FINAL STUDY REPORT
SHORTNOSE AND ATLANTIC STURGEON LIFE HISTORY STUDIES
RSP 3.22

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 Conowingo Project on February 4, 2010, approving the revised study plan with certain modifications. The final study plan determination required Exelon to conduct studies regarding shortnose and Atlantic sturgeon in the Susquehanna River.

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. An updated study report (USR) was filed on January 23, 2012 describing the combined results of the 2010 and 2011 Conowingo sturgeon studies. This final study report is being filed with the Final License Application for the Project.

Life history studies were conducted by: reviewing regionally pertinent information for sturgeon in the context of historical and contemporary presence and habitat requirements, reviewing East Coast fish passage facilities known to pass sturgeons in comparison with the Conowingo east fish lift, conducting an analysis of suitable habitat below Conowingo Dam, assessing sturgeon stranding below Conowingo Dam, and monitoring the Susquehanna River with field deployed, data-logging sonic telemetry receivers for presence of tagged fish from other systems.

The assessment of suitable habitat below Conowingo Dam is ongoing and will include analysis of project operational impacts on shortnose sturgeon habitat availability as part of the Instream Flow Habitat Assessment. The results of that study will be submitted under separate cover (Study 3.16).

Potential stranding areas below Conowingo Dam were assessed for fish stranding under minimum flow scenarios following higher peaking discharge periods in 12 surveys between late April and late November, 2010. No sturgeon were observed. Details and results of that study will be submitted under separate cover (Study 3.8).

The majority of known contemporary occurrences of sturgeons in the Susquehanna River and upper Chesapeake Bay resulted from the U.S. Fish and Wildlife Service (USFWS) and Maryland Department of Natural Resources (MDNR) coast-wide sturgeon tagging program, initiated in 1992, and a smaller reward program that was initiated in 1996 specifically to learn more about sturgeon in the Maryland portion of the Chesapeake Bay. In the 19 years since inception of the program, 5 shortnose sturgeon and no Atlantic sturgeon were reported from the tidal portion of the Susquehanna River, and 3 shortnose sturgeon were reported from the Susquehanna Flats area. In addition, two shortnose sturgeon were recorded from angler catchs in the Conowingo Dam tailrace in 1986. No collections of shortnose sturgeon have been reported in the river since 2004.

Records of Atlantic sturgeon captures as well as relocation data for hatchery-reared juveniles released to the Nanticoke River suggest that Atlantic sturgeon do not frequent the extreme upper Bay, though movement from the Delaware River via the Chesapeake & Delaware Canal has been observed.

A review of habitat requirements for both species suggests that suitable habitat is available in the Susquehanna River and upper Chesapeake Bay; however water quality issues in Chesapeake Bay may be a limiting factor for juvenile production.

Only a few East coast fish passage facilities are known to have passed sturgeons and, while passage efficiency is difficult to quantify, it is unlikely that any can be considered successful. Comparative attributes of the Conowingo east fish lift to the Holyoke fish lifts, Connecticut River, Massachusetts and the St. Stephen fish lock, Santee River / Rediversion Canal suggest that the Conowingo fish lift does not differ greatly in design or lift capacity.

Fixed station monitoring with full river-width coverage for sonic transmitter tagged sturgeons was continuous along two transects in the lower Susquehanna River from April – November, 2010 and from April – December, 2011. No tagged sturgeons were detected.

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LIST OF ABBREVIATIONS

Agencies

ASSRT	Atlantic Sturgeon Status Review Team
MDNR	Maryland Department of Natural Resources
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
USGS	United States Geological Survey
USFWS	United States Fish and Wildlife Service

Units of Measure

C	Celsius, Centigrade
cfs	cubic feet per second
CI	confidence interval
cm	centimeter
cms	cubic meter per second
ETM	estuarine turbidity maximum
fps	feet per second
km	kilometer
L	liter
m	meter
ml	milliliter
mm	millimeter
MW	megawatt
psu	practical salinity units

Regulatory

CFR	Code of Federal Regulations
ESA	Endangered Species Act
ILP	Integrated Licensing Process
FR	Federal Register
NOI	Notice of Intent
PAD	Pre-Application Document
PSP	Preliminary Study Plan
RSP	Revised Study Plan
USC	United States Code

Miscellaneous

C&D	Chesapeake and Delaware
DPS	distinct population segments
Exelon	Exelon Generating Company, LLC

A note on units: Metric units of measure were generally used; however, standard units are used for the hydraulic variables cubic feet per second (cfs) and feet per second (f/s).

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 license renewal 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 FERC 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 the following studies for shortnose and Atlantic sturgeon in the Susquehanna River (Study Plan 3.22):

1. Literature review for shortnose and Atlantic sturgeon occurrence in the Susquehanha River, life history, and habitat requirements;
2. A comparision between Conowingo fish lift and any East Coast passage facilities where successful shortnose or Atlantic sturgeon upstream passage has been documented;
3. Analysis of habitat types below Conowingo Dam;
4. Documentation of sturgeon stranding below Conowingo Dam; and
5. Monitoring of the Susquehanna River for use by sturgeon.

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. An updated study report (USR) was filed on January 23, 2012 describing the combined results of the 2010 and 2011 Conowingo sturgeon studies. This final study report is being filed with the Final License Application for the Project.

2.0 LITERATURE REVIEW

2.1 Objectives

Extensive reviews of life history, behavior, habitat requirements, and status have been published for shortnose sturgeon (e.g., Dadswell 1979, Dadswell et al. 1984, Crance 1986, NMFS 1987, Gilbert 1989, Kynard 1997, Bain 1997, NMFS 1998), and Atlantic sturgeon (Murawski and Pacheco 1977, Gilbert 1989, Taub 1990, Bain 1997, ASSRT 1998, 2007). Additionally, comprehensive guiding documents for research related to handling of shortnose and Atlantic sturgeon have been published, providing significant information regarding field sampling methodology and proper handling techniques (Moser et al. 2000, Damon-Randall et al. 2010, Kahn and Mohead 2010). The objective of this section was to provide a brief review of species status, occurrence in the Susquehanna River, and habitat requirements.

2.2 Background

Two species of sturgeons, the Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus* Mitchill) and shortnose sturgeon (*A. brevirostrum* Lesueur), inhabit the East coast of North America (Gilbert 1989). Both species have complex life histories and share some habitat overlap (Bain 1997), but do not share common life histories (Bemis and Kynard 1997). Substantial differences exist between the two species; for example, age and size at maturity, maximum size, timing and location of spawning, and migratory behavior (Bain 1997). Sturgeons are generally large fishes distinguished by an elongated snout, ventral protrusile mouth, a row of four barbells between the tip of the snout and the mouth, a head covered by bony plates, five rows of bony scutes (functioning like scales), and a strongly heterocercal (unequal lobes) tail. The sex of individuals usually is not determined by external examination except during spawning time (Gilbert 1989), though Vecsei et al. (2003) developed a technique that allowed them to determine the sex of adult shortnose sturgeon and sub-adult Atlantic sturgeon with fair accuracy (67-75 % for shortnose and 71-89% for Atlantic sturgeon). Atlantic sturgeon grow to a much larger maximum length (427 cm TL) compared to shortnose sturgeon (143 cm TL, Dadswell et al. 1984, Bain 1997; Damon-Randall et al. 2010), but juvenile Atlantic sturgeon may be confused with shortnose sturgeon. The most reliable characteristic to distinguish the two species is the ratio of mouth width to interorbital (between the eyes) distance (Atlantic sturgeon: <55%, shortnose sturgeon: >62%, Dadswell et al. 1984). Data indicate, however, that variability in this ratio is wide and there is some overlap between the species (Damon-Randall et al. 2010). Other characteristics that can aid in field identification include relative snout length and the (usual) presence of bony plates between the anal fin and lateral scutes of Atlantic, but not shortnose sturgeon (Damon-Randall et al. 2010).

2.3 Status

2.3.1 Shortnose Sturgeon

Shortnose sturgeon was listed as endangered range-wide in the first listing (32 FR 4001) under the federal Endangered Species Preservation Act in 1967 (16 USC 668 *et seq.*) and the listing was continued with enactment of the federal Endangered Species Act (ESA) in 1973 (16 USC 1531 *et seq.*). Although listed as endangered range-wide (i.e., as a single population) in the species recovery plan, the National Marine Fisheries Service (NMFS) recognized 19 distinct population segments (DPS) occurring in New Brunswick, Canada (1), Maine (2), Massachusetts (1), Connecticut (1), New York (1), New Jersey/Delaware (1), Maryland/Virginia (1), North Carolina (1), South Carolina (4), Georgia (4) and Florida (2) (NMFS 1998). NMFS noted that genetic information was needed to help resolve the discrimination of distinct population segments and that DPS recognition is subject to change pending an ongoing Status Review for the species. The recovery plan recognized that shortnose sturgeon were thought to no longer exist in some rivers where they historically occurred, particularly in the middle (e.g., Chesapeake Bay rivers, including the Susquehanna) and southern end of their range and was designed primarily to address recovery of extant population segments, deeming recovery in rivers where they were extirpated as low priority, but recognizing the importance of restoring the historically continuous range of the species (NMFS 1998).

Although virtually no information on shortnose sturgeon population dynamics in the Susquehanna River is available, the geographically adjacent Delaware River system has been relatively well studied. Hastings et al. (1987) reported the Delaware River shortnose sturgeon population calculated by three methods in the early 1980's with results ranging from 6,408 (Seber-Jolly method), to 12,796 (95% CI: 10,288-16,367, Schnabel method), to 14,080 (95% CI: 10,079-20,378, modified Peterson method). Another population estimate was calculated for mark recapture data collected in 1999 – 2003, yielding an estimate of 12,047 adult shortnose sturgeon (95% CI: 10,757 – 13,589, O'Herron Biological and Environmental Consulting, Inc. 2006 as cited in DRJTBC 2008). The similarity in these estimates suggests that the Delaware River population is stable with no significant population expansion since the 1980's.

2.3.2 Atlantic Sturgeon

Atlantic sturgeon was identified as a candidate species for listing under the ESA in 1991. In 1997, as the result of a petition to list the species as threatened or endangered, NMFS and the United States Fish and Wildlife Service (USFWS) determined that substantial information existed suggesting that the action might be warranted (62 FR 54018); subsequently, a status review was conducted (ASSRT 1998). In

1998, NMFS and USFWS published their 12-month review determination that listing was not warranted at that time (63 FR 50187); however, they retained the species on the candidate list. As a result of a 2003 workshop regarding Atlantic sturgeon, NMFS determined that a second status review was needed to determine if listing was warranted, and a second Atlantic Sturgeon Status Review Team (ASSRT) composed of scientists representing NMFS, USFWS, and the United States Geological Service (USGS) was assembled. The ASSRT recommended that Atlantic sturgeon be divided into five distinct population segments (DPSs): Gulf of Maine, New York Bight, Chesapeake Bay (including Susquehanna River), Carolina, and South Atlantic, and that the Gulf of Maine, New York Bight, Chesapeake Bay, and Carolina DPSs be listed as threatened. No listing recommendation was made for the Gulf of Mexico or South Atlantic DPSs, citing a lack of sufficient information to allow a full assessment (ASSRT 2007, 72 FR 15865). In October 2009, NMFS was again petitioned to list Atlantic sturgeon as endangered or to delineate the five DPS's as described by ASSRT (2007). In January 2010 following a 90-day review period, NMFS concluded that the petition presented sufficient information indicating that listing may be warranted (75 FR 838). In October 2010, based on the status review and additional information, NMFS proposed the five DPS's and listing the Gulf of Maine DPS as threatened and the other four DPS as endangered under ESA (75 FR 61872).

