persistence under a range of flow levels; (2) a fish passage impediment study (Study 3.7) that examined the ability of American shad to migrate up the lower Susquehanna River and locate the Conowingo Dam east fish lift (EFL) under different discharge levels; and (3) existing fish early life stage data for the lower Susquehanna River reviewed in the characterization of downstream aquatic communities study (Study 3.18).

An initial study report (ISR) was filed on February 22, 2011, containing Exelon's 2010 study findings. An initial study report meeting was held on March 9, 10 and 11, 2011 with resource agencies and interested members of the public. Formal comments on the ISR including requested study plan modifications were filed with FERC on April 27, 2011 by Commission Staff, several resource agencies and interested members of the public. Exelon filed responses to the ISR comments with FERC on May 27, 2011. On June 24, 2011, FERC issued a study plan modification determination order. The order specified what, if any, modifications to the ISRs should be made. For this study, FERC's June 24, 2011 order required no modifications to the original study plan. This final study report is being filed with the Final License Application for the Project. An addendum to this report details the results of ichthyoplankton sampling completed in 2012 for the river reach below Conowingo Dam.

Water temperature is thought to be the primary trigger for American shad spawning, but photoperiod, current velocity, and turbidity may also influence spawning timing. Water temperature and velocity were thought to be the most important variables in evaluation of spawning habitat suitability, but depth and substrate are also considered to impact suitability. In the lower Susquehanna River, studies in the early 1980's demonstrated American shad spawning in the lower riverine reach to upper tidal reach in the vicinity of Port Deposit and Lapidum, Maryland. American shad eggs were collected primarily in the tidal portion of the river with highest densities near the head of tide around Spencer Island. In studies conducted in both the 1960's and 2000's, small numbers of eggs have also been collected in upper Conowingo Pond (where conditions are somewhat more riverine than the lentic lower Conowingo Pond). It was not clear whether those were spawned in the Pond or farther upstream, and it was determined that habitat there was marginal for spawning and any spawning that did occur was not thought to materially contribute to annual shad production in the Susquehanna River.

Hickory shad spawning habitat preferences are not as well documented, and may be more diverse, but typically overlap with American shad; however, spawning runs tend to occur earlier for hickory shad. Mature adult hickory shad collections are known from both the Octoraro and Deer Creek tributaries to the lower Susquehanna River and in recent years, the hickory shad spawning run has exhibited resurgence. Icthyoplankton studies conducted during the 1980's yielded only a few hickory shad eggs from the lower Susquehanna River. More recently, the Susquehanna River hickory shad population has expanded and currently the largest hickory shad spawning population in Maryland waters occurs in Deer Creek, demonstrating consistent repeat spawning and age structure.

Where the river herring species are sympatric (ranges overlap), as in the Chesapeake Bay system, spawning habitat preferences differ somewhat. Alewife spawning generally occurs between 10-22°C and blueback herring spawning migrations typically occur a few weeks after the peak alewife runs, when water temperatures range from 14-25°C. Blueback herring appear to prefer to spawn in swift flows while alewife often select slow-moving water habitats for spawning. As a result, differences in substrate in spawning habitats have also been observed. Alewife spawn over a range of substrates from gravel to organic detritus and blueback herring spawn over gravel and sand where fertilized eggs adhere to the substrate. In the Susquehanna River, small river herring spawning populations were known in Deer Creek and Octoraro Creek. Icthyoplankton studies conducted during the 1980's resulted in river herring egg collections with the highest densities in the riverine (non-tidal) portion of the lower Susquehanna River near Conowingo Dam.

Chesapeake Bay and its tributaries comprise some of the most important spawning and nursery grounds for striped bass. Spawning habitat is often associated with the upper estuarine portion of coastal rivers, typically within the first 28 mi of freshwater. The Susquehanna River may have historically provided primary spawning habitat. Spawning may have shifted from the lower Susquehanna River to the Elk River and Chesapeake and Delaware (C&D) Canal as a result of dredging the Canal to sea level in 1927 and completion of Conowingo Dam in 1928.Currently, however, only a minimal amount of spawning is thought to occur in the upper Chesapeake Bay proper north of Turkey Point and researchers have hypothesized that the upper Bay, rather than the Susquehanna River, was historically the primary spawning ground because its proximity to more saline waters makes it more similar to other Chesapeake Bay spawning habitats. Photoperiod and water temperature are the important controlling effects on striped bass spawning, but some studies have suggested that spawning habitat suitability is positively correlated with increased river discharge as well. Most striped bass spawning productivity occurs when water temperatures are 13.5-18.0 °C. Generally, substrate is not considered to be an important factor to striped bass spawning. In ichthyoplankton surveys conducted in the 1980's, no striped bass eggs were collected.

Hydraulic conditions of the Susquehanna River below Conowingo Dam are generally dictated by the Susquehanna River natural flow and by the operation of Safe Harbor Dam. Additionally, a minimum flow agreement is in effect resulting in springtime minimums of 10,000 to 7,500 cfs. Typically, higher flows occur during spring. Substrate of the river below Conowingo Dam varies largely from boulders to pea sized pebbles in the riverine stretch (Rowland Island to the lower tip of Spencer Island). In the lower river or tidal-influenced portion (generally Lower Spencer Island to mouth of River) current velocities are reduced. From just downstream of Spencer Island to the mouth of the river, substrate transitions from similar to the riverine section, to greater concentrations of sand and silt along with the boulders and rocks, to primarily sand and mud, to silt deposition at the Susquehanna Flats off of the mouth of the river in Chesapeake Bay.

Modeling of the effects of Conowingo Dam operations on habitat suitability for anadromous fishes will be submitted in Conowingo Report 3.16-Instream Flow Habitat Assessment below Conowingo Dam.

Successful American shad spawning was documented in the lower Susquehanna River in a series of studies conducted in the 1980's. In addition, the MDNR documented a robust spawning population in the lower Susquehanna River. Although numbers estimated in 2009 have trended down since 2001 with EFL counts also trended down since 2002, results are likely reflective of the magnitude of cultured larval shad stocking in the system to some extent, as stocking has fallen off in recent years (SRAFC 2010); 48% of

American shad otoliths collected from the WFL and examined for hatchery marking were of hatchery origin. Environmental conditions documented for successful shad spawning are likely to not be altered by normal Conowingo Project spring operations.

Hickory shad has not been and is likely to remain not effected by Project operations in years to come. The Deer Creek population of hickory shad is now the largest in Maryland; the area just downstream of the mouth is targeted for collection of brood stock in MDNR's development of a hatchery program for restoration of hickory shad in other Chesapeake Bay tributaries. Deer Creek spawning habitat is largely unaffected by Project operations.

River herring (blueback and alewife) were documented to have spawned in the upper and lower riverine sections of the Susquehanna River below Conowingo Dam in the early 1980s. Although numbers are declining in the river, these declines cannot be attributable to Project operations, since populations are declining at the same rate throughout the Northeast. There are many potential causes for River herring decline and Project operations in the Susquehanna River are considered the least of those causes.

Striped bass populations have increased over the years and are considered to be thriving. Striped bass may have spawned in the lower Susquehanna River once, but that spawning habitat is believed to have shifted to the upper Chesapeake Bay and the C&D Canal. Clearly, Conowingo Dam operations have no effect on the success of striped bass spawning.

White perch were the dominant species collected in ichthyoplankton collections during the 1980's studies. It is evident that suitable habitat was available and successfully used. Since the primary spawning area was determined to be the upper tidal reach of the Susquehanna River, the potential for Conowingo Project operations impacts are minimized.

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Agencies

Exelon	Exelon Generation Company, LLC
FERC	Federal Energy Regulatory Commission
MDNR	Maryland Department of Natural Resources
PFBC	Pennsylvania Fish and Boat Commission
USGS	United States Geological Survey

Units of Measure

C	Celsius, Centigrade
cfs	cubic feet per second
cm	centimeter
ft	foot
h	hour
in	inch
km	kilometers
kW	kilowatt
l	liter
m	meter
mg	milligram
mi	statute mile
mm	millimeter
MW	megawatt
ppt	parts per thousand
s	second
V	volt

Miscellaneous

C&D	Chesapeake and Delaware
DC	Direct Current
DO	Dissolved Oxygen
EFL	East Fish Lift
HSI	Habitat Suitability Index
IFIM	Instream Flow Incremental Methodology
ILP	Integrated Licensing Process
MRPSP	Muddy Run Pumped Storage Project
NOI	Notice of Intent
PAD	Pre-Application Document
PECO	Philadelphia Electric Company
PSP	Proposed Study Plan
RSP	Revised Study Plan
VVP	Variable Voltage Pulsator

1.0 INTRODUCTION

Exelon Generation Company, LLC (Exelon) has initiated with the Federal Energy Regulatory Commission (FERC) the process of relicensing the 573-megawatt (MW) Conowingo Hydroelectric Project (Project). Exelon is applying for a new license using the FERC's Integrated Licensing Process (ILP). The current license for the Conowingo Project was issued on August 14, 1980 and expires on September 1, 2014.

Exelon filed its Pre-Application Document (PAD) and Notice of Intent (NOI) with FERC on March 12, 2009. On June 11 and 12, 2009, a site visit and two scoping meetings were held at the Project for resource agencies and interested members of the public. Following these meetings, formal study requests were filed with FERC by several resource agencies. Many of these study requests were included in Exelon's Proposed Study Plan (PSP), which was filed on August 24, 2009. On September 22 and 23, 2009, Exelon held a meeting with resource agencies and interested members of the public to discuss the PSP.

Formal comments on the PSP were filed with FERC on November 22, 2009 by Commission staff and several resource agencies. Exelon filed a Revised Study Plan (RSP) for the Project on December 22, 2009. FERC issued the final study plan determination for the Project on February 4, 2010, approving the RSP with certain modifications.

The final study plan determination required Exelon to conduct a study to examine the impact of Conowingo Hydroelectric Project operations on migratory fish reproduction above and below Conowingo Dam. The study was to be conducted by reviewing literature and existing information regarding spawning habitat requirements of anadromous American shad (*Alosa sapidissima*), hickory shad (*A. mediocris*), river herring (*A. aestivalis* and *A. psuedoharangus*), striped bass (*Morone saxatilis*), and white perch (*M. americana*).

An initial study report (ISR) was filed on February 22, 2011, containing Exelon's 2010 study findings. An initial study report meeting was held on March 9, 10 and 11, 2011 with resource agencies and interested members of the public. Formal comments on the ISR including requested study plan modifications were filed with FERC on April 27, 2011 by Commission Staff, several resource agencies and interested members of the public. Exelon filed responses to the ISR comments with FERC on May 27, 2011. On June 24, 2011, FERC issued a study plan modification determination order. The order specified what, if any, modifications to the ISRs should be made. For this study, FERC's June 24, 2011 order required no modifications to the original study plan. This final study report is being filed with the

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2.0 BACKGROUND

2.1 Conowingo Pond

Conowingo Pond is formed by Conowingo Dam and extends approximately 14 miles upstream from Conowingo Dam to the lower end of the Holtwood Project tailrace. The Conowingo Pond is generally maintained at an elevation of 109.2 feet (National Geodetic Vertical Datum of 1929 [NGVD 1929]), with a surface area of 9,000 acres and a design storage capacity of 310,000 acre-feet, of which 71,000 acre-feet are usable storage. Conowingo Pond is an interstate body of water with approximately 8 miles of the pond in Pennsylvania and 6 miles in Maryland. Conowingo Pond is bordered by 35 miles of shoreline, has a width varying from 0.5 to 1.3 miles, and has a maximum depth of about 98 feet (SRBC 2006c). The upper portions of Conowingo Pond provide riverine conditions based on the downstream proximity to the Holtwood Project. The majority of Conowingo Pond provides more lentic conditions with generally greater depths and lower water velocities compared to the riverine portions of the Project area.

Studies of American shad behavior in Conowingo Pond including evidence of reproduction have occurred since the 1960's (Carlson 1968). As a result of those studies, habitat in Conowingo Pond was considered marginal to support shad spawning. More recently, radiotelemetry studies in 2001 and 2008 of adult migrating American shad aggregation behavior in upper Conowingo Pond suggested spawning was a possibility. Following the 2001 telemetry study, gill nets targeting adult American shad in spawning condition were deployed during two consecutive spawning seasons in upper Conowingo Pond, and studies utilizing push nets mounted on the bow of a boat to target juvenile shad focused on numerous areas in upper Conowingo Pond. A few adult shad in running ripe spawning condition were captured in the gill net studies, and captures of very few juvenile shad by the push net in one year also suggested that a limited amount of spawning may occur in upper Conowingo Pond. Despite these results any shad reproduction that may occur in upper Conowingo Pond are not thought to materially contribute to the overall shad production for a given year. The juvenile shad studies also captured residualized (landlocked) alewife, although the specimens were judged to originate from upstream of Conowingo Pond.