Atlantic sturgeon abundance was high in the late 1800's and large scale commercial fisheries were created. The Delaware Bay fishery was the largest, but Chesapeake Bay supported several fisheries as well, specifically in the James, York, Rappahannock, Wicomoco / Pocomoke, Nanticoke, Choptank, Potomac, and Patuxent Rivers; apparently no landings were recorded for the upper Chesapeake Bay. By 1901 the mid-Atlantic fishery had collapsed (Secor 2002). Reviews of fishery dependent and independent captures for Atlantic sturgeon in Chesapeake Bay from the late 1950's through the mid-1990's yielded limited occurrences suggesting to researchers that stocks were depressed to the point that meaningful reproduction was not occurring (Speir and O'Connell 1996), and Secor et al. (2002) found that Chesapeake Bay stocks may be extirpated or below a viable abundance. Secor and Waldman (1999) used fisheries effort and landings data to estimate the historic (1800's) Delaware Bay population of Atlantic sturgeon, yielding an estimate of abundance of 180,000 adult females prior to the commercial scale fisheries of 1880-1890. The authors then used the Delaware Bay abundance estimate to extrapolate estimates for other states. Their method resulted in an estimate of 20,000 females for the entire Chesapeake Bay, 3,000 of those from the Maryland portion of the Bay. Although the authors cautioned that their method was probably biased by incomplete catch records, their results suggested that the Delaware Bay may have supported a population size an order of magnitude greater than in other systems.

By extension, the Maryland portion of the Bay supported one of the smallest populations and it is likely that the majority were from rivers of the mid Bay area.

2.4 Contemporary Occurrence in the Susquehanna River

2.4.1 Shortnose Sturgeon

Documented contemporary occurrences of shortnose sturgeon in the Susquehanna River are limited to commercial and recreational fishery reports. Most documented captures were reported through the USFWS and Maryland Department of Natural Resources (MDNR) coast-wide sturgeon tagging program initiated in 1992, and a smaller reward program initiated in 1996. The reward program was designed specifically to learn more about sturgeon in the Maryland portion of Chesapeake Bay by providing financial incentive for commercial fishermen to turn over live sturgeons to USFWS for tagging (Eyler et al. 2009, Mangold et al. 2007). An updated database of sturgeon captures reported through those programs was provided by USFWS in 2010 (Sheila Eyler, USFWS, personal communication). Overall, five fish have been reported from the Susquehanna River and three from the Susquehanna Flats, a sediment deposit at the mouth of the Susquehanna River, or the adjacent channel area (Figure 2.4-1) between 1997 and 2004 (Figure 2.4-2). Additionally, two shortnose sturgeon catches from the Conowingo Dam tailrace were reported by anglers in 1986 (Tim Brush, Normandeau Associates, personal communication). In a letter (dated August 14, 2006) to URS Corporation regarding their assessment of the presence of any threatened or endangered species in the Project area, NMFS noted that “reportedly, two shortnose sturgeon have been passed above Conowingo Dam at the fish lift operated by the facility”, but that “NMFS has no information on the dates when passage occurred”. We are unaware of any sturgeon passage occurring at the fish lifts (R. Bleistine, Normandeau Associcates, personal communication) and, therefore, believe that NMFS mistakenly referenced the two shortnose sturgeon that were caught by anglers in the tailrace as noted above. Perhaps because those fish were transported and held in tanks at the Conowingo Dam west fish lift facility, the events may easily have been confused for collections from the fish lift.

Collections of shortnose sturgeon were also reported from the upper Chesapeake Bay, Sassafrass, Bohemia, and Elk Rivers. Welsh et al. (2002B) hypothesized that shortnose sturgeon in the Chesapeake Bay may have dispersed from the more abundant Delaware River population. This hypothesis was supported by analysis of genetic samples collected from the Chesapeake Bay and Delaware River demonstrating similarity between haplotype frequencies of specimens (Grunwald et al. 2002, Wirgin et al. 2002, Wirgin et al. 2009).

2.4.2 Atlantic Sturgeon

Records of Atlantic sturgeon in the Susquehanna River are sparse. Historical accounts of large sturgeon in the river, as reported in newspaper articles prior to 1895 were noted in the species status review, and between 1978 and 1987 several sightings of sturgeon near the Susquehanna River mouth were noted (ASSRT 2007). Though it is assumed that those records referred to Atlantic sturgeon (and not shortnose sturgeon), it is not clear that they represented a spawning population. Gilbert (1989) placed Atlantic sturgeon distribution to the Susquehanna Flats, but noted that it probably once ranged farther upstream in the Susquehanna River; however no basis for that claim was presented. In their letter regarding the presence of threatened and endangered species in the Project area (dated August 14, 2006), NMFS noted that Atlantic sturgeon occupy the mainstem of the Chesapeake Bay and at least the York, Rappahannock, Naticoke, and Susquehanna Rivers, and further noted that Atlantic sturgeon have been documented in the lower Susquehanna River. Additionally, MDNR (letter dated July 21, 2006) noted occurences of both shortnose and Atlantic sturgeon at Conowingo Dam. It is difficult to determine the validity of those claims because no references for the records noted were presented. Presumably they referred to the anecdotal references provided in ASSRT (2007), suggesting that the occurrences of Atlantic sturgeon noted by MDNR at Conowingo Dam were confused with the two shortnose sturgeon reported from the Conowingo Dam tailrace in 1986.

The most informative contemporary data regarding distribution of Atlantic sturgeon in the upper Bay comes from the the USFWS's coast-wide sturgeon tagging database and the USFWS and MDNR reward program for live sturgeon captured in the Maryland portion of Chesapeake Bay. Welsh et al. (2002A) compiled reports from the reward program for 1996-2000 depicting the distribution of collections reported throughout much of the upper Chesapeake Bay. Only two were from as far up bay as Elk Neck (adjacent to the Susquehanna River) and none were from the Susquehanna River. An updated database of Atlantic sturgeon captures reported in the coast-wide sturgeon tagging database and the Maryland reward program was provided by USFWS in fall, 2010 (Sheila Eyler, USFWS, personal communication). Overall, 122 fish were reported from the upper Chesapeake Bay, defined here as north of Annapolis, Maryland, and its tributary rivers (Figure 2.4-1, 3).

2.5 Life History and Habitat Requirements

2.5.1 Shortnose Sturgeon

Shortnose sturgeon are generally considered to be freshwater amphidromous, moving within a river with spawning occurring in fresh water and growth in estuarine water or near the freshwater-saltwater interface (Bemis and Kynard 1997). Kynard (1997) suggested that a latitudinal pattern of saltwater use may reflect bioenergetic adaptations for optimal foraging and growth and noted that an acceptable thermal regime in fresh water is longest in north-central rivers. Adults in the north-central to central part of the range reportedly only briefly enter the freshwater-saltwater interface areas (Kynard 1997, Buckley and Kynard 1985, O'Herron et al. 1993). Recent evidence, however, suggests that, at least with regards to migratory behavior, expanding populations may result in increased use of saline and oligohaline zones (Wrona et al. 2007, Fernandes 2010, LaBella 2010).

Genetic samples from shortnose sturgeon collected in Chesapeake Bay and the Delaware River showed no genetic differentiation, leading to the conclusion that fish collected in Chesapeake Bay represented migrants from the Delaware system (Wirgin et al. 2005, 2009). It is assumed that the logical migratory route is through the C&D Canal (Brundage and Meadows 1982, Welsh et al. 2002B) because it provides a short and direct (approximately 30 km) pathway to the upper Chesapeake Bay and shortnose sturgeon collections are documented from the reach of the Delaware River estuary near the C&D Canal (Brundage and Meadows 1982); however, movements have been documented only from the Chesapeake Bay to the Delaware River and not the reverse (Welsh et al. 2002B). Brundage and Meadows (1982) cited no captures of shortnose sturgeon in the C&D Canal despite intensive sampling, but reported four shortnose sturgeon taken off Ocean City, Maryland (about 1/3 of the distance between Delawaware Bay and Chesapeake Bay), perhaps suggesting a marine migratory corridor between the two systems. More recent observations of habitat use and movements of two adult femal shortnose sturgeon in the Potomac River, including one that exhibited spawning migration behavior, led Kyndard et al. (2009) to conclude that those specimens may be colonizers from the Delaware River.

Suitable habitats for Atlantic and shortnose sturgeon have been characterized, including: foraging, overwintering, spawning, and nursery habitats, and those characterizations are reviewed here in the context of suitable habitat for sturgeons using the Susquehanna River.

2.5.1.1 Forage

Appropriate forage habitat and fauna are necessary for individual and population growth. Several studies suggest that access to forage habitat in tidal segments of rivers and the freshwater-saltwater interface are important for shortnose sturgeon (Dadswell 1979, Hall et al. 1991, Dovel et al. 1992, Kynard 1997, Bain et al. 2007). Taubert (1980) noted that a population segment above Holyoke Dam in the Connecticut River demonstrated slow growth rates, leading Kynard (1997) to surmise that advantages are associated with foraging in the lower river or freshwater-saltwater interface. One other population segment, in the Santee-Cooper Lake system, South Carolina, appears to be restricted from the estuary by dams. Collins et al. (2003) observed that those fish appeared to be of relatively poor condition relative to fish collected in the Cooper River population downstream of a dam that effectively separates the two groups of fish (Cooke et al. 2002). Post-spawn adults in the Merrimack River were shown to either use a freshwater forage area for the rest of the year (after spawning), or to move downstream to the estuary for about six weeks before returning to the freshwater forage area (Kieffer and Kynard 1993), despite the fact that they are not restriced from the estuary. In the Delaware River, most reports of shortnose sturgeon from 1817 – 1979 were from the upper tidal freshwater portion of the estuary (Brundage and Meadows 1982). Hastings et al. (1987) and O'Herron et al. (1993) also found that the greatest concentrations of shortnose sturgeon were in the upper tidal reach rather than the freshwater-saltwater interface areas, though they noted that those concentrations may have been influenced by poor water quality and periodic low dissolved oxygen concentrations downstream.

Shortnose sturgeon are benthic feeders; juveniles reportedly feed on insects and crustaceans while mollusks become the primary food source for adults (NMFS 1987). Adult and juvenile foraging behavior may be individually variable (Kynard 1997) and shortnose sturgeon exhibit adaptive feeding depending on prey availability. In the Santee-Cooper system where foraging fish have no access to the freshwater-saltwater interface, shortnose sturgeon were shown to feed largely on mayfly larvae, while fish collected from the Savannah and Edisto Rivers fed primarily on amphipods (Collins et al. 2006, 2008). Forage habitats are often mud flats and sandy substrates where prey is concentrated (NMFS 1987). In the Hudson River shortnose sturgeon ranged over a large portion of the fresh and brackish reaches of the estuary in deep channel habitats, feeding primarily on mollusks, crustaceans, and insects (Bain 1997). In the Potomac River, most telemetric relocations of two shortnose sturgeon in a 2005 – 2007 study were in mud substrate with sand-mud as the second most used substrate, and most substrate samples contained small bivalve mollusks (Kynard et al. 2009).

The lower tidal Susquehanna River and upper Chesapeake Bay provide extensive sand, sand-mud, and mud substrate areas. The freshwater-saltwater interface varies in Chesapeake Bay by 10 – 30 km (Boynton et al. 1997, North and Houde 2001) and has been documented 15 – 35 km downstream of the mouth of the Susquehanna River, (Sanford et al. 2001), or approximately 30 – 50 km downstream of Conowingo Dam. Boynton et al. (1997) found elevated abundance of white perch and striped bass larvae and potential prey species in and around the estuarine turbidity maximum (ETM), a region generally associated with the estuarine salt front, and they hypothesized that the ETM may be an important fish nursery area where biological conditions structured by the physics of the region could promote recruitment potential.

2.5.1.2 Wintering

Juvenile and adult shortnose sturgeon have been shown to use limited and distinct home ranges, typically in reaches of curves and runs with islands (Kynard 1997). In the Saint John River, New Brunswick, adults and juveniles overwintered in deep estuarine water with mud substrate (Dadswell 1979). In the Pee Dee and Savannah Rivers, South Carolina, adults overwintered in the lower estuary in saline waters (Hall et al. 1991, Dadswell et al. 1984). Bain (1997) noted that non-spawning adult shortnose sturgeon behave differently than those that are entering reproductive condition. Non-spawners use overwintering habitat concentrated in brackish waters of the lower Hudson River while spawners (in the upcoming spring) overwinter in a single concentration in deep channel habitats further upstream. A similar behavior was noted in the Connecticut River, where Buckley and Kyndard (1985) found that some adults, including gravid females, overwintered on or near spawning grounds below Holyoke Dam, and both spawning (in the upcoming spring) and non-spawning adults overwintered in the freshwater river rather than estuarine areas. In the Delaware (O'Herron et al. 1993) and Potomac Rivers (Kynard et al. 2009) shortnose sturgeon were documented wintering in the freshwater – saltwater interface area and the tidal freshwater river.

Most captures reported from the upper Chesapeake Bay and four of the captures reported from the Susquehanna River were made in winter (Figure 2.4-2), so overwintering habitat is apparently available in the tidal freshwater lower Susquehanna River, freshwater reach of the upper Bay and in the freshwater – saltwater interface area of Chesapeake Bay.

2.5.1.3 Spawning

Annual spawning success and recruitment of sturgeons is highly unpredictable and may be zero if there are unfavorable conditions during the brief reproductive window (Bemis and Kynard 1997). Reproductive success is thought to depend on suitable river conditions during the spawning season (NMFS 1998), but spawning has been documented under a range of conditions.

Shortnose sturgeon age at first spawning varies latitudinally. Females first spawn at around 15 years in the St. John River, 9-14 years in the Holyoke Pool, Connecicut River, 11 years in the Hudson and Delaware Rivers, 7–14 years in South Carolina Rivers, and 6 years or less in the Altamaha River, Georgia (NMFS 1987).

Spawning migrations of both shortnose and Atlantic sturgeon can represent different migration strategies: short one-step spawning migrations, when fish move directly upstream to the spawning site a few weeks before spawning; long one-step migrations, done over many weeks in winter and early spring before spawning; and short two-step migrations involving upstream migration in the fall, overwintering near the spawning site; and a short migration to spawn the following spring (Bemis and Kynard 1997, Kynard 1997). In the Delaware River shortnose sturgeon have been shown to overwinter a short distance downstream of spawning areas and undergo a short (<25 km) spawning mingration (O'Herron et al. 1993), and in the Potomac River, Kynard et al. (2009) observed one female shortnose sturgeon undertake a short one-step spawning migration (~45+ km).

Kynard (1997) synthesized known spawning habitat data for 10 shortnose sturgeon spawning populations including most of the species geographic range (Altamaha River, Georgia to St. John River, New Brunswick) and concluded that adults may have a behavioral drive to reach historical spawning areas at about river km 200 or more, but when a dam blocks the migration, females may move as far upstream as possible and may or may not spawn in the reach below the dam. In the Delaware River, spawning areas are the most upstream reach of the river used by shortnose sturgeon (O'Herron et al. 1993). In the Cooper River, South Carolina, shortnose sturgeon have been shown to make use of available habitat for spawning at the base of a dam when their migration was presumably obstructed (Cooke et al. 2002, Cooke and Leach 2004a, Duncan et al. 2004).

Spawning occurs in the late winter to mid-spring when river temperature increases to about 9°C and usually ends at 12-15°C (Dadswell et al. 1984, Kynard 1997), but has been observed in temperatures as high as 19°C (Cooke and Leach 2004a). One gravid female was tracked to presumed spawning habitat in the Potomac River in mid-April when water temperature was rapidly warming from about 14–17°C.

A variety of shortnose sturgeon spawning sites have been described. They are characterized by areas with hard substrate of gravel, cobble, or large rocks (Taubert 1980, Buckley and Kynard 1985, Kynard 1997), pebble, gravel, cobble and woody debris imbedded in sand (Gibbons et al. 2009), submerged timber, scoured clay, and gravel (Hall et al. 1991), as well as in hard barren marl with pockets of gravel sized substrate (Cooke and Leach 2004a). Shortnose sturgeon eggs are demersal and adhesive (Dadswell et al. 1984) and are deposited close to the substrate (Bain 1997).

Spawning is generally thought to occur in moderate current velocities (Buckley and Kynard 1985, Kieffer and Kynard 1996, Kynard 1997, Hall et al. 1991). High river discharge during the normal spawning period could inhibit spawning by creating unacceptably fast velocities at or near the bottom (Buckley and Kynard 1985), therefore reducing spawning success (Kynard 1997, NMFS 1998). This caused Kynard (1997) to hypothesize that operation of hydroelectric facilities controls habitat suitability in terms of water velocity for spawning of shortnose sturgeon directly below hydropower dams in tailrace flows. Duncan et al. (2004) determined that spawning occurred below a dam in discharge conditions ranging from <500 to >20,000 cfs. Cooke and Leach (2004a) described depth averaged velocities at the same site, a peaking hydroelectric facility, as typically exceeding 3.3 ft/s and often approaching 6.6 ft/s, but periodically returning to no flow. Viable eggs were identified in both studies, but juvenile production has not been determined.

2.5.1.4 Early Life and Nursery Habitat

Hatching of shortnose sturgeon eggs occurs at around 5–12 days (Smith et al. 1986, Buckley and Kynard 1981, Richmond and Kynard 1995). In laboratory studies, free embryos (yolk-sac larvae) from one to eight days post-hatch demonstrated photonegative behavior and vigorously sought cover leading Richmond and Kynard (1995) to conclude that substrate with abundant crevices is likely critical for survival of eggs and embryos. Yolk-sac larvae transitioned to feeding larvae at 8-12 days post-hatch (about 15 mm TL) (Buckley and Kynard 1981, Kynard 1997) and from 9–16 days post-hatch demonstrated photopositive behavior and nocturnal activity, left bottom cover and swam in the water column, likely initiating downstream movements (Richmond and Kynard 1995). Kynard (1997) noted that most emigration was short (2 days) while some continued for 14 days providing sufficient time to move many kilometers, but not to move to the estuary from any known unobstructed spawning location. Shortnose sturgeon larvae in the Hudson River were associated with deep waters and strong currents (Hoff et al. 1988 in Bain 1997).

Young-of-year shortnose sturgeon probably reside in suitable habitat until a yearling migration period when juveniles join adults and demonstrate similar patterns of habitat use (Kynard 1997). Juvenile shortnose sturgeon in the Hudson River typically used the same deep channel habitats throughout the tidal reach as adults (Bain 1997). The success of recovery of sturgeons may be most affected by young-of-year survival because that life stage establishes year-class strength and has the greatest impact on overall population growth rate (Gross et al. 2002, Secor et al. 2002). Fundamental elements to promote early life survival include macro-habitat characteristics of substrate, prey, and water quality.

Water quality issues may be of particular importance because sturgeons are more sensitive to low dissolved oxygen concentration than other fish species (Secor and Gunderson 1998). Campbell and Goodman (2004) examined shortnose sturgeon response to low dissolved oxygen with temperature and salinity conditions representative of the freshwater-saltwater interface - critical nursery and forage habitats in southeastern rivers. They found that young-of-year shortnose sturgeon are particularly sensitive to low dissolved oxygen with concentrations lethal to 50% of test organisms at 26–42% saturation depending on test conditions. Jenkins et al. (1993) found that juvenile shortnose sturgeon tolerance to both increased salinity and decreased dissolved oxygen concentrations increased with age. By the time fish were yearlings, they could tolerate salinities of 20 practical salinity units (psu) and tolerated (< 20% mortality) dissolved oxygen concentrations of 2.5 mg/l.

2.5.2 Atlantic Sturgeon

Atlantic sturgeon life history differs from shortnose sturgeon in that they are anadromous; spawning occurs in fresh water, but late juvenile and adult fish can reside for years in marine waters and undertake long-distance migrations along the Atlantic coast (Bain 1997). Emigration from natal estuaries to primarily marine habitats occurs at ages 1 to 6 years, after which subadults wander among coastal and estuarine habitats until maturation (Dovel and Berggren 1983, Smith 1985, Stevenson and Secor 2000). The use of non-natal estuarine habitats may be an important life history strategy used by Atlantic sturgeon (Bushnoe et al. 2005) where fish produced in larger rivers that historically supported large spawning populations exploit food or water quality resources of other rivers as nursery. Recently, overwintering by Delaware River Atlantic sturgeon has been noted in the James River, Virginia (Fisher 2009a), and Simpson (2008) observed sub-adult Atlantic sturgeon using the Chesapeake & Delaware Canal to move south to the upper Chesapeake Bay. In the Delaware River estuary, sub-adult Atlantic sturgeon had limited ranges in the summer, typically occupying discrete river reaches of 5 – 10 km, but in spring and fall sometimes moved more than 100 km /d (Simpson 2008).

2.5.2.1 Forage

Generally, juvenile and subadult Atlantic sturgeon use areas around the freshwater – saltwater interface as forage habitat. In South Carolina, juveniles may ascend rivers, but they primarily inhabit estuarine habitats for forage (Collins and Smith 1997). Adult Atlantic sturgeon diets include mollusks, gastropods, amphipods, isopods, and fish. Juveniles feed on aquatic insects and other invertebrates (ASSRT 2007). While residing in estuaries, clear differences in the diets of Atlantic sturgeon compared to shortnose sturgeon have been documented. In the Hudson River, polychaetes and isopods were the primary foods of Atlantic sturgeon while amphipods were the dominant prey of shortnose sturgeon (Haley et al. 1996). Similarly, sub-adult Atlantic sturgeon collected from the same habitats as shortnose sturgeon in the Savannah and Edisto Rivers, South Carolina fed primarily on polychaetes while shortnose sturgeon fed mostly on amphipods, leading the authors to conclude that the two species do not compete for food resources (Collins et al. 2006, 2008). Savoy (2007) found that the diet of Atlantic sturgeon in the Connecticut River and Long Island Sound was dominatned by polychaetes and decapod shrimp. In the St. Lawrence River estuary, Atlantic sturgeon and lake sturgeon (*A. fulvescens*) co-occur in the estuarine transition zone. Guilbard et al. (2007) found that young-of-year of both species fed mainly on gammarid amphipods and that juveniles and subadults from both species fed mainly on oligochaetes and gammarids, but in opposite proportions with oligochaetes being the dominant prey species for Atlantic sturgeon. Subadult Atlantic sturgeon also fed on fish, insects and mollusks, but the authors concluded that areas near the freshwater–saltwater interface, where oligochaetes and gammarids are found, are important feeding habitats for the age-0, juvenile, and subadult stages.