2.2 Susquehanna River below Conowingo Dam

The lower river is the 10 mile stretch of the Susquehanna River from Conowingo Dam to the Chesapeake Bay. Within this 10 miles the character of the river varies considerably. The tailrace extends from Conowingo Dam to below Rowland Island. The maximum depth at zero generation is 23 ft. The main flow of water occupies the deep channel between the west bank and Rowland Island. In the riverine reach below the tailrace, the water flow spreads out toward the east shore. This is a typical shallow bedrock river with numerous boulders and bedrock outcroppings. At the head of this reach is Lee's Ferry. This is a shallow, rocky pool with depths of 6.5 ft at zero generation. From Lee's Ferry water flows through shallow riffles, runs, and pools to a larger area called The Pool, which has a depth of 10 ft at zero generation. The non-tidal portion of the lower river is composed of the tailrace and the riverine reach. The lower limit to the riverine reach is the *de facto* tidal limit at Deer Creek. The tidal portion of the lower river extends from just upstream of Deer Creek to the mouth of the river at the head of the Susquehanna Flats. The upper end of the tidal area is rocky and shallow similar to the riverine reach. Below Spencer Island the river deepens and broadens. Maximum depth is approximately 39 ft. The tidal amplitude in this reach is normally 2 ft.

Radio telemetry studies in 1982 documented American shad spawning in the tidal portion of the river at Port Deposit, Maryland (RMC 1985a). Shad eggs were captured with plankton nets set downstream of active shad in the evening and at night. Physical habitat data (e.g., dominant substrate type, available cover, weather, water temperature, dissolved oxygen content, distance from shore, general flow characteristics) for American shad located in the spawning area at the times of egg collection were obtained. Follow-up studies conducted in 1983 and 1984 included extensive larval fish sampling with plankton nets at locations throughout the non-tidal and tidal river reaches targeting evidence of American shad spawning. Those field surveys yielded eggs and larvae from anadromous American shad, river herring, and white perch, as well as resident fish species. The 1983 and 1984 results extended and refined the known spawning area for American shad, originally described as near Port Deposit, Maryland to an area including the islands area upstream of Port Deposit downstream to Lapidum, Maryland (directly across-river from Port Deposit).

3.0 SPAWNING HABITAT REQUIREMENTS

3.1 American Shad

American shad spawn in freshwater (Walburg 1960), but spawning location may be near brackish water (Stier and Crance 1985) or far upriver (Mansueti and Ko1b 1953). Spawning may occur throughout a river, but preferred areas are dominated by broad flats or shallow water (Hildebrand and Schroeder 1927, Marcy 1972, Hightower and Sparks 2003). Water temperature is thought to be the primary trigger for American shad spawning, but photoperiod, current velocity, and turbidity may also influence spawning timing (Leggett and Whitney 1972, Klauda et al. 1991a). In the first habitat suitability indices (HSIs) for American shad, it was understood that shad spawn over a wide variety of substrates and depths so habitat suitability for spawning was thought to be limited primarily by water quality and water temperature and current velocity were considered to be the two most important water quality variables for evaluating habitat (Stier and Crance 1985). The authors developed HSI curves for American shad that were intended for use with the Instream Flow Incremental Methodology (IFIM) in assessment of instream flow alterations on riverine habitat. As described in the following paragraphs, recent research has invoked alterations to those HSI curves including incorporation of substrate and changes to the suitability indices for flow.

Stier and Crance (1985), citing data of Walburg and Nichols (1967), concluded that spawning ranges from water temperatures of 8 to 26°C, but that the optimal temperature range was from 14 to 20°C. Temperatures below 8 or above 26°C were not suitable. As a result of field evaluations of existing HSI models, Ross et al. (1993) recommended extending the optimal temperature range to 24.5°C. For the Susquehanna River IFIM study a spawning season of April – June was defined (see Study 3.16).

Spawning has been observed over a wide range of depth, though Stier and Crance (1985) recognized that American shad may more often use shallow water areas. Additionally, Hightower and Sparks (2003) suggested that shallow reaches were important in the Roanoke River, North Carolina., and Ross et al. (1993) found that spawning was more often observed in runs, defined as relatively shallow mid-river stretches with moderate to high current velocity. For the Susquehanna River IFIM study, appropriate spawning habitat included 1-50 ft and optimal depth was defined as 5-20 ft (see Study 3.16).

Preferred water velocities of 1 to 3 ft/s (Walburg 1960, Walburg and Nichols 1967) are considered to be optimal in Stier and Crance (1985). However, Beasley and Hightower (2000) observed spawning in velocities as high as 4.3 ft/s in the Neuse River, North Carolina. Ross et al. (1993) found that spawning occurred at velocities below 1 ft/s, and that optimal suitability did not occur at velocities greater than 2.3 ft/s in the Delaware River. Relative preference for high velocities may be reflective of suspended sediment load so that higher velocity water with low sediment may be acceptable while high turbidity is not. High concentrations of suspended sediment were shown to be detrimental to larval production. Auld and Shubel (1978) recorded high larval mortality when exposed to sediment concentrations greater than 100 mg/l for 96 h. Spawning preference is generally considered to be over sand and gravel bottom with sufficient water velocity to eliminate silt deposits (Walburg and Nichols 1967). Substrate was not considered to be a controlling factor in habitat suitability (Stier and Crance 1985), and Bilkovic et al. (2002b) found that physical variables, including substrate, were less predictive than hydrographic variables for spawning and nursery habitat suitability in two Virginia rivers. However, Read and Hightower (2005) prepared modified HSI models to include not only water temperature and velocity, but also a component for substrate. They found that the most important factor in determining the amount of suitable American shad spawning habitat in the upper Roanoke River Basin, Virginia was related to the assumed values applied to substrate. Several studies in North Carolina and Virginia rivers suggested that American shad preferentially spawn over larger substrates (gravel, cobble, boulder, bedrock) than sand (Beasley and Hightower 2000, Bowman 2001, Hightower and Sparks 2003, Read and Hightower 2005). These results suggest that substrate, while perhaps not a determining factor in spawning habitat preference for American shad, is indicative of preferred velocities. Eggs are semi-buoyant, but may sink to the bottom. Habitats of sand and larger substrates represent areas where there is sufficient water velocity to prevent suffocation of eggs due to sedimentation (Walburg and Nichols 1967).

Greene et al. (2009) synthesized habitat requirements of east coast anadromous fishes and noted that American shad may use discrete spawning sites, foregoing areas with highly suitable habitats that are further downstream, suggesting that there are other variables that influence habitat choice (Bilkovic et al. 2002a), such as selective pressures like density of egg predators (Ross et al. 1993). Other characteristics of water quality have also been considered in determining habitat suitability including dissolved oxygen concentration and pH. Walburg and Nichols (1967) reported that dissolved oxygen (DO) concentrations of 5.0 mg/l or more are required; however, Chittenden (1973) reported spawning in DO concentrations of 4.0 mg/l. Read and Hightower (2005) suggested that rivers with lower DO concentrations might provide lower quality habitat, but those conditions did not occur until temperature was above 26°C and would impact juveniles rather than spawners. Bilkovic et al. (2002b) suggested a broad optimal pH range of 6.0 – 9.9.

HSI curves to be used in IFIM for the Conowingo Hydroelectric Project were determined specifically for the Susquehanna River and will be submitted under separate cover (see Study 3.16).

3.2 Hickory Shad

Klauda et al. (1991a) reviewed hickory shad status in Chesapeake Bay. Spawning runs may occur earlier than American shad, typically beginning in March and April. For the Susquehanna River IFIM, a spawning season of March – May was defined (see Study 3.16). Spawning habitat preferences are not well defined, but often overlap with American shad. Spawning adult American shad and hickory shad were collected from similar habitats in the Patuxent River, Choptank River, and Marshyhope Creek (tributary to Nanticoke River), Maryland. Spawning sites are generalized as encompassing areas just below the fall line to areas near the salt wedge (Richardson et al. 2007). While specific spawning habitats are not well documented in Chesapeake Bay, hickory shad spawning sites may be more diverse than American shad, including mainstem rivers near the fall line or further downstream, in tributaries, and in flooded areas off of the main channel (Speir 1987, Klauda et al. 1991a). Hickory shad may prefer deeper spawning habitat than American shad (Hawkins 1980, Greene et al. 2009). In the Susquehanna River below Conowingo Dam, collections of adult hickory shad are known from both the Octoraro and Deer Creek tributaries, and in recent years hickory shad have exhibited a spawning run resurgence in the Susquehanna River (Richardson et al. 2007). Analysis of angler catch-per-effort data for hickory shad fishing in Deer Creek indicated high catch rates, ranging from 3.6 – 8.3 / hr, with inter-annual variation but no long-term trend (Jarzynski and Sadzinski 2009).

Greene et al. (2009), citing B.M. Richardson (Maryland Department of Natural Resources - MDNR), noted that adult hickory shad were collected in areas with complex structures, such as ledges and fallen trees as well as mud, sand, and/or gravel substrates. In the Roanoke River, Harris and Hightower (2007) reported hickory shad spawning in areas of moderate to high water velocity and cobble, gravel, and sand - but not silt - substrates. Hickory shad eggs are slightly adhesive and semi-demersal in slow moving water, but partially buoyant in higher velocity water (Klauda et al. 1991a).

Hickory shad spawning has been documented in water temperatures from 8 to 23°C (Greene et al. 2009). Peak spawning in the Susquehanna River is from 15.8 to 18.5°C (Richardson et al. 2007). Little information is available regarding DO concentration and preferred spawning habitat, but it appears likely that, like American shad, levels of 5 mg/l or more are required (Greene et al. 2009). Hickory shad appear to spawn over a range of water velocities, but generally appear to prefer moderate to fast flowing water and in Maryland, may prefer faster flowing water than American shad (Greene et al. 2009 citing B.M. Richardson, MDNR, personal communication). In the Roanoke River, Harris and Hightower (2007) noted that hickory shad spawned in higher velocity main channel areas with median velocities of 0.6 to 1.3 ft/s rather than in slower velocity areas nearby.

3.3 River Herring

Alewife and blueback herring are collectively referred to as river herring. Their movements onto spawning grounds are influenced by temperature, light intensity, and water flow. In the Susquehanna River below Conowingo Dam, Klauda et al. (1991b) noted small and possibly declining spawning populations in the Deer Creek and Octoraro Creek tributaries.

Alewife tend to move to the spawning grounds during daylight and in higher flows. In Chesapeake Bay, alewife spawning migrations typically begin when water temperatures range from 10-18°C and spawning generally occurs between 10-22°C (Loesch 1987, Klauda et al. 1991b). Alewife spawning migrations occur earlier than blueback herring (Loesch 1987, Greene et al. 2009), and for the Susquehanna River IFIM study, a spawning period of April – May was defined (see Study 3.16). Where the species are sympatric alewife and blueback herring may use separate spawning sites to reduce competition (Loesch 1987). Alewife spawning habitat is often in slow-moving water in streams, coastal ponds and lakes. Alewife broadcast spawn over a range of substrates from gravel to organic detritus. Eggs are slightly adhesive until water-hardened and semi-demersal to pelagic (Klauda et al. 1991b).

Blueback herring spawning migrations typically occur a few weeks after the peak alewife runs when water temperatures range from 14-25°C (Hildebrand and Schroeder 1928, Klauda et al. 1991b). For the Susquehanna River IFIM study, a spawning period of April – June was defined (see Study 3.16). Blueback herring spawn from slightly brackish water to far upstream. Where the two river herring species are sympatric, they may use separate spawning sites (Loesch 1987). Blueback herring tend to select the swifter main stream flow, and gravel and clean sand substrates for spawning (Loesch and Lund 1977, Loesch 1987, Klauda et al. 1991b, Greene et al. 2009). Eggs are broadcast spawned, pelagic in moving water and demersal in still water, and slightly adhesive until water hardened (Klauda et al. 1991b).

3.4 Striped Bass

Mature adult striped bass typically undergo annual spawning migrations. Spawning habitat may be located from near brackish water to far upstream (Bigelow and Schroeder 1953, Crance 1984), but is often associated with the upper estuarine portion of coastal rivers, typically within the first 28 mi of freshwater (Talbot 1966, Bain and Bain 1982, Crance 1984). The freshwater-saltwater interface area may create the lower boundary for striped bass spawning (McGovern and Olney 1996), perhaps acting as a barrier to egg and larval advection (Secor and Houde 1995).

Chesapeake Bay and its tributaries comprise some of the most important spawning and nursery grounds for striped bass. Kernehan et al. (1981) reviewing striped bass spawning information found that only a minimal amount of spawning was thought to occur north of Turkey Point (the southern tip of the Elk Neck peninsula on the east side of Chesapeake Bay, about 7 miles southeast of Susquehanna Flats). Dovel and Edmunds (1971, as cited in Kernehan et al. 1981) found primary spawning habitat for upper Chesapeake Bay striped bass had shifted from the lower Susquehanna River below the current location of Conowingo Dam to the Elk River and C&D Canal as a result of dredging the Canal to sea level in 1927 and completion of Conowingo Dam in 1928. Kernehan et al. (1981), however, suggested that the upper Bay was historically the primary spawning ground because its proximity to saline waters is more similar to other Chesapeake Bay spawning grounds. Ichthyoplankton surveys of the C&D Canal and eastern side of the upper Chesapeake Bay for distribution of early life stages of striped bass resulted in determination of two primary spawning areas: in the upper Chesapeake Bay south of Turkey Point and in the western end of the C&D Canal (toward Chesapeake Bay). Eggs spawned in the C&D Canal were mostly transported to the Delaware River due to a net eastward flow (Kernehan et al. 1981).