In the Merrimack River, juvenile Atlantic sturgeon used a saline reach of the river from mid-May – October, but appeared to emigrate out of the river for overwintering. An area downstream of that forage area consisting of tidal mud and sand flats appeared to be used only as a conduit from the marine environment to the estuarine forage area (Kieffer and Kyndard 1993). In the Delaware River estuary, late-stage juvenile Atlantic sturgeon aggregated in an area of silt – mud with isopods and amphipod forage; however, invertebrate densities declined over the summer suggesting that the area served as a thermal refuge that became over grazed (Fisher 2009a). Simpson (2008) found that sub-adult Atlantic sturgeon preferred gravel / hard bottom substrate in deep (>8m) areas in the Delaware River estuary. As noted previously, the lower tidal Susquehanna River and upper Chesapeake Bay provide extensive sand, sand-mud, and mud substrates and the freshwater-saltwater interface is typically 15–35 km downstream of the mouth of the Susquehanna River (Sanford et al. 2001), or approximately 30 – 50 km downstream of Conowingo Dam. The area associated with the ETM may provide significant dietary resources for juvenile and adult Atlantic sturgeon.

2.5.2.2 Wintering

Mature, non-spawning adult Atlantic sturgeon typically reside in the coastal marine environment. Juveniles are thought to remaine within river esuarine systems (Bain 1997) year-round for 1–6 years before emigrating to coastal zone to mature (Smith 1985). In the Merrimack River, juvenile Atlantic sturgeon emigrated out of the river in October, apparently for overwintering in the coastal marine environment (Kieffer and Kyndard 1993). In South Carolina, sub-adults were shown to form overwintering aggregations in the coastal zone off of Charleston Harbor (ASSRT 2007), but overwintering in the Santee and Cooper Rivers may also occur in freshwater reaches after spawning; evidence of young-of-year Atlantic sturgeon in the Santee and Cooper Rivers estuaries suggested a fall spawn there. Since the upper Chesapeake Bay contains an extensive freshwater–saltwater interface area and long saline gradient, appropriate overwintering habitat exists there, as evidenced by the observation that the majority of collections of Atlantic sturgeon reported from the upper Chesapeake Bay were made during winter months (Figure 2.4-3).

2.5.2.3 Spawning

Atlantic sturgeon spend much of their lives in the marine environment, but return to coastal estuaries and rivers to spawn. The minimum age for maturity of Hudson River female Atlantic sturgeon is 15 years (Bain 1997) while males mature at 12 years old or more (Van Eenennaam et al. 1996). Also, it is suspected that Atlantic sturgeon may not spawn annually (Bain 1997). Males appear to enter the river earlier than females and move upstream on flooding tides, meandering across the channel, but remaining in water greater than 7.6 m deep. Females enter the Hudson River for spawning in mid-May and move directly to spawning habitat in deep channel or off channel areas (in)(Dovel and Berggren 1983 in Bain 1997). The authors reported spawning near the freshwater-saltwater interface in the Hudson River estuary that progressed upstream with the season. Howsever, Van Eenennaam et al. (1996) concluded that spawning is unlikely to occur near brackish water in the Hudson River because early life stages are sensitive to saline conditions and some length of river is needed to accommodate dispersal.

Atlantic sturgeon eggs are adhesive and deposited on hard, structured surfaces in regions between the salt front and fall-line of large rivers (Hildebrand and Schroeder 1927), reportedly in optimal current velocities of 46–76 cm/s (Crance 1987). Embryos remain on the bottom in deep channel habitats of the Hudson River from river km 60-148 (Dovel and Berggren 1983).

2.5.2.4 Early Life and Nursery Habitat

Atlantic sturgeon eggs hatch at about 4–6 days after spawning, undergo a 7–10 day swimming period, and then settle out and adopt a benthic lifestyle (Smith et al. 1980), remaining close to their natal habitats within estuaries during the first year of life (Dovel and Berggren 1983, Bain, 1997). The juvenile phase of the life cycle can be divided into early and late stages (Bain 1997). In the Hudson River, early juveniles are limited to deep channel riverine habitats distributed over much of the river. In laboratory studies, gravel substrate was suggested to be superior to sand for early development. Yolk-sac larvae exposed to gravel, sand, and control (no substrate) used gravel more readily and had the highest energy content during the first 5 days post-hatch. Additionally, at onset of exogenous feeding (~14 days post-hatch) the specific growth rate of larvae in gravel exceeded that of larvae in sand (Gessner et al. 2009).

Early phase juveniles, those that have not yet emigrated from the natal river to the marine environment, typically aggregate in the freshwater-saltwater interface zone. Juveniles in the Hudson River were found to form an overwintering distribution in brackish water (Dovel and Berggren 1983). In the Edisto River estuary, South Carolina, McCord et al. (2007) collected and tagged age-1 juveniles in relatively high abundance at the freshwater-saltwater interface. After emigration, juveniles may reside along the Atlantic coast, in river mouths, and in lower coastal river sections (Murawski and Pacheco 1977, Bain 1997). Waldman et al. (1996) noted that most Atlantic sturgeon in central Atlantic coast rivers are probably from the Hudson River population.

In an experimental program, Secor et al. (2000) released approximately 3,000 yearling Atlantic sturgeon to the Nanticoke River, Maryland. They examined dispersion of juveniles by collecting commercial fishery recapture data. Approximately 9% were captured in fisheries, demonstrating both high vulnerability to commercial gear and dispersion into Chesapeake Bay with their distribution concentrated from the Patuxent River to around the Patapsco River. Their results indicated that Chesapeake Bay can support nursery functions.

Water quality issues may be of particular importance with regards to nursery habitat in Chesapeake Bay though, because sturgeons are more sensitive to low dissolved oxygen concentration than other fish species (Secor and Gunderson 1998). Juvenile (young-of-year and yearling) Atlantic sturgeon demonstrated maximum growth rates when dissolved oxygen concentration was above 70% and salinity was between 8 – 15 psu in laboratory studies (Niklitschek and Secor 2009). Hypoxic conditions have increased temporarily and spatially in Chesapeake Bay since the 1950's (Secor et al. 2002, Officer et al. 1984) resulting from increased nutrient loading. Hypoxic zones are contained by stratification which is enhanced by freshets (Taft et al. 1980). Niklitschek and Secor (2005) modeled potential Atlantic sturgeon production in Chesapeake Bay. Because of the species low tolerance to high temperature (>28°C), they predicted that early juveniles would occupy deeper, cooler waters as temperature increased, but since most thermal refugia were located down-bay, a large fraction of potential habitat was unsuitable due to persistent hypoxia. As a result, suitable summer habitat for juveniles was restricted and annually variable, ranging from 0–30% of modeled Chesapeake Bay surface area, generally occurring in a small portion of the upper Bay from the Annapolis – Love Point area to the Aberdeen Proving Ground – Sassafras River area. Secor and Gunderson (1998) concluded that the increased frequency of hypoxia throughout the 20th century had a detrimental impact on Atlantic sturgeon production and suggested that a restoration program for Atlantic sturgeon cannot be easily justified unless the conditions that led to the declines are addressed.

2.6 Comparison of Conowingo Fish Lift and Other Facilities Known to Pass Sturgeons

In the final study plan determination for the Project (issued February 4, 2010), FERC required a modification to the Study 3.22 plan to include a comparison of the Conowingo east fish lift to other East Coast passage facilities where successful shortnose or Atlantic sturgeon upstream passage has been documented. Since success criteria for sturgeon passage at East Coast fish passage facilities are not well defined and population structures are often poorly understood, success of sturgeon passage is difficult to evaluate. There are some documented cases of sturgeon passage, but it is unlikely that any existing facilities may be considered successful at passage of those species.

In most rivers, the majority of historic Atlantic sturgeon spawning habitat is considered to be currently accessible, but it is unknown whether it is fully functional (NMFS 2010, 75 FR 61872, 61904, October 6 2010). Not surprisingly then, incidence of Atlantic sturgeon in existing fishways is rare. To our knowledge, documentation of Atlantic sturgeon use of East Coast fishways is limited to one occurrence at the Holyoke fish lifts, Connecticut River, Massachusetts and one occurrence at the St. Stephen fish lock, Santee River / Rediversion Canal, South Carolina. Collins and Smith (1997) reported two occurrences of Atlantic sturgeon in the Santee-Cooper Lakes, South Carolina, however, and it is possible that those fish entered the lake system by the Pinopolis Dam Navigation Lock on the Cooper River.

Documentation of upstream passage of shortnose sturgeon appears to be limited to mechanical fishways (e.g., fish lift and lock). Fishways that have collected or passed shortnose sturgeon include the Holyoke fish lifts and St. Stephen fish lock. Additionally, the Pinopolis Dam Navigation Lock on the Cooper River, South Carolina has been shown to attract shortnose sturgeon, but passage is, at most, severely limited. These fish passage facilities are described below, with pertinent aspects summarized in Table 2.6-1, and compared with the Conowingo east fish lift.

2.6.1 Conowingo Dam and Fish Lifts

Conowingo Dam was completed in 1928 at river km 16 (approximately 338 km from the Atlantic Ocean at the mouth of Chesapeake Bay) on the Susquehanna River at Darlington, Maryland. Facilities included an approximately 25 m high dam with 275 m long powerhouse and 700 m long spillway. The original power house had seven turbine units and in 1964, 4 more were added. Peak generation capacity is 573 MW and powerhouse hydraulic capacity is 86,000 cfs. Excess flows are spilled through two regulating and 50 crest gates. Annual average river discharge is approximately 40,861 cfs, and average discharge during March and April, the period when adult shortnose sturgeon would be expected to undertake spawning migrations in the region (O’Herron et al. 1993), is 75,090 cfs (1968 – 2010 annual and monthly summary data, USGS gage # 01578310).

In 1972 a trap-and-transport fish lift facility was constructed at Conowingo Dam (west fish lift) as a keystone facility in a cooperative private, state, and federal effort to restore American shad (*Alosa sapidissima*) and other migratory fishes to the Susquehanna River. In 1991, a second fish lift (east fish lift) was constructed at the east end of the Conowingo powerhouse, between the powerhouse and spillway

(Normandeau Associates 2009b, Figure 2.6-1), and in recent years the west fish lift has been used only for experimental or hatchery brood stock collection purposes. The east fish lift has three entrances that are 10 ft high by 14 ft wide and has an attraction flow capacity of 300 – 900 cfs, but is typically operated at 310 cfs (Figure 2.6-2). Target attraction flow velocities are 4–5 ft/s. The fish lift hopper capacity is 3,500 gallons (468 cubic feet). Minimum flow releases from the station during the spring spawning and fishway operating season include 10,000 cfs or natural river flow, whichever is less in April; 7,500 cfs or natural river in May; and 5,000 cfs or natural river in June if fish lift operations occur (Normandeau Associates 2009b).