Photoperiod and water temperature are the important controlling effects for striped bass spawning (Kernehan et al. 1981, Hill et al. 1989). Bain and Bain (1982), however, noted that studies have suggested that spawning habitat suitability is positively correlated with increased river discharge. In the upper Chesapeake Bay and C&D Canal, the striped bass spawning season was shown to occur from mid-April through mid-June (1973-1977) within a wide range of water temperatures, 8.4-29°C. Most of the production, however, occurred during a short period when water temperatures were 13.5-18.0°C. For the Susquehanna River IFIM study, April – June was defined as the spawning period (see Study 3.16)

Striped bass eggs are non-adhesive and semi-buoyant (Hardy 1978, Fay et al. 1983, Hill et al. 1989), so substrate is not generally considered to be an important factor to striped bass spawning. Crance (1984) found that striped bass spawning occurs over mud/ silt substrate in Chesapeake Bay, but coarse substrate, which does not allow excessive suspension of material, is considered to be most suitable. Egg survival is dependent on sufficient flow to keep eggs suspended (Mansueti 1958).

3.5 White Perch

White perch, one of the most abundant fish in Chesapeake Bay, is semi-anadromous (Setzler-Hamilton 1991), with diverse spawning habitats including estuaries, rivers, lakes, and marshes (Stanley and Danie 1983). Spawning can occur in salinities ranging from freshwater to 4.2 ppt (Hardy 1978, Stanley and Danie 1983), but optimal salinities range from 0-1.5 ppt, and most white perch eggs collected in the upper Chesapeake Bay are from salinities less than 5 ppt (Setzler-Hamilton 1983, North and Houde 2001).

In Maryland waters of Chesapeake Bay, spawning occurs from late March through early June with peak spawning in April and May at water temperatures of 10 - 16°C (Setzler-Hamilton 1983); however, sudden drops in water temperature have been shown to result in egg mortality (Hardy 1978). For the Susquehanna River, a spawning season of April – June was identified (see Study 3.16, Stanley and Danie 1983).

Spawning generally occurs at depths of 3-20 ft (Hardy 1978, Setzler-Hamilton 1983). White perch eggs are generally demersal and attach to substrate, debris, or vegetation (Stanley and Danie 1983), but can be pelagic in flowing water (Hardy 1978, Setzler-Hamilton 1983). Spawning occurs over a range of substrates including clay, gravel, and sand (Hardy 1978). Since a wide variety of habitats is used, water velocity is not apparently an important factor in spawning habitat preference. Exposure to high concentrations of suspended sediments; however can be detrimental to hatching success and sediment deposition over more than half of egg diameter can result in significant mortality (Morgan et al. 1983), so egg deposition must be in habitats with sufficiently clear water or swift enough currents to prevent significant deposition.

4.0 EFFORTS TO COLLECT EARLY LIFE STAGES OF ANADROMOUS SPECIES

4.1 Conowingo Pond

4.1.1 Introduction

In 1994, the Pennsylvania Fish and Boat Commission (PFBC) embarked on a program to monitor the distribution and abundance of alosine fishes in the Susquehanna River and selected tributaries using a variety of fisheries techniques. The program anticipated future volitional passage of anadromous fishes into Susquehanna River sections upstream of and into Conowingo Pond. Volitional passage of anadromous species into Conowingo Pond via the Conowingo East Fish Lift (EFL) began in 1997.

Between 1994 and 1998, sampling efforts focused on Susquehanna River tributaries above Holtwood Dam in an effort to collect juvenile American shad. Between 1998 and 2005, the sampling effort broadened to include river herring and adult and juvenile life stages of American shad using gill nets, pushnet, and both pram and boat-mounted electrofishing techniques. During this period, the areas sampled included sections of the Susquehanna River as far north as the Fabri-Dam at Sunbury, Pennsylvania (river mile 118) as well as the Conowingo Pond and selected tributaries therein.

4.1.2 Methods Used

4.1.2.1 Gill Nets

Gill netting undertaken from 2003 through 2005 had the primary objective of ascertaining the feasibility of collecting spawning American shad to develop a shad egg collection program in the Susquehanna River, which could support long-term hatchery production similar to that developed in the Hudson and Delaware Rivers. Both of these rivers have been sources for shad eggs to support the American shad restoration program on the Susquehanna River for many years. Monofilament gill nets with four 50-ft by 8-ft panels of 4.0, 4.5, 5.0, and 5.5-in stretch mesh were used to collect adult American shad. Nets were deployed perpendicular to river flow, allowed to drift for a short time, retrieved, and the catch removed. Nets were set in the areas depicted in Figure 4.1-1 in the upper section of Conowingo Pond. Sampling occurred between 1900 and 2400 h every three days for 10 events beginning in mid-May and ending by mid-June. Sampling commenced once specific criteria for water temperature and adult shad lifted into Conowingo Pond were achieved (Normandeau Associates, Inc. 2003a, 2004, 2005).

Ripe female shad collected in the gill nets were stripped of eggs, then the eggs were fertilized using milt stripped from collected males, washed, and allowed to water harden. Effort was made to use a ratio of at least two males to one female when fertilizing stripped eggs. Spent or green fish along with non-target species were released. When three or more liters of eggs were collected, they were packed in a double plastic bag with an equal volume of water and oxygen, sealed, placed into a cooler, and transported 90 mi to the PFBC's hatchery in Thompsontown, Pennsylvania.

4.1.2.2 Pushnet

Pushnetting was used in attempts to collect early-stage juvenile shad from upper portions of Conowingo Pond (Figure 4.1-2) annually from 1998 through 2003 (Normandeau Associates, Inc. 1998, 1999c, 2000c, 2001c, 2002, 2003b). Twelve evening pushnet surveys including ten sampling stations were conducted each year between mid-June and mid-July. Surveys began at or near sunset and were concluded when all 10 stations were sampled. The station locations were concentrated along the shorelines of islands and the river in upper Conowingo Pond.

The pushnet consisted of a 5-ft beam trawl with a 60-in square mouth opening lashed to a 4.9-ft by 4.9-ft steel frame. The net was 7-foot in length made of No. 63 knotless 1/4-in stretch (1/8-in bar) mesh netting tapering to a 12-in canvas collar cod-end. For each sample, the pushnet was suspended from the boat bow into the water to fish from the surface to 5-ft deep and pushed upstream for 5 minutes. The net was then retrieved and the sample emptied into a flat enamel pan. Fish were identified and enumerated and non-target species were returned to the river. Any American shad collected were frozen for otolith analysis and shipped to the PFBC Benner Spring Fish Production Station in State College, Pennsylvania.

4.1.2.3 Electrofishing - Large Tributaries

Electrofishing in selected large tributaries to the Susquehanna River occurred to ascertain whether the they were used by spawning adult American shad. This program originally planned for annual sampling from 1999 through 2003 but was terminated after 2001 due to poor results (Normandeau Associates, Inc. 1999a, 2000a, 2001a). Daytime electrofishing surveys were conducted in numerous lower Susquehanna River tributaries between May and June. Muddy Creek was the only large tributary selected for sampling in Conowingo Pond. The study design specified sampling the tributaries in the vicinity of the first upstream impediment identified after consultation with the PFBC's study representative. Reports previously prepared for the PFBC determined that these tributaries were capable of supplying suitable habitat for adult American shad (Carline et al.1994, 1995, 1997).

Electrofishing was conducted using a Coffelt VVP-15 variable voltage pulsator, powered by a 3.5 kW generator, and mounted either in a 6-ft inflatable raft or a 14-ft or 18-ft aluminum boat depending upon stream characteristics. Pulsed DC current (180 to 400 volts) was used. Surveys in each stream began about 500 to 1,000 m below the first upstream impediment and concluded after 1 h or the upstream barrier was reached. Surveys were concentrated along the shorelines, riffles, pools, and other habitats typically utilized by spawning adult American shad. American shad collected were frozen for otolith analysis and shipped to the PFBC Benner Spring Fish Production Station in State College, Pennsylvania.

4.1.2.4 Electrofishing - Small Tributaries

Electrofishing in selected small tributaries to the Susquehanna River occurred to document adult river herring use of these tributaries. Originally planned for annual sampling from 1999 through 2003, this program was terminated after 2001 due to poor results (Normandeau Associates, Inc. 1999b, 2000b, 2001b). Daytime electrofishing surveys were conducted in Fishing Creek and Peters Creek, the only tributaries selected within the Conowingo Project boundary. Both streams are located mid-reservoir in Lancaster County, Pennsylvania. Sampling commenced once the trigger number (10,000) of river herring was passed into Conowingo Pond via the EFL. Fishing Creek and Peters Creek were sampled biweekly between mid-May and mid-June. The study design specified sampling each tributary in areas immediately below the first upstream impediment. The location of the impediment in each tributary was identified after consultation with PFBC's representative. Reports previously prepared for PFBC determined that these tributaries were capable of supplying suitable habitat for adult river herring (Carline et al. 1994, 1995, 1997).

Electrofishing was conducted with a Coffelt VVP-15 variable voltage pulsator, powered by a 3.5 kW generator, mounted in a 6-ft inflatable raft. Pulsed DC current (400 to 490 volts) was used. Surveys in each tributary began where the influence of the impoundment was no longer evident and concluded after 1 h or the upstream barrier/impediment was reached. Surveys occurred along the shorelines and in riffles, pools, and other habitats likely utilized by adult river herring.

4.1.3 Results

Both the large and small tributary sampling efforts in Conowingo Pond were curtailed after 2001 due primarily to few anadromous fish collected. The small tributary work in Peters Creek and Fishing Creek yielded no river herring during the three years the program was conducted. Likewise, the large tributary sampling in Conowingo Pond ended after three years. Weekly sampling efforts during 1999-2001 in Muddy Creek collected only two adult American shad, both in 2001.

The results from the American shad egg collection program using gill nets are summarized in Table 4.1-1. The number of adult shad collected (138 in 2003, 87 in 2004, and 4 in 2005) declined steadily after the first year, and as a result, the program was terminated following the 2005 season. Of the adult shad collected, most males were ripe yet the condition of the females collected was either green, partially spent, or spent. Consequently, few eggs (< 2 liters) were available for transport to the Van Dyke Hatchery.

The results of the pushnet program from 1998 through 2003 are summarized in Table 4.1-2 and Figure 4.1-3. Excepting 2001, few juvenile shad were collected in any year, and in three years, no shad were collected. The 2001 catch of 136 young shad coincided with the highest number of adult American shad (193,574) passed into Conowingo Pond via the EFL. Juvenile American shad were not measured but, due to the mesh size used (1/8-in bar), were of a length and coloration that permitted distinguishing American shad from other juvenile clupeids, such as gizzard shad (*Dorosoma cepedianum*) and alewife *(Alosa pseudoharengus*). Young American shad were typically collected along with small juvenile gizzard shad. Figure 4.1-3 shows the cumulative spatial distribution of young American shad caught during the program. Most (> 85%) young American shad were collected in areas associated with Lower Bear, Big Chestnut, and Hennery islands away from the main river flow along the east side of the river. Since mixed collections of American shad and gizzard shad were common, both species may utilize similar habitats associated with island shorelines for rearing.

4.1.4 Discussion

Based on the size attained and collection time in June and July, the juveniles collected by the pushnet most likely originated upstream of Muddy Run Pumped Storage Project (MRPSP) and perhaps also upstream of Conowingo Pond. The juveniles collected were likely transported by currents past MRPSP to collection sites in the island complex below the Project. It cannot be determined where the shad were spawned from the pushnet data, but they do suggest that some juvenile shad may utilize habitats within the island complex for rearing. However, the collection of some ripe adult shad suggests that spawning may also occur in upper Conowingo Pond. By necessity due to current flow and obstructions, however, the majority of gill net effort that yielded ripe adult shad occurred downstream of locations where the small juveniles were taken by pushnet.

American shad are broadcast spawners capable of spawning anywhere in rivers, yet they prefer habitats composed of shallow flats with sandy, pebbly bottoms in rivers with velocity sufficient to sweep away silt (Stier and Crance 1985). The semi-buoyant eggs quickly sink to the bottom (they roll about on the bottom with the current). The PFBC commissioned several programs to collect adult and juvenile life stages of shad in upper Conowingo Pond where, presumably, better spawning habitat exists. Substrate in the lower section of Conowingo Pond is heavily composed of sand and silt and does not represent good spawning habitat. The limited success of these programs is consistent with the earlier work of Carlson (1968), who suggested that Conowingo Pond provided marginally suitable habitat for the reproduction of American shad.

4.2 Susquehanna River Below Conowingo Dam

4.2.1 Introduction

By order issued August 14, 1980, FERC issued a new major license to Philadelphia Electric Company (PECO) and Susquehanna Electric Company (licensees) for continued operation of the Conowingo Project (FERC No. 405). In granting the license, FERC reserved two environmental issues for further consideration, one issue was whether certain minimum flows were necessary to protect and enhance indigenous fish resources and water quality in Project waters. Based on this consideration, biological-based studies (by FERC-approved Study Plan) were to be conducted for two successive 5-year periods (1982 to 1986; 1987 to 1991). The various elements of study continued through 1987. In 1988, PECO (now Exelon) reached a settlement agreement with the resource agencies that included flow needs, and the study was halted. Because the studies were terminated following the settlement agreement, most collected data were only tabulated, processed electronically and stored on PECO's mainframe system, but were not analyzed or formally reported. The biological data stored on electronic media were subsequently lost. As a result, data presented here are drawn from three progress reports and other available hard-copy data stored by Normandeau.

Radio telemetry studies conducted in 1982 documented American shad spawning in the tidal river at Port Deposit, Maryland (Figure 4.2-1). Shad eggs were captured with plankton nets set downstream of areas where shad were active in the evening and at night. Physical habitat data (e.g., dominant substrate type, available cover, weather, water temperature, dissolved oxygen content, distance from shore, general flow characteristics) for American shad located in the spawning area at the times of egg collection were measured.

Follow up studies in 1983 and 1984 targeted shad spawning during extensive larval fish sampling with plankton nets at locations throughout the non-tidal and tidal river reaches (RMC 1985b, RMC 1985c) These targeted field surveys yielded eggs and larvae from anadromous American shad, river herring, and white perch, as well as resident fish species. The 1983 and 1984 results extended and refined the known shad spawning area, which was originally described as from the islands area upstream of Port Deposit, Maryland downstream to Lapidum, Maryland (RMC 1985b, RMC 1985c), which is directly across from Port Deposit (Figure 4.2-1).

4.2.2 Methods

From 1982 to 1984, ichthyoplankton sampling was generally performed from late March to late June to characterize the use of the lower Susquehanna River by resident and anadromous fishes as a spawning and nursery area. In 1982 eight regular sampling transects or locations were established for the study: three in the tidal area below Spencer Island and five in the more riverine, non-tidal area above Robert Island (Figure 4.2.1). In addition to samples at the regular river stations, surface tows were made in Deer and Octoraro creeks near their confluences with the Susquehanna River. The sample stations have been categorized by their locations: upper river (tailrace), lower river (Lee's Ferry and The Pool), upper tidal, lower tidal, and creeks (Figure 4.2.1).

The sampling was conducted weekly at all regular stations, but during the suspected peak of spawning, samples were generally collected twice per week at each station. Samples were collected with a 1.6 ft plankton net (0.02 in. mesh). Nets were towed for five minutes heading upstream at speeds sufficient to maintain the net no more than one foot below the surface. Bottom samples were collected at the mid-channel stations on the three lowermost transects in 1982 and 1983 and at the two lowermost transects in 1984. In 1983, 33 additional samples targeting American shad were collected near Spencer Island, supplemented by 21 additional collections taken at other areas in tidal water where telemetered American shad frequented or were observed spawning.

The volume of water filtered for each sample was measured with a General Oceanics model 2030 digital flowmeter mounted in the center of the net mouth, and calculated by the formula:

$$V = n\,(f/100)\,A$$

Where "V" was the volume of water filtered; "n" was the number of flowmeter revolutions; "f" is a constant for converting counts/sec to velocity (ft/s), and "A" was the cross sectional area of the net mouth (0. 0.644 ft^2).

Field samples were immediately preserved in 20 to 25% formalin, rinsed in the laboratory, stained with rose bengal (to facilitate sorting), sorted, and stored in vials of 5% buffered formalin. Specimens were examined under a stereoscopic dissecting microscope, identified to the lowest taxon, and enumerated. Specimens were classified as eggs, larvae, or young. Some damaged specimens were tabulated as unidentifiable. Larvae of the genus *Alosa*, particularly blueback herring and alewife, were indistinguishable to species and were reported as *Alosa* spp. The larval stage was defined as the early development after hatching during which the yolk sac and larval finfold were absorbed and the fin rays were formed. The larval stage was subdivided into prolarvae and postlarvae. Prolarvae were those specimens that had not completely absorbed their yolk sac. Postlarvae had absorbed the yolk sac but not completely differentiated to their adult form. Young were fully transformed larvae, characterized by complete absorption of the larval finfold and attainment of the adult compliment of rays and spines in all fins.

4.2.3 Results

Overall, from 1982 to 1984 a total of 275,710 eggs, prolarvae, or postlarvae from 27 taxa was collected from 1,322 icthyoplankton samples downstream of Conowingo Dam (Table 4.2-1). White perch comprised 74% of all icthyoplankton collected (197,108 fish). River herring (alewife and blueback herring) comprised 24% of the icthyoplankton collected (N=65,276 fish). American shad accounted for less than 1% of the specimens collected during routine sampling (324 fish). The seasonal peak of ichthyoplankton collections generally occurred from mid May through early June (Figure 4.2-2). The majority of icthyoplankton collected were eggs, which comprised 81%, 85%, and 90% of the total specimens collected each year from 1982 – 1984, respectively (Tables 4.2-2, 4.2-3, 4.2-4).

4.2.3.1 *Alosa*

From 1982 to 1984, the highest river herring egg densities occurred from late April to early June when river temperatures ranged from 7 to 26°C (RMC 1985 a,b,c), indicating earlier spawning than other species. Egg densities were highest at sites in the upper river near Conowingo Dam, moderately high in the lower river and relatively low in the upper and lower tidal areas (Figure 4.2-3, 4.2-4, from RMC 1985a,c). The increased relative proportion of prolarvae and postlarvae stages at stations further downstream in the upper and lower tidal areas indicated recently hatched larvae were quickly transported downstream.

In 1983, *Alosa* were collected throughout the study area from 17 April through 26 June (Table 4.2-6) at water temperatures of 7 to 26°C (RMC 1985b). Peak abundance for *Alosa* occurred on 22 May at 19°C (9,187 fish). Mean density was highest in the upper river stations below Conowingo Dam with a secondary peak at the old bridge piers near the head of tide in the lower river (Figure 4.2-4, RMC 1985b).

In 1984, *Alosa* were collected from 15 April through 24 June (Table 4.2-7). Eggs were first collected on 15 April at water temperatures of 8°C (RMC 1985c). Peak abundance occurred on 13 May (11,794). *Alosa* were most abundant in the upper riverine, non-tidal reach, particularly near Conowingo Dam (Table 4.2-5). As in 1982 and 1983, stations within the tidal area in 1984 had higher numbers of prolarvae than those stations located further upstream (Table 4.2-5), indicating that recently hatched prolarvae were quickly transported downstream. The near absence of postlarvae suggested that either most development takes place downstream in the Susquehanna Flats or upper Chesapeake Bay or the rate of larval mortality is high.

4.2.3.2 American shad

In 1982 only seven American shad eggs were collected during the routine collections (Table 4.2-2); most were taken at the end of May (RMC 1985a). Additional egg collections were made in 1982 to verify observed telemetered shad spawning behavior. Based on observations of fish splashing, egg collections and concentrations of telemetered fish, the Spencer Island spawning area was designated that portion of the river which lies between the upper portion of Spencer Island and lower portions of Wood and Robert Island. Spawning activity was not exclusive to this area, but abundant spawning activity was observed here. Based on numbers of telemetered fish and subsequent egg collections, the peak spawning period in that area occurred between 13 and 17 May, 1982. During that period, temperature increased from near 18 to 20° F. Actual river flows were between 16,000 and 23,000 cfs and maximum daily generation ranged from 15,000 to 75,000 cfs. The Station shut down to one small unit at 1800, 1815, 2200, and 1605 hr on the 13, 14, 15, and 17th of May, respectively.

In 1983, a total of 138 American shad eggs was collected at regular sampling stations (RMC 1985b); nearly all were collected within the tidal zone. A single prolarvae was collected at the mouth of Deer Creek on 5 May when water temperature was 16°C. In late May 1983, telemetered adults were documented moving in the tidal zone towards the spawning area near Spencer Island on several occasions in the late evenings. The 33 additional samples collected near Spencer Island from 15 May through 21 June, 1983 yielded 145 eggs (Table 4.2-8). Densities ranged from 0 to 0.34 eggs/m^3. Eggs were taken from 25 to 27 May and 19 to 20 June. Generally, egg densities were lower in May and increased in early June, remaining above 0.1 eggs/m^3 through 12 to 13 June. The highest densities (0.3 eggs/m^3) occurred on 5 to 6 June. Water temperature ranged from 15-23°C when eggs were collected and was near 19°C at the time of peak egg density. Samples were taken at station depths ranging from 2-6 ft depending upon tidal stage and/or river flow (RMC 1985b).

Also in spring 1983, a total of 21 collections were taken at other areas where telemetered American shad frequented or were observed spawning (Table 4.2-9). Eggs were collected from 20 May through 5 June. A total of 533 eggs was collected and densities ranged from 0 to 2.8 eggs/m^3. Higher egg densities (>0.5 eggs/m^3) were estimated on 20 to 21 May, 1 to 2 June, and 5 to 6 June when water temperature ranged from 16-19°C. Eggs were taken at station water depths of 3-13 ft; the higher egg densities (>0.5 eggs eggs/m^3) were observed where water depths ranged from 3-4 ft. Surface water velocities in areas of spawning activity ranged from 0.7 to 2.4 ft/s. The sampling areas where the shad eggs were collected were around 3 ft deep, depending upon tidal stage. Bottom substrate was primarily gravel and cobble. High egg densities and observed spawning activity indicated that a shad spawning area was along the east and west shores of Spencer Island (RMC 1985b).

In 1984, 48 night collections on 6 and 27 May, and 3 and 17 June yielded 179 eggs (Table 4.2-7). The majority was collected on 3 June (170 eggs) when water temperature averaged 11°C (RMC 1985c). Samples were taken at station depths of 6-12 feet depending upon tidal stage and/or river flow. Most eggs (91 eggs) were collected at upper tidal Station 7009 (along the west shore of the Susquehanna River near Lapidum boat launch, RMC 1985c).

4.2.3.3 White Perch

White perch was the most frequently caught species in each sample year. In 1982 spawning activity for white perch was extensive, as indicated by relatively high egg density (1.0 eggs/m^3, Table 4.2-2). High egg and prolarvae densities were recorded from late April through the end of May when the river temperatures ranged from 12.2 to 26.1°C (RMC 1985a).

In 1983, white perch was the most abundant ichthyoplankton taxa and accounted for 80% of the eggs and 75% of the prolarvae collected (Table 4.2-3). Eggs were first collected on 5 April at 8.3°C (RMC 1985b). Peak spawning activity and egg density occurred on 21 May (168.7 eggs and prolarvae/m^3) at 17.2°F (RMC 1985b). Highest daily abundance of prolarvae occurred on 24 May (3.9 /m^3). White perch eggs are generally demersal and adhesive and, therefore, were much more abundant in bottom collections. Egg density at the three tidal Stations combined was 0.4 eggs/m^3 on the surface compared to 2.2 eggs/m^3 on the bottom (RMC 1985b). The greatest spawning activity occurred near the tide line. Egg densities were greatest near Wood Island, followed by Stations immediately downstream near Lapidum. Some spawning occurred throughout the non-tidal riverine area, but densities of eggs and prolarvae at the three Stations in and just below the Conowingo tailrace were lower (RMC 1985b).

In 1984, white perch accounted for 68% of the eggs and 90% of the prolarvae collected (Table 4.2-4). Eggs were first collected on 12 April at 8.3°C (RMC 1985c). Peak spawning activity and egg density occurred on 22 May at 17.2°C (RMC 1985c). The greatest spawning activity occurred in the upper tidal area as indicated by the large amount of eggs collected (Table 4.2-5). Egg densities were greatest near Wood Island followed by stations just above Deer Creek off of Lapidum. Similar to 1983, fewer eggs and prolarvae were collected further upstream throughout the non-tidal, riverine area.

4.2.3.4 Hickory shad

No hickory shad were collected in 1983, and a total of 25 hickory shad was collected during ichthyoplankton sampling in 1984 (RMC 1985b, 1985c). The first dates of collection for hickory shad ranged from 22 April to 3 June. Peak abundance occurred on 6 May (N=11 fish).

4.2.3.5 Striped Bass

No striped bass were collected during ichthyoplankton sampling in 1982 to 1984.

5.0 HYDRAULIC CONDITIONS AND HABITAT CHARACTERIZATION

The hydraulic conditions of the Susquehanna River below Conowingo Dam are generally dictated by the Susquehanna River natural flow and in a large part to Safe Harbor Corporation's operation of Safe Harbor Dam. The Conowingo Project has limited active storage available owing to reservoir size and the relatively small allowable variation in headwater level. The Conowingo license stipulates that it must keep certain elevations in Conowingo Pond seasonally. In addition, minimum flows during times of lower than normal river flows had been agreed upon by Exelon and several federal and state agencies. Those agreed upon minimum flows are the following:

March 1 – March 31	3,500 cfs or natural river flow
April 1 – April 30	10,000 cfs or natural river flow, whichever is less
May 1 – May 31	7,500 cfs or natural river flow, whichever is less
June 1 – September 14	5,000 cfs or natural river flow, whichever is less
September 15 – November 30	3,500 cfs or natural river flow, whichever is less
December 1 – February 28	3,500 cfs intermittent (maximum six hours off followed by equal amount on).