Overall annual fish passage through the east fish lift has approached 1 million fish of approximately 30 different species. Shortnose sturgeon occurrence in the river is rare and Atlantic sturgeon occurrence is contemporarily un-documented. Two shortnose sturgeon were landed by anglers below Conowingo Dam in 1986 (Tim Brush, Normandeau Associates, personal communication), but no shortnose or Atlantic sturgeons have been documented in the fish lift.

2.6.2 Holyoke Dam / Hadley Falls Station and Holyoke Fish Lifts

The fish lifts at Holyoke Dam have the most documented shortnose sturgeon passages. The Holyoke Dam, a 300 m long, 10 m high granite block structure, was built in 1900 at river km 140 , about 150 ft downstream from a timber crib dam that was constructed in 1849. The Holyoke Project consists of a three level canal system, a mainstem power house and tailrace canal (Hadley Falls Station), and a spillway to a short (~900 m) bypassed reach before its confluence with the Hadley Falls Station powerhouse tailrace canal (Figure 2.6-3). Annual average total river discharge is 13,170 cfs. Total river discharge during April and May, the time period encompassing the shortnose sturgeon spawning migration period (Taubert 1980, Buckley and Kynard 1985), is 31,712 (1984-2008 annual and monthly summary data, USGS gage #1172010). Hadley Falls Station turbine discharge at maximum operational capacity is about 8,000 cfs and flow to the Holyoke Canal system is about 6,000 cfs at maximum capacity (Kleinschmidt 2006a). In springtime when river flows are high, discharge is generally near capacity (FERC 1999).

Fish ladders were built at Holyoke Dam in 1873 (on the original timber crib dam) and in 1940, but both were unsuccessful in fish passage. The first hydroelectric generation powerhouse at Hadley Falls was constructed in 1950 and the first fish lift was constructed in 1955 providing passage of fish from the powerhouse tailrace (tailrace fish lift). A second fish lift was constructed in 1976 providing passage for fish from the spillway (spillway fish lift) (Kleinschmidt Associates 2006b). Both fish lifts have a hopper capacity of 330 cubic feet.

The tailrace fish lift has an entrance gallery with two currently used entrances (east and west entrance) both entrances are elevated 13 m above the bottom of the tailrace. The west entrance does not have an adjustable gate (e.g. variable weir for adjusting attraction flow velocity). The east entrance has a surface gate designed to provide a high velocity surface flow for attraction of Atlantic salmon (*Salmo salar*). An attraction water system draws water from the Holyoke canal system, serving both fish lifts, and can distribute up to 120 cfs to each entrance for the tailrace fish lift (240 cfs total). The entrances are designed for attraction water velocities of 3–8 ft/s. In typical conditions, water velocity across the west entrance is approximately 3-4 ft/s and across the east entrance is approximately 5-6 ft/s. Both entrances are subject to high turbulence due to turbine discharge upwelling (Kynard 1998).

The spillway fish lift has a single entrance without a variable entrance gate, and the entrance channel floor is only elevated 0.6 m above the river bed. The attraction water system is capable of distributing up to 200 cfs to the spillway fish lift entrance and in typical condictions, water velocity across the spillway entrance is 3-4 ft/s. The spillway and tailrace fish lifts discharge into a common exit flume. A fish counting room is located between the fish lifts and the flume exit upstream of the Hadley Falls Station intakes (Figure 2.6-4).

Kynard (1998) evaluated passage patterns of pre-spawn adult shortnose sturgeon passed upstream by the Holyoke fish lifts from 1975–1996. In 22 years of monitoring, 97 sturgeon were lifted with annual passage ranging from 0 to 16 and a median passage of 4. Annual passage numbers represented only a small proportion of available fish though. The proportion passed compared to abundance estimates in 1982, 1994, and 1995 ranged from <1% to 6%. Since both fish lifts empty to a common exit flume, the specific lift was only noted in 23 instances and all of those were from the spillway lift, leading Kynard (1998) to suggest that the primary difference is in water depth at the entrances of the two facilities. Later, Ducheney et al. (2006) noted that between 1980 and 2005, 112 shortnose sturgeon were lifted, but they did not describe annual passage numbers or differentiate between the two lifts. Comparison of the passage number presented by Ducheney et al. (2006), Kynard (1998) and more recent data results in a calculation of 26 shortnsoe sturgeon passed from 1997–2003. In recent years, handling protocols required that any sturgeon collected in the Holyoke fish lifts be documented, tagged, and returned downstream. The numbers of shortnose sturgeon collected have remained low, however; only 9 fish were lifted from 2006–2010 (Table 2.6.2-2). No population estimates or relative abundances of shortnose sturgeon in the area below Holyoke Dam are available for most years, but the population size in the lower river overall was thought to have increased to as many as 1,000 individuals (Savoy 2004).

Little is known of the Atlantic sturgeon population that may be available for passage at Holyoke Dam; however Hadley Falls, the site of Holyoke Dam, is likely the historic upstream limit for Atlantic sturgeon migration in the Connecticut River (NMFS 2010, 75 FR 61872, 61904, October 6 2010). Only one Atlantic sturgeon has ever been collected from the Holyoke fish lifts. The fish was collected from the spillway fish lift during summer 2006, and was PIT tagged and returned downstream (Kleinschmidt Associates 2009).

2.6.3 St. Stephen Fish Lift, Santee River / Rediversion Canal, South Carolina and Pinopolis Lock, Cooper River, South Carolina

The adjacent Santee and Cooper Rivers have been anthropogenically linked for more than two centuries and it is useful to consider them together. In 1800, the first summit canal in the country was constructed to provide trade navigation, linking the two rivers. In 1942, the Santee–Cooper Diversion Project was completed, diverting most of the Santee River to the adjacent Cooper River (Edgar 1984). A navigation lock at Pinopolis Dam constructed at the headwaters of the coastal drainage Cooper River provided boat passage between Cooper River and Lake Moultrie and maintained some connectivity between the estuarine environment and the impoundments and upper rivers (Cooke and Eversole 1994). Pinopolis Dam is located at river km 77 (Cooke et al. 2002) and the Santee River diversion dam was located at river km 143 on the Santee River (Cooke and Leach 2003). Historic annual average Santee River flow was 18,541 cfs, but with diversion was reduced to 2,225 cfs; the remainder was diverted to Cooper River (Kjerfve 1975). Because of siltation downstream in Charleston Harbor, South Carolina, flow from the Cooper River was diverted back into the Santee River via a new ‘Rediversion’ Canal in 1985, increasing the mean annual Santee River flow to about 10,400 cfs. A hydroelectric dam and upstream fish passage facility were constructed at rkm 95 near St. Stephen, South Carolina to control the rediversion of water (Rediversion Canal, Figure 2.6-5).

The St. Stephen fish lock facility consists of two entrance channels with variable weirs to control entrance flow velocity; a common collection chamber and crowder gate; a variable gravity fed pass-through attraction flow of up to 250 cfs and a siphon fed bypass attraction flow with incremental capacity of 0, 166, 334, and 500 cfs; a 5.5 m x 5.5 m x 20 m high lock chamber with brail basket; and an exit channel with underwater viewing windows (Cooke and Leach 2003, Figure 2.6-6, 7). Hydraulic capacity of the lock in the lower position varies with discharge and tailrace water level; at low water, the depth is about 2.4 m. Annual average discharge from St. Stephen Dam is 7,689 cfs. Total river discharge during February and March, the time period encompassing the shortnose sturgeon spawning migration period (Cooke et al. 2002) is 13,305 cfs (1987–2009 annual summary data, USGS gage # 2171645).

The fish lock was operated annually during the anadromous alosine fish spawning migration period beginning in 1986. As of the 2009 season more than 14.4 million anadromous fish were passed (Post 2009). Little is known regarding the shortnose sturgeon population structure or abundance in the Santee River, but during the operational life of the fish lock, only six shortnose sturgeon have been collected. In 1994, four shortnose sturgeon were passed (Cooke and Chappelear 1994) and in 1998, 2 shortnose sturgeon were collected in the fish lock, but apparently died while in the facilities (Cooke 1998). Only one Atlantic sturgeon, in 2007, has ever been collected in the St. Stephen fish lock (Post 2007).

The Pinopolis Navigation Lock was not designed as a fishway, but its existence probably is accountable for the persistence of anadromous American shad and blueback herring in the Santee-Cooper system, prior to construction of the St. Stephen fish lock. The navigation lock is 18 m wide by 73 m long and with a lift of about 22 m high with a 15 m sill at the upstream end (Cooke et al. 2002). Average discharge is essentially constant at around 5,000 cfs (2002–2009 annual and monthly summary data, USGS gage # 02172002). Scruggs and Fuller (1954) documented that blueback herring were passed into the Santee-Cooper system by the Pinopolis Lock, and Curtis (1977) instituted a hydroacoustic monitoring system in 1975 to estimate the biomass of blueback herring passed into the system. The biomass estimation for lock operations done during the anadromous fish run period has continued since that time. In addition to on-demand boat lockages, lock operations are currently done approximately six times per day for fish passage in season. Annual average fish passage biomass estimates are 396 tons; however the biomass counter system is not considered to provide accurate data, rather it is used as an inter-annual index (Post 2009). There is no visual monitoring system for fish passage at this site, so sturgeon passage would generally be undetected; however several studies have helped to define passage potential. Cooke et al. (2002) monitored for shortnose sturgeon passage in five years of radio telemetry experiments. They found that as much as 83% of tagged sturgeon entered the lock with many lock entries at night when the downstream gates were left open to allow fish entry but the lock was not operated, or fish entered and then exited again between fill cycles. Only seven fish were detected in the lock during a locking cycle and none passed upstream. The authors attributed the overall lack of passage to lack of overnight operations and physical features of the lock and its cycle, most notably, the 15 m high sill at the upstream end of the lock chamber that would require sturgeons to swim up into the water column to pass upstream. Timko et al. (2003) used three dimensional acoustic telemetry techniques to analyze the movements of 15 adult shortnose sturgeon that were tagged and placed in the lock and retained through a lock cycle. Their results demonstrated that the fish tended toward the lower half of the water column and further downstream in the lock, reducing the potential for upstream passage. One of the 15 tagged fish retained in the lock during a cycle successfully passed upstream. The population of spawning shortnose sturgeon occurring just below Pinopolis Dam during the spawning season was estimated to range from 87 in 1996 (95% CI: 56–170), to 123 in 1997 (95% CI: 123–319), to 301 in 1998 (95% CI: 150–659) (Cooke et al. 2004). The results of Timko et al. (2003) taken in consideration with those of Cooke et al. (2004) suggest that though sturgeon may occasionally pass upstream through the lock, the rate of passage is very low even though fish are relatively abundant and a large proportion enter the structure from downstream.