The timing of spawning for the anadromous species is generally between April 1 and May 31. At the minimum, flows of 10,000 to 7,500 cfs will be available to those species and typically, higher river flows are available during a normal spring. Daily average discharge data from Conowingo Dam for April – June, 1981 – 2010 were compiled (Figure 5-1). Flows were highly episodic, often with the greatest magnitude discharge peaks occurring in April and May.

Substrate in the river below Conowingo Dam varies largely from boulders to pea-sized pebbles in the non-tidal riverine stretch (Rowland Island to the lower tip of Spencer Island). In the tidal-influenced portion (generally Lower Spencer Island to mouth of river), currents are commonly reduced due to widening and deepening of the river and to tidal influence. Consequently, this portion of the river is a silt depository. Just downstream of Spencer Island, the substrate is basically similar to the riverine section with increasing proportion of fine substrates and more imbedded boulders and rocks. As distance increases down river, the proportion of fine sediments increases to the Susquehanna Flats, a large silt deposit off of the mouth of the river.

A more detailed analysis and investigation into existing conditions for anadromous fish spawning in the study reach will be provided in Conowingo Report 3.16-Instream Flow Habitat Assessment below Conowingo Dam.

6.0 DISCUSSION AND CONCLUSIONS

Successful American shad spawning was documented in the lower Susquehanna River in a series of studies conducted in the 1980's. Results of those studies, including observations of fish splashing (indicative of spawning behavior), egg collections, and concentrations of telemetered fish, resulted in determination of spawning habitat in the lower riverine reach to the upper tidal reach of the river particularly from upper Spencer Island to lower Robert Island and in the upper tidal area near Port Deposit and Lapidum, Maryland. In the 2000's, MDNR documented a robust spawning population in the lower Susquehanna River. Their population estimate, 188,113 in 2009, has trended down since 2001 and EFL counts have also trended down since 2002 (Jarzynski and Sadzinski 2009). Those results are likely reflective of the magnitude of cultured larval shad stocking in the system to some extent, though, as stocking has fallen off in recent years (SRAFC 2010), and 48% of American shad otoliths collected from the WFL and examined for hatchery marking were of hatchery origin. It is not surprising then that the population has trended downward. Additionally Jarzynski and Sadzinski (2009) reported an upward trend in repeat spawning and in angler CPUE in recent years; signs of a stabilizing population, the majority of which appear to be of wild spawned origin, presumably from the lower Susquehanna River. In the 1980's studies, spawning was determined to occur within the suite of variables defining suitable habitat: eggs were collected or spawning was observed when water temperature was between 11-23°C and peaked when water temperatures were 11 to 20°C; eggs were collected in depths ranging from 3-13 ft with peak collections in 3-4 ft; surface water velocities of 0.7-2.4 ft/s were observed in areas of spawning activity; and substrate was primarily gravel and cobble (RMC 1985 a, b, c) . Based on these observations, suitable spawning habitat exists downstream of Conowingo Dam and in response to its operations, and that habitat is used annually and successfully by American shad. Given the controllable operating regimes (barring environmental anomalies) of Conowingo Dam, it is unlikely that routine operations of the Project will adversely impact American shad spawning success.

In the 1980's studies, hickory shad began to appear in ichthyoplankton surveys in 1984. The Deer Creek population is now the largest in Maryland, and is robust with consistent and ideal age structure and repeat spawning (Jarzynski and Sadzinski 2009). The area of the mouth of Deer Creek downstream to Lapidum is now targeted for collection of brood stock in MDNR's development of a hatchery program for restoration of hickory shad in other Chesapeake Bay tributaries (Richardson et al. 2009). Since hickory shad appear to prefer the tributary streams, and the stock has improved, it is evident that suitable habitat is available and being successfully used for spawning in the Susquehanna River and Deer Creek tributary. It is evident that operations of the Conowingo Project have not adversely impacted spawning of hickory shad.

Though not identified to species, river herring were collected in relatively large densities in the 1980's ichthyoplankton surveys, representing the second most abundant, and contributing 24% of the total ichthyoplankton collected. Eggs and larval life stages were collected throughout the upper and lower riverine reaches as well as the upper tidal reach. The greatest density of eggs was collected in the upper riverine section and the greatest density of postlarvae was collected in the upper tidal reach, suggesting that young river herring were transported down river. As a result of these studies, we conclude that suitable spawning habitat exists in the lower Susquehanna River. More recently there is little information due to declining stocks of river herring; however those declines are likely attributable to sources unrelated to Conowingo Project operations. Populations of blueback herring have been declining in the northeast due to a number of potential causes including habitat loss, targeted catch or bycatch at sea via commercial fishing, and increased numbers of striped bass and other types of predators (ASMFC 2009).

While striped bass use the Susquehanna River for forage, they do not spawn there and so the effects of Conowingo Project operations on spawning cannot be assessed. It is generally accepted that the lower Susquehanna River once provided significant spawning habitat for striped bass but that the spawning habitat shifted to the upper Chesapeake Bay and the C&D Canal; however, this belief is disputed in the literature. Currently the Chesapeake Bay striped bass population is thriving.

White perch were the dominant species in the 1980's ichthyoplankton sampling, contributing 72% of the total ichthyoplankton collections. Peak egg collection tended to occur in mid to late May when temperatures were around 17°C. White perch eggs are generally demersal and, therefore, were much more abundant in bottom collections. The greatest spawning activity occurred in the upper tidal area as indicated by the large amount of eggs collected. Given theses results, it is evident that suitable habitat is available and successfully used. Additionally, since the primary spawning area was determined to be the upper tidal reach, the potential for Conowingo Project operations impacts are minimized.

Little suitable spawning habitat likely exists in the Conowingo Pond for anadromous fishes. Between 1998 and 2005, the PFBC commissioned several programs to collect adult and juvenile life stages of American shad and adult alewife and blueback herring (collectively river herring) in upper Conowingo Pond. Study purposes were 1) identify whether adults of these species enter specified tributaries, and 2) locate areas of high juvenile shad abundance. The upper section of Conowingo Pond presumably has better spawning habitat, while habitats in the lower section of Conowingo Pond are heavily dominated by sand and silt substrates, and do not represent good spawning habitat for the species considered.

The limited success of these programs was consistent with the work reported by earlier authors who suggested that Conowingo Pond provided marginally suitable habitat for the reproduction of American shad. No river herring and only two adult American shad entered the selected tributaries. The few juvenile shad collected in the upper reaches of Conowingo Pond most likely originated upstream of Muddy Run Pumped Storage Project (MRPSP) and probably upstream of Conowingo Pond.

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TABLE 4.1-1: SUMMARY OF ADULT AMERICAN SHAD USED FOR A SHAD EGG SOURCE FROM GILL NET COLLECTIONS IN UPPER CONOWINGO POND, 2003-2005.

Date	Water Temperature (°C)	Secchi Disk (inches)	Number of Net Drifts	Average River Flow (cfs)[2]	Start Time (h)	End Time (h)	Number of American Shad	Liters of Eggs Collected	Number Females	Male: Female Ratio
12-May-03	17.5	NA	6	41,000	1925	2116	2	0.00	1	2.0:1
14-May-03	16.5	NA	6	40,600	1900	2130	22	0.00	6	3.7:1
19-May-03	14.0	33	7	52,600	1846	2103	38	0.10	15	2.5:1
21-May-03	15.5	36	8	43,500	1845	2230	21	0.75	7	3.0:1
23-May-03	15.5	40	7	39,700	1845	2130	28	0.33	18	1.6:1
27-May-03	16.0	35	6	52,200	1900	2200	26	0.80	16	1.6:1
18-Jun-03	21.5	35	5	44,900	1820	2045	1	0.00	1	1.0:1
13-May-04	21.8	26	6	69,700	1903	2125	39	0.00	33	1.2:1
17-May-04	23.0	25	6	51,100	1915	2120	16	0.00	14	1.1:1
20-May-04	22.0	23	6	42,400	1904	2120	22	0.00	11	2.0:1
27-May-04	23.0	21	6	60,600	1910	2120	7	0.00	5	1.4:1
1-Jun-04	20.5	21	6	41,900	1905	2100	3	0.00	3	1.0:1
11-May-05	16.5	41	5	21,800	1930	2130	0	0.00	0	NA
16-May-05	18.0	65	5	19,200	1928	2120	3	0.00	2	1.5:1
18-May-05	19.0	58	5	17,850	1928	2130	1	0.00	1	1.0:1
24-May-05	19.0	36	5	15,500	1910	2120	0	0.00	0	NA
26-May-05	18.0	43	5	14,900	1925	2130	0	0.00	0	NA
Total			***100***				***229***	***1.98***	**133**	**1.7:1**
Mean	***18.7***	***32***		***39,379***						

(1) Source: Normandeau Associates, Inc. 2003a, 2004, 2005). (2) River flow taken from the USGS gauge station located in Marietta, PA.
(3) NA = Not Available.

TABLE 4.1-2: SUMMARY OF LARVAL AND JUVENILE AMERICAN SHAD COLLECTED BY PUSHNET AT LOCATIONS IN CONOWINGO POND, JUNE AND JULY 1998 THROUGH 2003.

Station No.[2]	Location	Number of American Shad Collected						Total
		1998	1999	2000	2001	2002	2003	
	East Shore Stations	0	0	0	ELIMINATED AFTER 2000			0
1	Deepwater Island	NOT SAMPLED UNTIL 2001			1	0	0	1
2	Turkey Island	NOT SAMPLED UNTIL 2001			1	0	0	1
3	Muddy Run Station	NOT SAMPLED UNTIL 2001			11	0	0	11
4	Sicliy Island	0	0	0	7	0	0	7
5	Hennery Island	2	0	0	27	0	0	29
6	Big Chestnut Island	0	0	0	10	0	0	10
7	Big Chestnut Island	0	0	0	19	0	0	19
8	Big Chestnut Island	0	0	0	14	0	0	14
9	Lower Bear Island	1	1	0	7	0	0	9
10	Lower Bear Island	6	2	0	39	0	0	47
TOTAL		**9**	**3**	**0**	**136**	**0**	**0**	**148**

(1) Source: Normandeau Associates, Inc. 1998, 1999c, 2000c, 2001c, 2002, 2003b).

(2) Corresponds to key in Figure 4.3-2.

TABLE 4.2-1: TOTAL NUMBER ICHTHYOPLANKTON COLLECTED BY 0.5M PLANKTON NETS LOWER SUSQUEHANNA RIVER 1982 TO 1984

Species	**1982**	**1983**	**1984**		
No. Taxa	**18**	**20**	**22**		
No. Samples	**405**	**446**	**471**	**Total 1,322**	**% of Total**
American shad	**7**	**138**	**179**	**324**	**0.1%**
River herrings	**11,772**	**26,827**	**26,677**	**65,276**	**24%**
White perch	23,270	112,249	61,589	197,108	72%
Carp	371	307	118	796	0.3%
Gizzard shad	3,911	3,464	1,886	9,261	3.4%
Other	1,040	1,099	806	2,945	1.1%
TOTAL	40,371	144,084	91,255	275,710	

TABLE 4.2-2: SUMMARY OF ICHTHYOPLANKTON DENSITIES (N/M3) COLLECTED BY 0.5M PLANKTON NETS LOWER SUSQUHANNA RIVER, APRIL THROUGH JUNE 1982.

Species	Eggs	Prolarvae	PostLarvae	Older	Total Density	Total Number
American shad	**0.00**	**0.00**	**0.00**		**0.00**	**7**
River herrings	**0.52**	**0.04**	**0.02**		**0.58**	**11,969**
White perch	1.03	0.11	0.00		1.14	23,270
Carp	0.01	0.00	0.00		0.02	371
Gizzard shad	0.03	0.01	0.15	0.00	0.19	3,911
Other	0.01	0.02	0.01	0.00	0.04	843
TOTAL	1.60	0.19	0.18	0.00	1.97	40,371
% Composition	81%	10%	9%	0%		

TABLE 4.2-3: SUMMARY OF ICHTHYOPLANKTON DENSITIES (N/M3) COLLECTED BY 0.5M PLANKTON NETS LOWER SUSQUEHANNA RIVER, MARCH 30 THROUGH JUNE 28, 1983.

Species	Eggs	Prolarvae	PostLarvae	Older	Total Density	Total Number
American shad	**0.01**				**0.01**	**138**
River herrings	**1.13**	**0.17**	**0.00**		**1.30**	**26,827**
Gizzard shad	0.00	0.04	0.13	0.00	0.17	3,464
Carp	0.01	0.00	0.00		0.01	307
White perch	4.65	0.69			5.34	112,249
Other	0.02	0.02	0.01	0.00	0.05	1,099
TOTAL	5.82	0.92	0.14	0.00	6.88	144,084
% Composition	85%	13%	2%	0.0%		

TABLE 4.2-4: SUMMARY OF ICHTHYOPLANKTON DENSITIES (N/M3) COLLECTED BY 0.5M PLANKTON NETS LOWER SUSQUEHANNA RIVER APRIL 3 THROUGH JUNE 28 1984.