2.6.4 Comparison of Facilities

As noted above, none of the facilities discussed here can likely be considered successful at sturgeon passage. There is, however, evidence of sturgeon passage, most notably via the Holyoke fish lifts. It is important to understand that, due to lack of studies or scarcity of fish available to pass, little is known about passage rates at any of these facilities.

Of the facilities discussed, Pinopolis Lock is the most unique in that it is not a specifically designed fishway, yet it has functioned for decades to pass anadromous fish upstream. While the dam is thought to obstruct sturgeon passage, the existence of a spawning population is well documented below the dam (Cooke and Leach 2004a, Duncan 2004). The lock may be one of the most effective East Coast fishways used by American shad and blueback herring (Normandeau Associates 2003), but it has been demonstrated to be, at best, very limited for passage of shortnose sturgeon.

The two specifically designed fishways discussed where sturgeon passage has been documented are generally similar in design and function to the Conowingo east fish lift in that they share similar critical design components including an attraction flow, entrance channels, crowder, lift / lock component, and exit channel. Each location differs with regards to river width and volume of flow, however. The St. Stephen fish lock is an integral part of a dam that is removed from the Santee-Cooper system's water control spillway at the Santee Dam, where no passage facility exists (see Figure 2.6-5). The canal below the dam is entirely excavated and there is no structure representative of a natural falls such as boulder and bedrock. Both Holyoke Dam and Conowingo Dam are wide rivers with wide spillways, and both the Susquehanna and Connecticut Rivers have extensive boulder and bedrock structure. In contrast to Conowingo Dam, the Hadley Falls Station powerhouse tailrace canal is hydraulically isolated from the bypass reach / spillway for a distance of < 1km, while the Conowingo Dam tailrace and spillway are hydraulically contiguous. Where Holyoke Dam has two fish lifts, one serving the powerhouse tailrace and one serving the spillway, Conowingo Dam east fish lift is situated between the tailrace and spillway. Fish lifts and fish lock capacities vary as well; the St. Stephen fish lock has the greatest capacity, but that is probably not an important characteristic for comparison with regards to sturgeon passage given numbers observed.

River size and discharge varies greatly among these sites. As noted, the Rediversion Canal at St. Stephen Dam is an entirely excavated channel and is less than 100 m wide, while the Connecticut River below Holyoke Dam is approximately 300 m wide with most of that in the spillway. The Susquehanna River below Conowingo Dam, by contrast, is more than three times as wide as the Connecticut River and 15 times as wide as the Rediversion Canal with approximately a third of the river width in the tailrace. River discharge also varies, but the discharge to the Rediversion Canal is disproportionately greater relative to river width. Susquehanna River average discharge during the sturgeon migration period (as described earlier) is more than twice that of the Connecticut River and more than 5 times the Rediversion Canal. Note that, although shortnose sturgeon have passed by the Holyoke fish lifts during April – October (Kyndard 1998), the spawning period is presented here for purposes of comparison to the Conowingo fish lift and other fish passage facilities.

Perhaps the more important variables for comparision of these facilities are the characteristics of attraction flow and entrance configuration. The proportion of attraction flow to project discharge will naturally vary with river flow, but a general comparison can be made using summary statistics. Given a nominal attraction flow of 310 cfs and average in-season discharge volumes of 75,000 cfs from Conowingo Dam, the ratio of attraction flow to total discharge is 0.41%. For the Holyoke tailrace fish lift, given a nominal attraction flow of 240 cfs and average in-season project discharge of 31,712 cfs and maximum capacity discharge to the powerhouse tailrace of 8,000 cfs, the ratio of attraction flow to total river discharge is 0.76% and to tailrace discharge is 3.00%. For the Holyoke spillway fish lift, with a nominal attraction flow of 200 cfs and average in-season discharge to the spillway (total river discharge minus maximum discharge to the powerhouse tailrace and the Holyoke Canal system) of 17,712 cfs, the ratio of attraction flow to total river discharge is 0.63% and to spillway discharge is 1.13%. For the St. Stephen fish lock, given a nominal attraction flow of 250 cfs and given an average in-season discharge of 13,305 cfs, the ratio of attraction flow to total river discharge is 1.88% (Table 2.6-1).

The Conowingo east fish lift is characterized by entrance channels that are stepped off of the river bottom and fitted with variable weirs that adjust from the bottom up to control entrance velocities. A similar configuration is used for the St. Stephen fish lift and the Holyoke tailrace fish lift entrances except that the tailrace fish lift entrances are elevated well above the tailrace canal bottom and the two entrances have significantly different flow characteristsics since one does not have a weir, and one has a gate designed to accelerate flow at the surface. All of these entrances require fish to orient into a rapid flow in the upper water column. The one exception is the Holyoke spillway fish lift entrance which has no variable weir and is situated near the river bottom.

2.6.5 Response to Comments

The Initial Study Report (ISR) for Conowingo Hydroelectric Project, FERC Project No. 405, relicensing was filed with FERC Feburary 22, 2011. Agency comments on the ISR were filed on April 27, 2011, and Exelon's responses to those comments were filed on May 27, 2011. Comments and response pertinent to RSP 3.22 included:

PAFBC Comment 1:

> Additional information should be provided that results in a recommendation by the licensee as to what steps need to be taken at Conowingo dam to improve conditions for passage of shortnose sturgeon.

Exelon Response:

> As described in Section 2.6 of the Initial Study Report, there are several features that may be used for comparison of the Conowingo east fish lift with other fish passage facilities that have passed shortnose sturgeon, including: river width, river discharge, fishway attraction flow / proportion of attraction flow to river discharge, and fishway entrance configuration. Of those, attraction flow volume and entrance configuration might be incorporated into designs to potentially improve the likelihood of sturgeon passage. The two considerations are necessarily linked; any entrance channel designs to facilitate sturgeon passage must allow for discharge of the higher volume of attraction flow in conjunction with existing / other entrances while maintaining appropriate velocities. Entrance design would include minimizing height above the river bottom, preferably without a standard entrance weir. Alternatively, a ramped approach to the entrance may be considered.
>
> Exelon considered alternatives at a screening level to improve conditions for passage of shortnose sturgeon at the EFL, as part of the Conowingo RSP 3.9-Biological and Engineering Studies of the East and West Fish Lift study. However, developing a conceptual engineering design proved difficult because there are no demonstrated design criteria for this species. In follow-up discussions, NMFS stated that at present upstream passage of sturgeon at Conowingo Dam is not one of NMFS goals. As such, Exelon deemed additional analysis of this alternative impractical and unwarranted at this time.

TABLE 2.6-1: SUMMARY COMPARISON OF CONOWINGO EAST FISH LIFT WITH EAST COAST FISHWAYS KNOWN TO HAVE PASSED STURGEONS UPSTREAM.

Facility	Distance Upstream from River Mouth	Dam Summary	In-Season MonthlyMean Discharge (cfs)	Fishway Type	Lift Capacity	Attraction Flow	Relative Attraction Flow (% of total river flow)
Conowingo East Fish Lift	16 km / 338 km from mouth of Chesapeake Bay	975 m long: powerhouse fish lift, and spillway	75,090 [1]	fish lift: 3 entrances with variable weirs	13.25 m^3	300-900 cfs, usually 310 cfs	0.41
Holyoke Tailrace Fish Lift	140 km	300 m long: dam, powerhouse tailrace canal	31,712; 17,712 [2]	fish lift: 2 surface oriented entrances one with high velocity weir	9.34 m^3	120 cfs to each entracnce (240 cfs combined)	3.00
Holyoke Spillway Fish Lift	140 km	(see previous) spillway	31,712; 8,000 [2]	Fish lift: one entrance, no weir	9.34 m^3	200 cfs	1.13
St. Stephen Fish Lock	95 km	65 m long: powerhouse and fish lock (no spillway)	13,305 [3;]	fish lock: 2 entrances with variable weirs	~73.4 m^3	to 750 cfs (nominally 250 cfs)	1.88
Pinopolis Navigation Lock	77 km	160 m long: navigation lock and powerhouse (no spillway)	4,895 4	navigation lock	~2,2712 m^3	-	-

[1] Monthly average discharge for March–April, 1968-2010, USGS Gage 01578310, Susquehanna River at Conowingo, MD. [2] Monthly average discharge for April–May, 1984–2008, USGS Gage 01172010, Connecticut River at I-391 Bridge at Holyoke, MA. Values for the tailrace fish lift are total river discharge and maximum capacity discharge to the powerhouse canal; ratio of attraction flow calculation uses the lower value. Values for spillway fish lift are total river discharge and discharge to the Holyoke dam spillway, assuming maximum capacity of flow to the powerhouse tailrace canal and Holyoke Canal system; ratio of attraction flow calculation uses the lower value. [3] Monthly average discharge for February-March, 1987-2009, USGS Gage 02171645, Rediversion Canal at Santee River near St. Stephen, SC. [4] Monthly average discharge for February-March, 2002 - 2009, USGS Gage 02172002, Lake Moultrie Tailrace Canal at Moncks Corner, SC.

TABLE 2.6.2-2: ANNUAL SHORTNOSE STURGEON PASSAGE / COLLECTION AT THE HOLYOKE FISH LIFTS

Year	Number Passed / Handled		Lift
1975	5		Tailrace
1976	3		
1977	0		
1978	1		
1979	3		
1980	0		
1981	4		
1982	4		
1983	4		
1984	10		
1985	6		
1986	13		
1987	3		
1988	4		
1989	4		
1990	5		
1991	0	112	
1992	4		
1993	6		
1994	1		
1995	1		
1996	16		
1997			
1998			
1999			
2000			
2001		26	
2002			
2003			
2004		0	
2005		1	
2006		1	Spillway
2007		5	Tailrace
2008		3	Spillway
2009		0	2 spillway, 1 tailrace
2010		0	

Annual data for 1975 – 1996 from Kynard (1998); collective data for 1980 – 2005 Ducheney et al. (2006); data for 2004 and 2005 from Kleinschmidt Associates (2006b); data from 2007, 2008, 2009, and 2010 from (Normandeau Associates 2007, 2008, 2009a, 2010, 2010-in preparation; total count for 1997 – 2003 was derived from other data presented here.

FIGURE 2.4-1: MAP OF THE UPPER CHESAPEAKE BAY.