Species	Eggs	Prolarvae	PostLarvae	Older	Total Density	Total Number
American shad	**0.01**	**0.00**	**0.00**	**0.00**	**0.01**	**179**
River herrings	**0.85**	**0.04**	**0.01**	**0.00**	**0.90**	**26,677**
White perch	1.89	0.18	0.00	0.00	2.07	61,589
Carp	0.00	0.00	0.00	0.00	0.00	118
Gizzard shad	0.00	0.01	0.06	0.00	0.06	1,886
Other	0.01	0.01	0.00	0.00	0.03	806
TOTAL	2.8	0.2	0.1	0.0	3.074	91,255
% Composition	90%	8%	2%	0.0%		

TABLE 4.2-5: MONTHLY SUMMARY OF ALOSA (EGGS AND LARVAE) BY AREA, APRIL THROUGH JUNE 1984.

	April			May			June			Total		
	Egg	Pro larvae	Post larvae	Egg	Pro larvae	Post larvae	Egg	Pro larvae	Post larvae	Egg	Pro larvae	Post larvae
Upper river	383			9,443	46		1,743	9		11,569	55	
Lower river	584	1		5,913	37	4	296	5		6,793	43	4
Upper tidal	344	4		5,884	443		388	290	4	6,616	737	4
Lower tidal		1		22	281		3	39	229	25	321	229
Creeks	16	16		158	44		40	7		214	67	
TOTAL	1,327	22		21,420	851	4	2,470	350	233	25,217	1,223	237

TABLE 4.2-6: WEEKLY SUMMARY OF ICHTHYOP1ANKTON (EGGS AND LARVAE) TAKEN BY 0.5 M PLANKTON NET IN THE SUSQUEHANNA RIVER BELOW CONOWINGO HYDROELECTRIC STATION, APRIL THROUGH JUNE 1983.

	A 4/3/1983	A 4/10/1983	A 4/17/1983	M 5/1/1983	M 5/8/1983	M 5/15/1983	M 5/22/1983	M 5/29/1983	J 6/5/1983	J 6/12/1983	J 6/19/1983	J 6/26/1983	Total
White perch	8	3	359	2,372	2,583	30,752	14,751	47,660	10,992	2,744	22	3	112,249
Alosa spp.			**15**	**2,168**	**1,746**	**6,921**	**9,187**	**6,143**	**601**	**45**		**1**	**26,827**
Gizzard Shad			1			208	308	311	1,539	449	627	21	3,464
Unid. Eggs			4	82	55	125	73	48	34	9	1		431
Carp						1	4	12	277	10	2	1	307
Quillback					1	21	130	78	14	20		1	265
Cyprinidae					19	50	115	29	5	2	2		222
American Shad				**1**		**1**		**135**		**1**			**138**
Percidae				2		7	11	37	3	3			63
Catostomidae						2	14	6	10	4			36
White crappie							1	2	4	17	5	1	30
Yellow perch				1		1	15	3		1			21
Creek chubsucker				1			1			6			8
Bluegill						1	1			2	3	1	8
Unid. Larvae						5							5
Northern hog sucker							2						2
Shorthead redhorse							2						2
Pumpkinseed										2			2
Centrarchidae						1							1
Largemouth bass											1		1
Tessellated darter				1									1
Walleye					1								1
TOTAL	8	3	379	4,628	4,405	38,096	24,615	54,464	13,479	3,315	663	29	144,084
No. of species	1	1	3	7	5	12	14	11	9	14	7	7	20
No. of samples	1	1	1	2	1	5	6	7	7	6	1	1	39
No./Sample Day	8.0	3.0	379.0	2314.0	4405.0	7619.2	4102.5	7780.6	1925.6	552.5	663.0	29.0	

TABLE 4.2-7: WEEKLY SUMMARY OF ICHTHYOP1ANKTON (EGGS AND LARVAE) TAKEN BY 0.5 M PLANKTON NET IN THE SUSQUEHANNA RIVER BELOW CONOWINGO HYDROELECTRIC STATION, APRIL THROUGH JUNE 1984

Common Name	A 4/8/1984	A 4/15/1984	A 4/22/1984	A 4/29/1984	M 5/6/1984	M 5/13/1984	M 5/20/1984	M 5/27/1984	J 6/3/1984	J 6/10/1984	J 6/17/1984	J 6/24/1984	Total
White perch	457	1,866	2,436	4,797	6,260	13,726	9,215	2,726	11,639	7,159	883	425	61,589
Alosa spp.		**186**	**33**	**2,950**	**1,026**	**11,794**	**5,724**	**1,911**	**1,821**	**1,193**	**30**	**9**	**26,677**
Gizzard shad		1	1	5	14	12	28	45	16	665	819	280	1,886
Yellow perch		215			1	3		3	5	1		1	229
Suckers					8		25	16	63	37	23	9	181
American shad					**3**			**2**	**170**		**4**		**179**
Minnows				1	1	20	27	29	17	32	37	9	173
Carp								2	7	9	99	1	118
Unidentified (eggs)		2	1	3	5	11	21	22	14	19	16		114
Hickory shad			**3**	**6**	**11**	**1**	**1**		**3**				**25**
Quillback								1	10	2	6	2	21
Perches					1	5	2	1	8	2			19
Bluegill									1	1	6		8
Tessellated darter						1			4	2	1		8
Smallmouth bass											6		6
Creek chubsucker									1			3	4
Sunfish family									2	2			4
White crappie											4		4
Spotfin shiner									1		1		2
Spottail shiner					1	1							2
White sucker							2						2
Largemouth bass												1	1
Pumpkinseed					1								1
Shorthead redhorse									1				1
Walleye					1								1
TOTAL	457	2,270	2,474	7,762	7,333	25,574	15,045	4,758	13,783	9,124	1,935	740	91,255

TABLE 4.2-8.NUMBER AND DENSITY (N/M3) OF AMERICAN SHAD EGGS TAKEN BY ANCHORED 0.5M PLANKTON NETS, FISHED NEAR THE BOTTOM, OFF THE NORTHEAST SHORE OF SPENCER LSLAND (X-1075; Y-6825, SEE FIGURE 4.2-5), 14 MAY THROUGH 20 JUNE 1983.

Date	No. Samples	Time Span	Total Sampling Time (min)	Approximate Flow X 10^3 Range (cfs)*	Water Temperature (F)	Eggs Collected No.	Eggs Collected Average Density n/m^3	Range of Egg Density (n/m^3)
14-15 May	3	0836-0943	46	10.6-20.7	60.8	2	0.03	0.00-0.04
16-17 May	3	0638-0802	45	5.5-22.3	59.0	1	0.01	0.00-0.01
18-19 May	3	0311-0711	45	16.5-40.7	61.4	10	0.12	0.06-0.31
20-21 May	1	0752-0802	10	50.6	61.2	4	0.04	0.04
24-25 May	1	0124-0139	15	73.0	62.6	2	0.02	0.02
26-27 May	1	0236-0251	15	73.0	62.6	-	0.00	0.00
28-29 May	1	0001-0016	15	66.1	63.4	3	0.06	0.06
1-2 Jun	5	0145-0641	75	5.4-29.5	63.3	18	0.22	0.00-0.84
3-4 Jun	3	2329-1051	45	10.6-53.4	66.0	32	0.26	0.06-0.31
5-6 Jun	2	0718-0802	30	5.3-49.2	66.2	31	0.34	0.29-1.23
7-8 Jun	2	0804-0858	30	5.4-30.1	68.4	1	0.01	0.00-0.01
9-10 Jun	2	0736-0815	30	5.4-30.1	69.9	19	0.14	0.00-0.57
11-12 Jun	1	1318-1333	15	10.7	72.5	1	0.24	0.24
12-13 Jun	3	0827-1002	45	10.7-30.1	72.9	21	0.19	0.13-0.42
19-20 June	2	1118-1203	30	29.6	78.8	-	0.00	0.00

* Flow's from Conowingo Hydroelectric Station approximately 1.5 hr prior to initiation of sampling

TABLE 4.2-9.NUMBER AND DENSITY (N/M3) OF AMERICAN SHAD EGGS TAKEN BY ANCHORED 0.5 M PLANKTON NETS FISHED NEAR TELEMETERED AMERICAN SHAD AND/OR SPLASHING ACTIVITY ASSOCIATED WITH SPAWNING BELOW CONOWINGO DAM, 20 MAY THROUGH 6 JUNE 1983.

	Location [b]			Depth					Eggs Collected	
Date*	X	Y	Water Temp (F)	Water Column	Net	Time Span	Water Velocity Surface (ft/s)	Flow**	No.	Density n/m^3
20-21 May	975	7330	60.8	7	-	2210-2220	2.4	51.4	62	0.92
22-23 May	1200	7000	61.2	9	9	0129-0144	-	62.5	3	0.04
28-29 May	1100	8000	63.4	13	13	2115-2130	2.6	66.1	16	0.32
28-29 May	400	900	-	4	4	2209-2224	-	66.1	-	-
28-29 May	-100	1500	-	4	4	2318-2324	-	66.1	-	-
29-30 May	1150	9000	63.4	19	Surface	0135-0150	0.4	30	-	-
30-31 May	970	7650	63.5	7	Surface	2134-2149	1.8	63.6	22	0.22
30-31 May	970	7650	63.5	7	7	2154-2209	1.8	63.6	5	0.33
1-2 Jun	-50	1475	64.3	5	5	21J5-2150	1.6	62.9	2	0.03
1-2 Jun	-50	1475	64.3	4	Surface	2200-2215	0.7	39.1	123	2.79
1-2 Jun[a]	1000	7500	68	-	Surface (tow)	1940-1945	-	62.9	2	0.04
1-2 Jun[a]	1000	7500	68	9	9	2025-2037	-	62.9	24	0.58
1-2 Jun[a]	1000	7500	68	9	9	2048-2100	-	62.9	2	0.03
1-2 Jun[a]	1000	7850	68	10	10	2110-2129	-	62.9	84	2.63
1-2 Jun[a]	1000	7850	68	10	Surface	2133-2147	-	62.9	23	0.41
2-3 Jun	900	7100	64.1	-	Surface	0212-0227	-	5.4	-	-
3-4 Jun	260	1505	66.2	3	Surface	2113-2128	1.8	21.1	1	0.01
5-6 Jun	1000	7750	66.2	8	Surface	2233-2248	1.6	64.4	127	1.34
5-6 Jun	1000	7750	66.2	8	Surface	2256-2311	1.5	64.4	23	0.26
5-6 Jun	1000	7800	66.2	8	8	0827-0842	0.7	49.2	7	0.99
5-6 Jun	1000	7800	66.2	8	8	0848-0903	1	49.2	7	0.87

*Dates are listed by the night time period
**Flows from Conowingo Hydroelectric Station approximately 1.5-hr prior to initiation of sampling, except for samples taken where Y < or =1550 m these are reported as current generation status
a Collected by Delmarva Ecological Laboratory, Inc.
b See Figure 4.2-5 for study area downstream of Conowingo Dam grid coordinates

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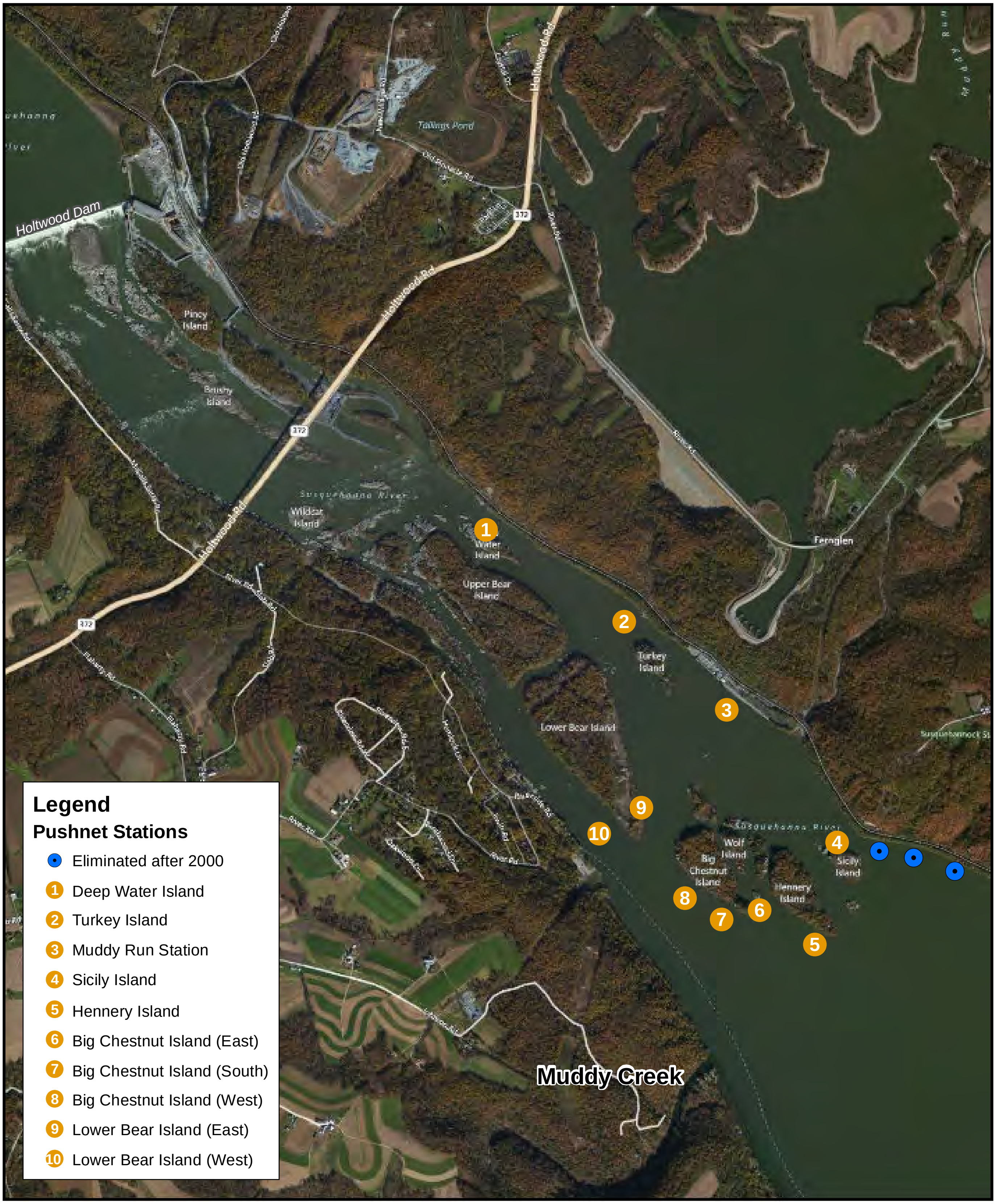
1 inch = 0.4 miles

0 0.25 0.5 1 Miles

N

Figure 4.1-1.
Figure Title: Gill net locations in Conowingo Pond used to collect American shad eggs, May 2005.

Path: X:\GISMaps\project_maps\study_plan\conowingo\study_3.21\Gillnet_Locations.mxd



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PROJECT NO. 405

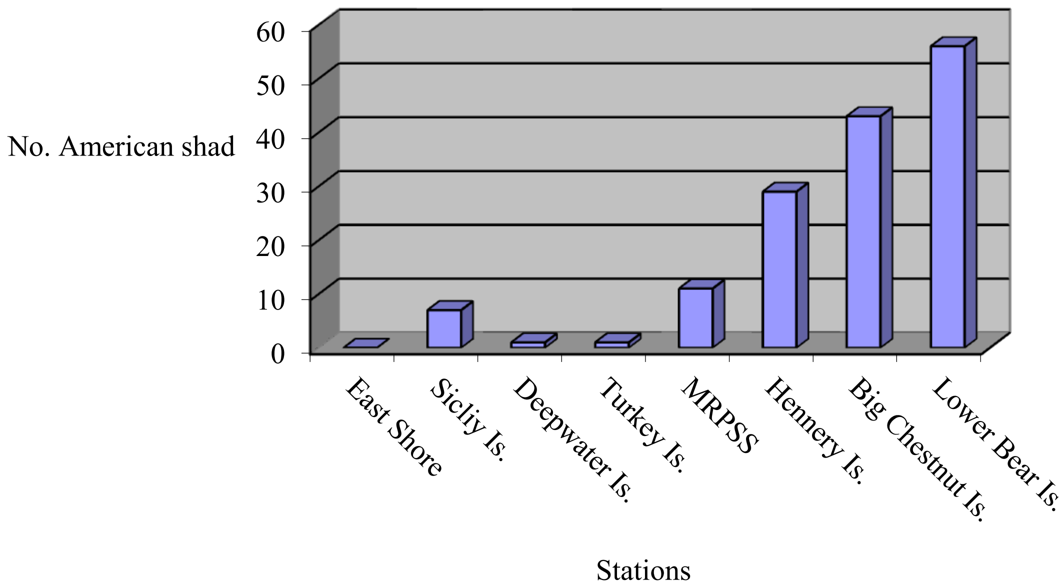
1 inch = 0.4 miles

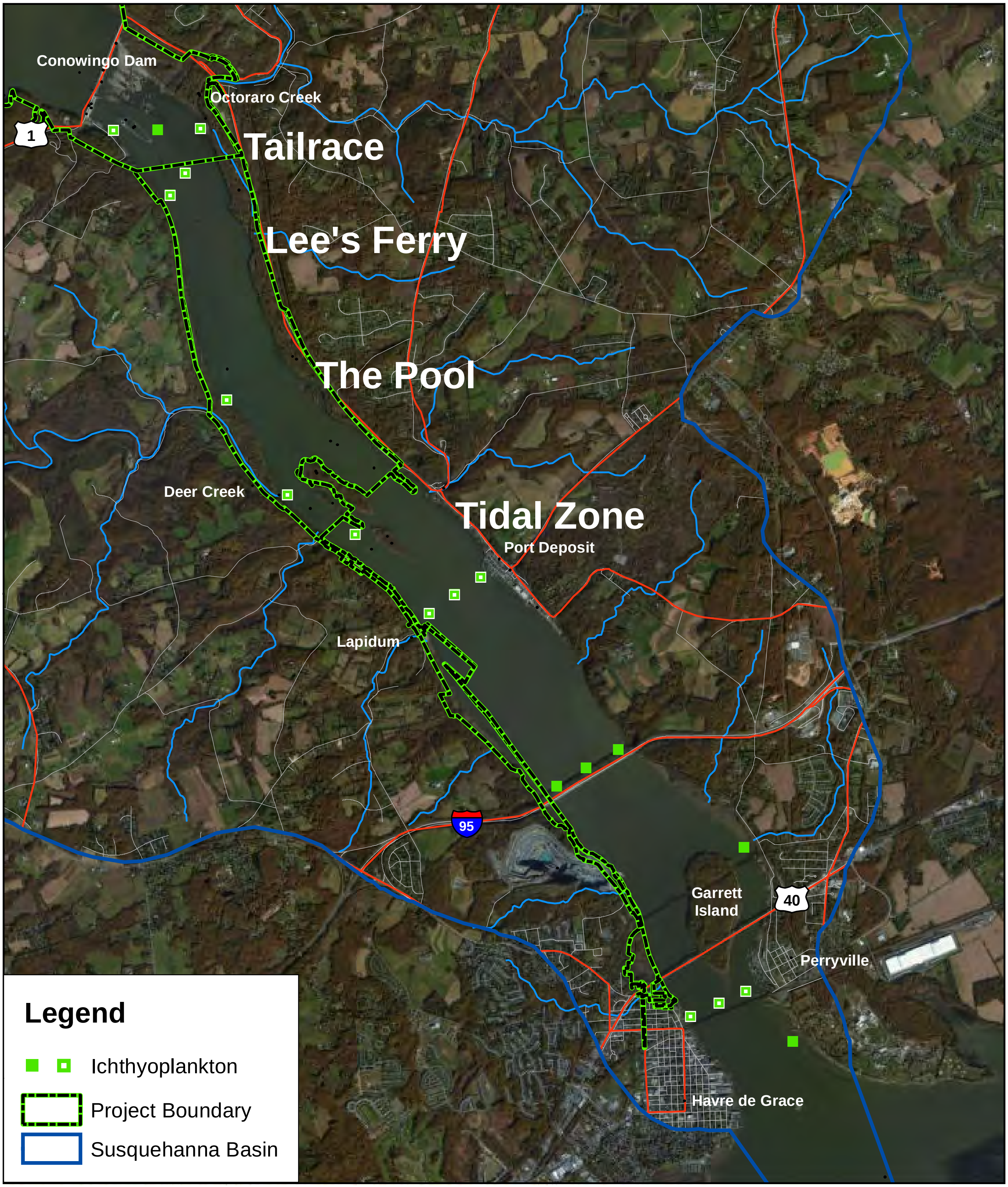
0 0.25 0.5 1 Miles

Figure 4.1-2.
Figure Title: Map of pushnet stations sampled for alosids in Conowingo Pond, 1998 - 2003.

Path: X:\GISMaps\project_maps\study_plan\conowingo\study_3.21\Pushnet_Locations.mxd

FIGURE 4.1-3: COMPOSITED CATCH OF AMERICAN SHAD LARVAE AND JUVENILES COLLECTED BY PUSHNET IN UPPER CONOWINGO POND, 1998 THROUGH 2003.





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PROJECT NO. 405

1 inch = 1.1 miles

0 0.5 1 2 Miles

Figure 4.2-1:
Sampling Transects for
Lower Susquehanna River
Ichthyoplankton Syrveys, 1982-1984

Path: X:\GISMaps\project_maps\study_plan\conowingo\study_3.21\sampling_transects.mxd

FIGURE 4.2-2: MONTHLY TOTAL AND *ALOSA* ICTHYOPLANKTON COLLECTED 1983 AND 1984.

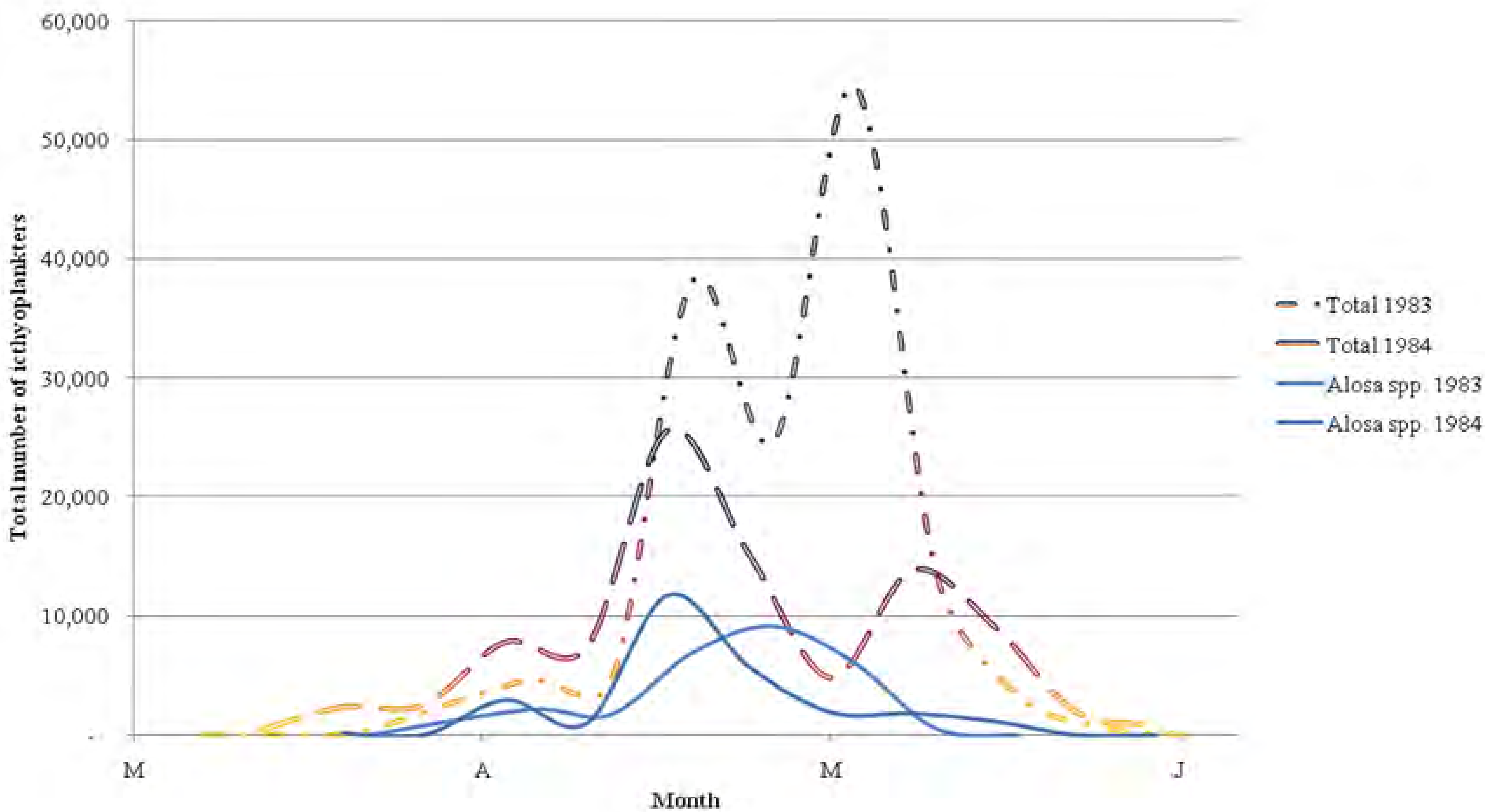


FIGURE 4.2-3: PERCENT DISTRIBUTION OF RIVER HERRING ICHTHYOPLANKTON COLLECTED BELOW CONOWINGO DAM, APRIL – JUNE 1982.