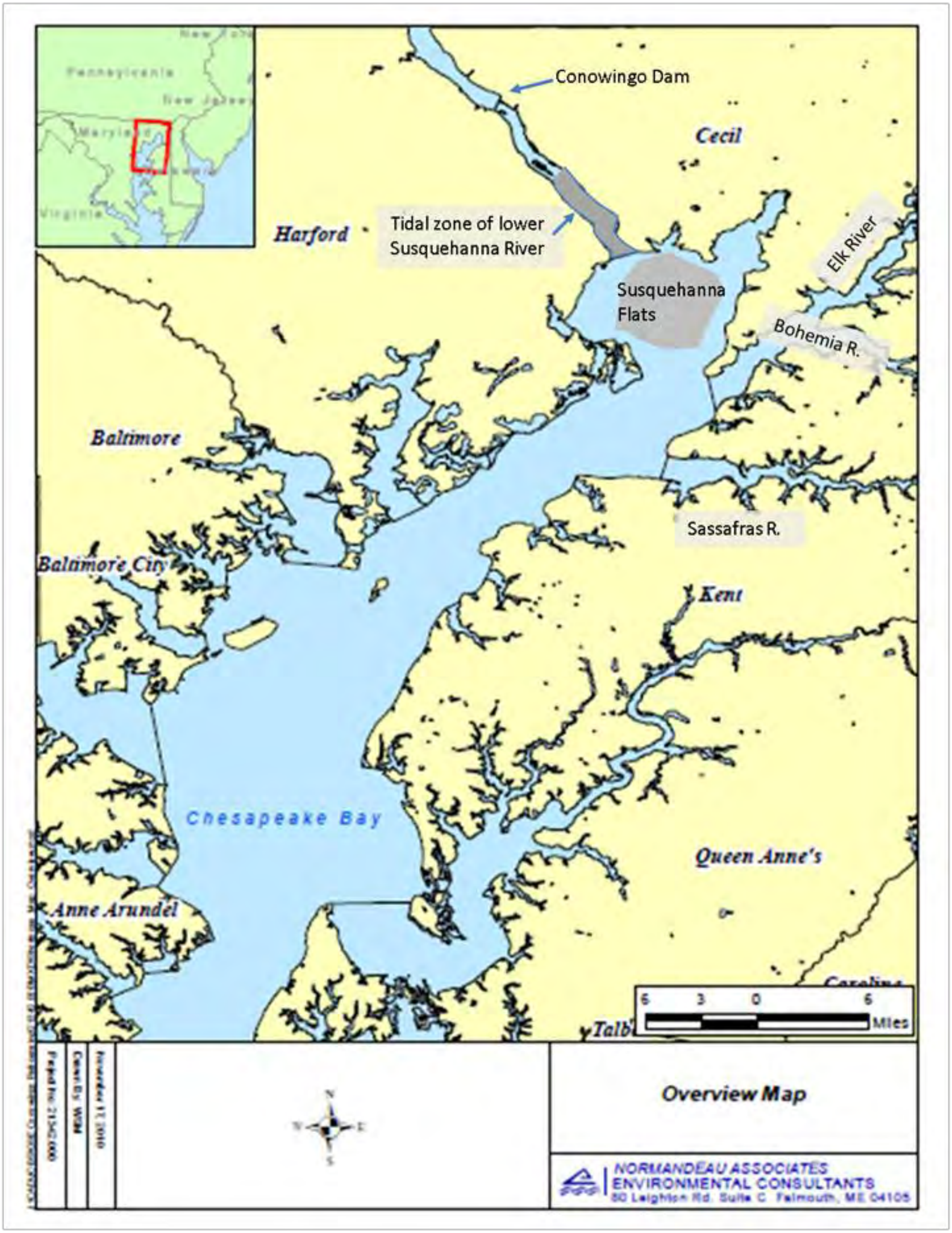
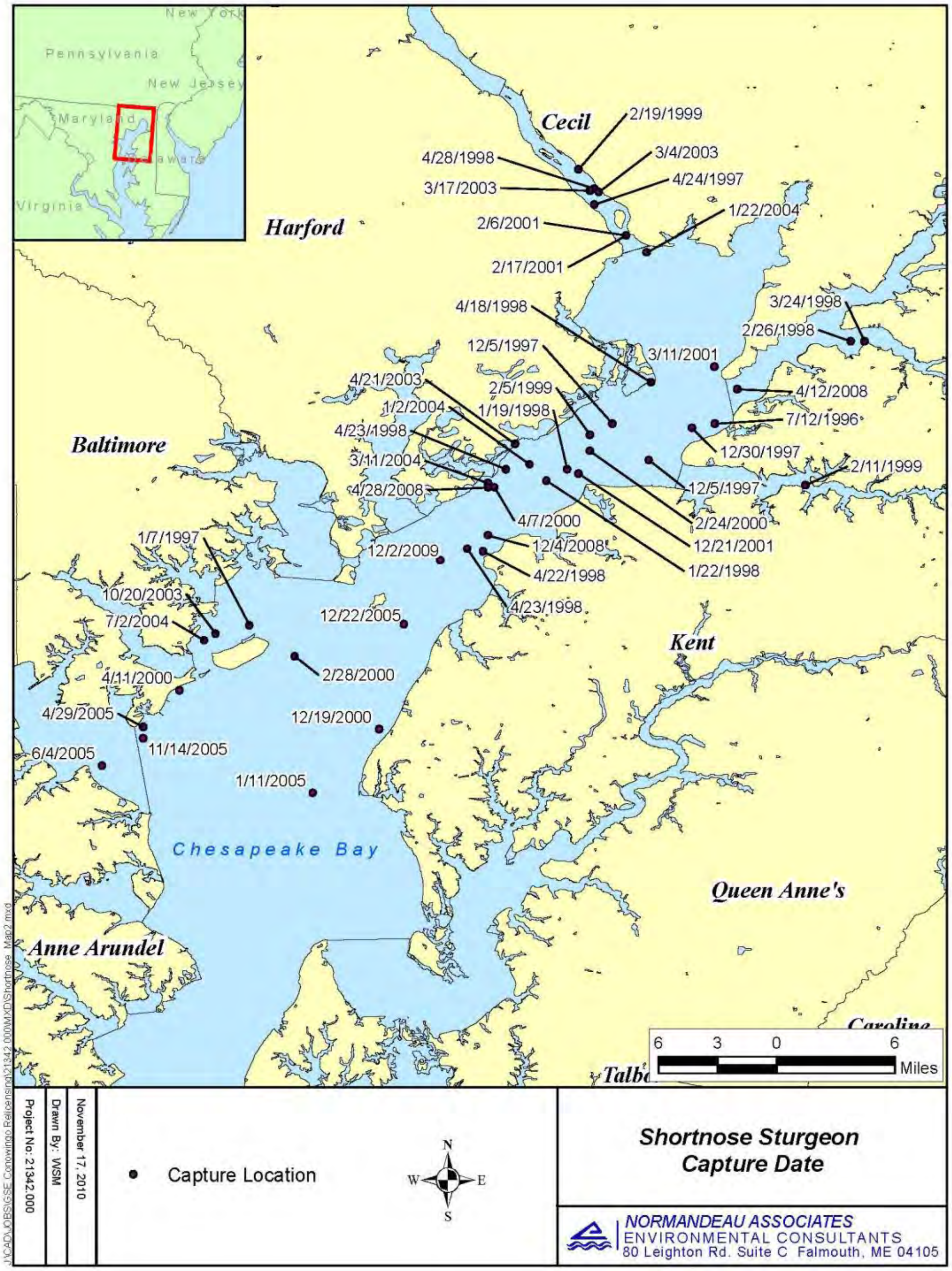


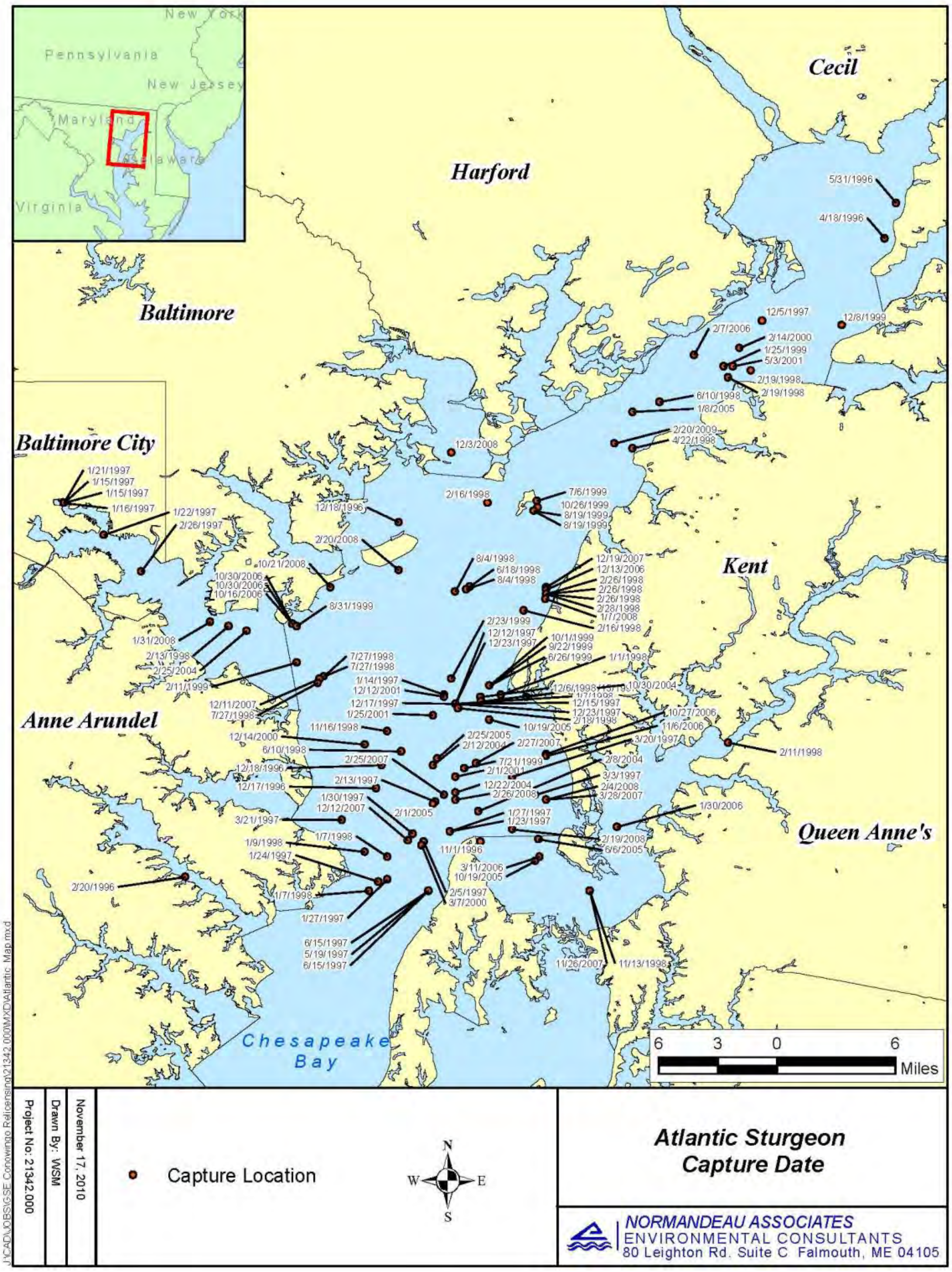
FIGURE 2.4-2: SHORTNOSE STURGEON CAPTURES FROM THE UPPER CHESAPEAKE



BAY (LABLED BY DATE OF CAPTURE).

Collection data reported to the USFWS for the Coastwide Atlantic Sturgeon Tagging Program and Atlantic Sturgeon Reward Program for Maryland Waters of the Chesapeake Bay, 1992 – Fall 2010, courtesy of Sheila Eyler, USFWS.

FIGURE 2.4-3: ATLANTIC STURGEON CAPTURES FROM THE UPPER CHESAPEAKE BAY (LABELED BY DATE OF CAPTURE).