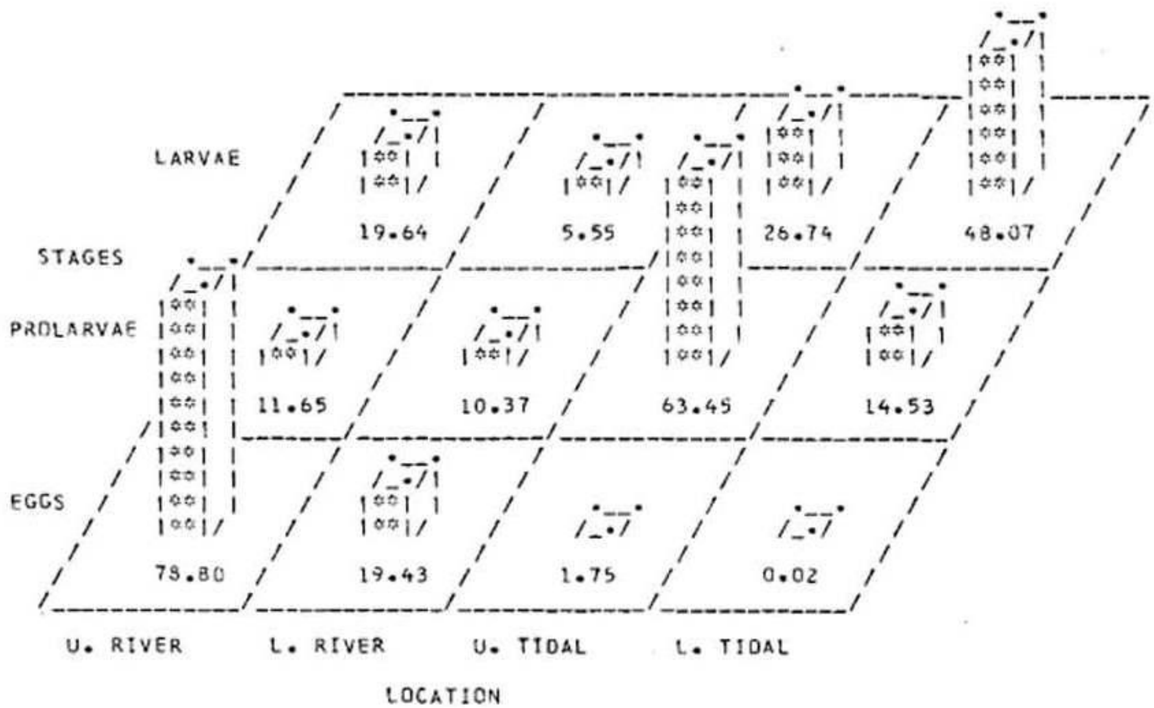


FIGURE 4.2-4: DENSITY (N/M^3) DISTRIBUTION OF RIVER HERRING ICHTHYOPLANKTON COLLECTED BELOW CONOWINGO DAM, APRIL – JUNE 1983.

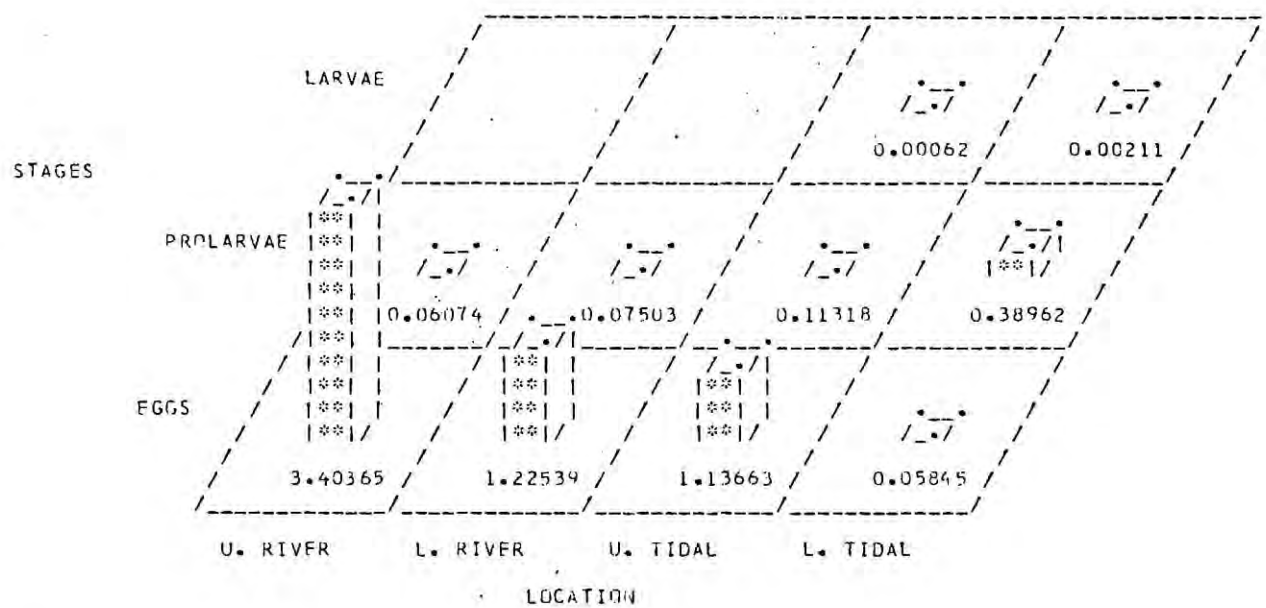


FIGURE 3.1-2.

Density (n/m^3) distribution of larval stages of river herring (Alosa spp.) below the Conowingo Hydroelectric Station, April through June 1983.

FIGURE 4.2-5: LOWER SUSQUEHANNA RIVER SAMPLING AREA GRID, REFERENCED IN TABLE 4.2-9.

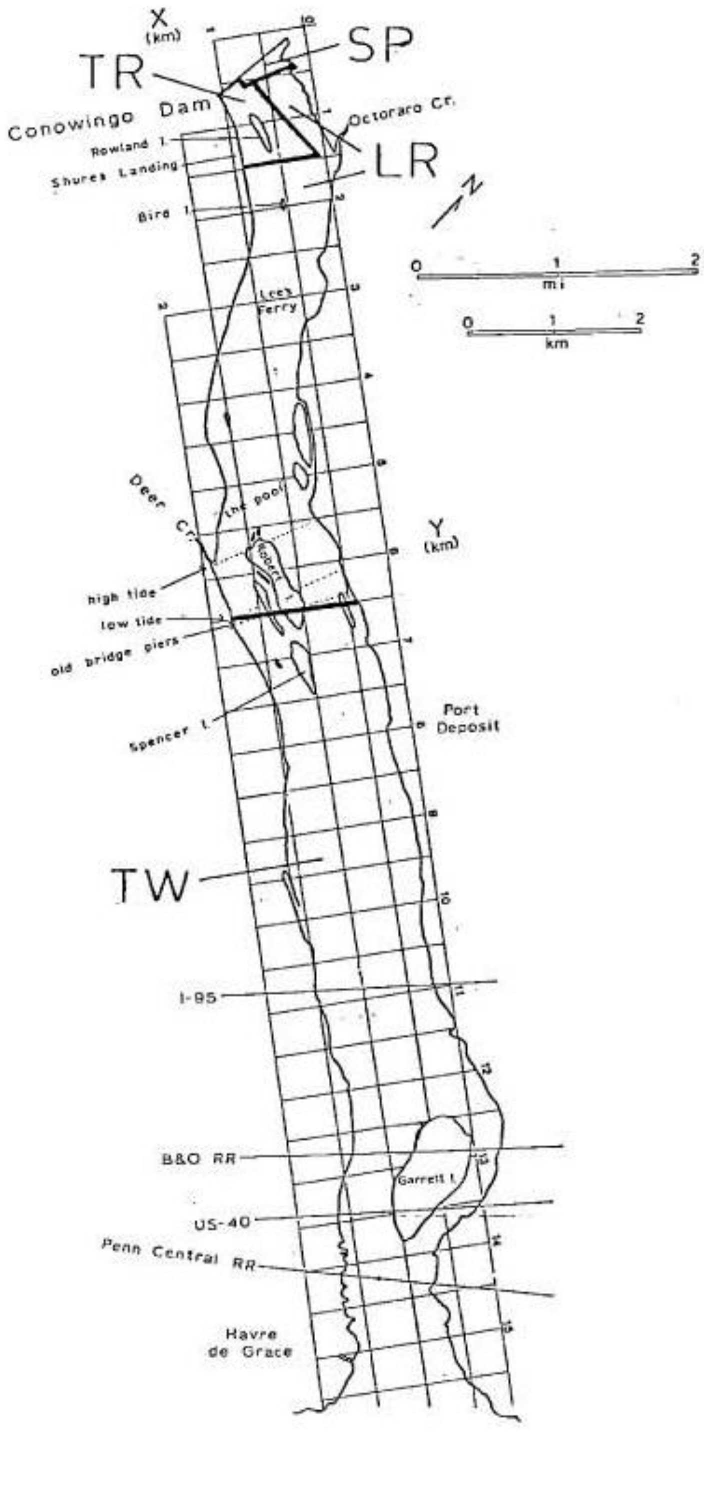
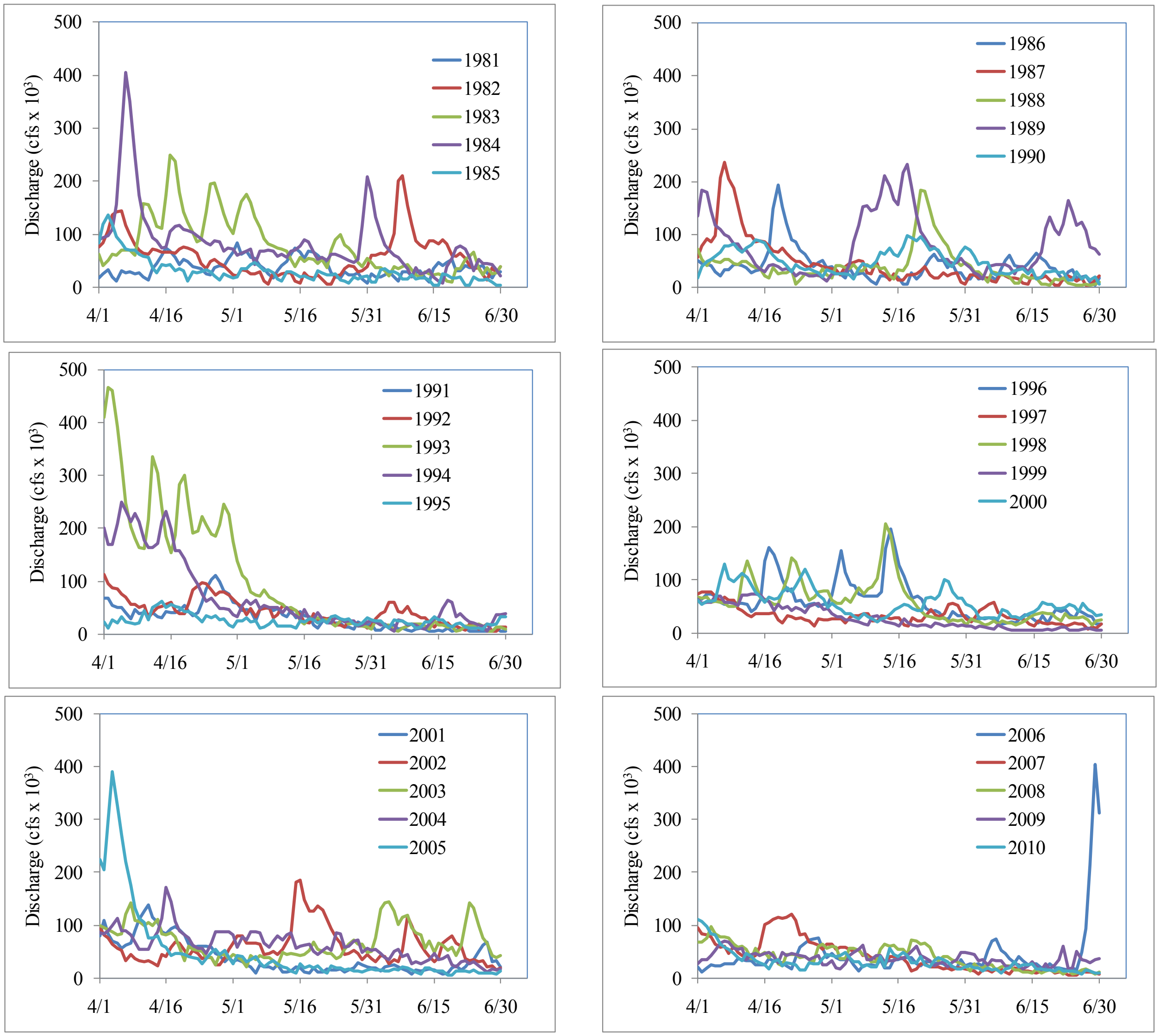


FIGURE 5-1: DAILY AVERAGE SUSQUEHANNA RIVER DISCHARGE AT CONOWINGO DAM FOR APRIL – JUNE, 1981 - 2010.



Data from USGS Gauge No. 01578310; 2010 data are provisional and subject to revision