Collection data reported to the USFWS for the Coastwide Atlantic Sturgeon Tagging Program and Atlantic Sturgeon Reward Program for Maryland Waters of the Chesapeake Bay, 1992 – Fall 2010, courtesy of Sheila Eyler, USFWS. Data courtesy of Sheila Eyler, USFWS.

FIGURE 2.6-1: AERIAL VIEW OF CONOWINGO DAM, SUSQUEHANNA RIVER, MARYLAND.

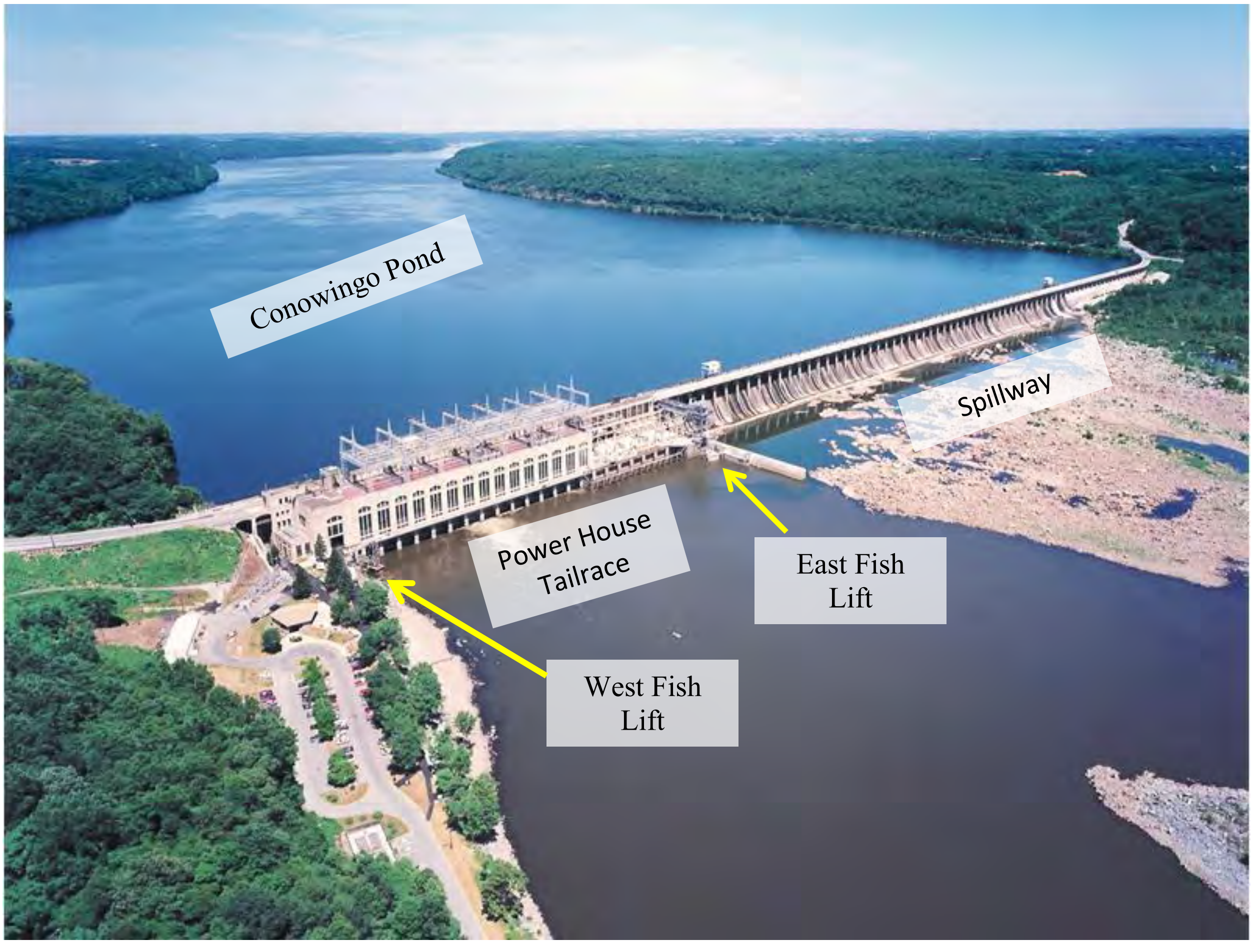
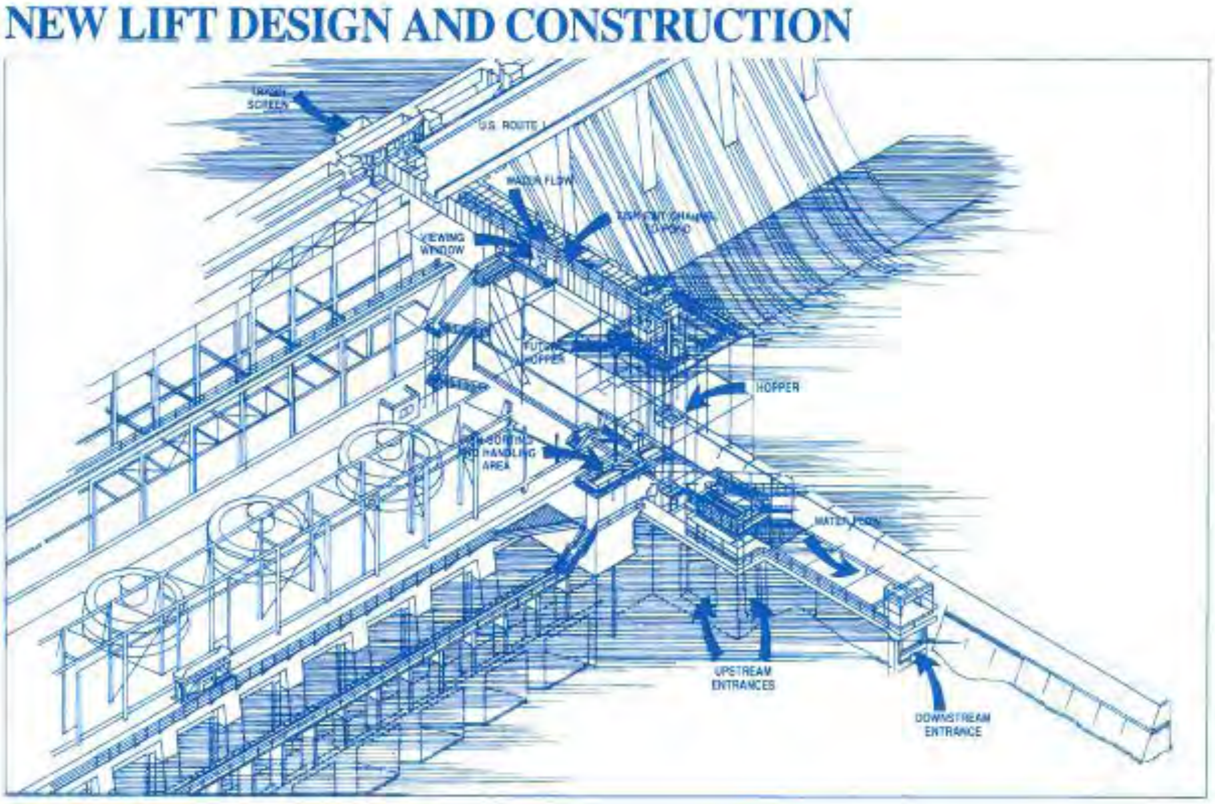
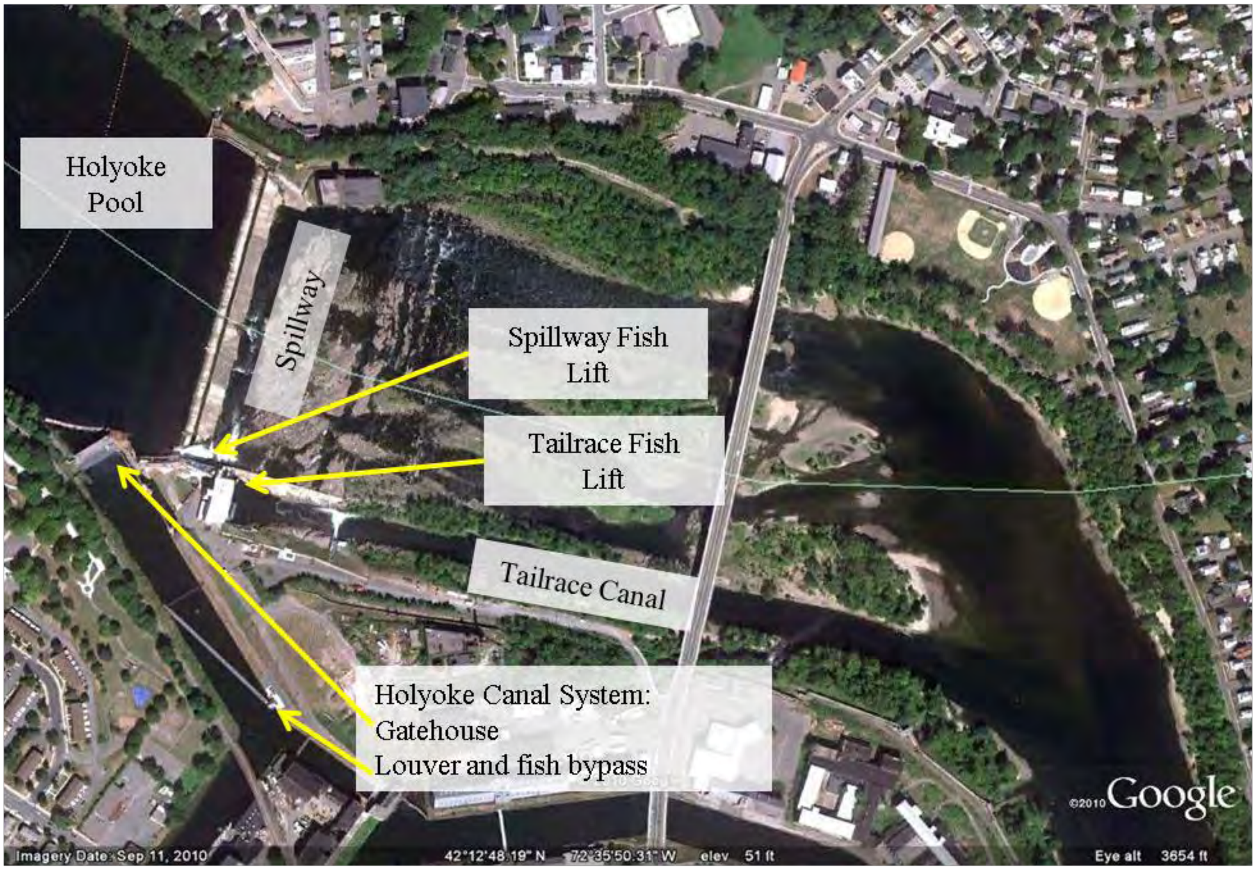


FIGURE 2.6-2: LINE DRAWING OF CONOWINGO EAST FISH LIFT.



Credit: Stone and Webster Engineering, Cherry Hill, NJ

FIGURE 2.6-3: AERIAL IMAGE OF HOLYOKE DAM, CONNECTICUT RIVER, MASSACHUSETTS.

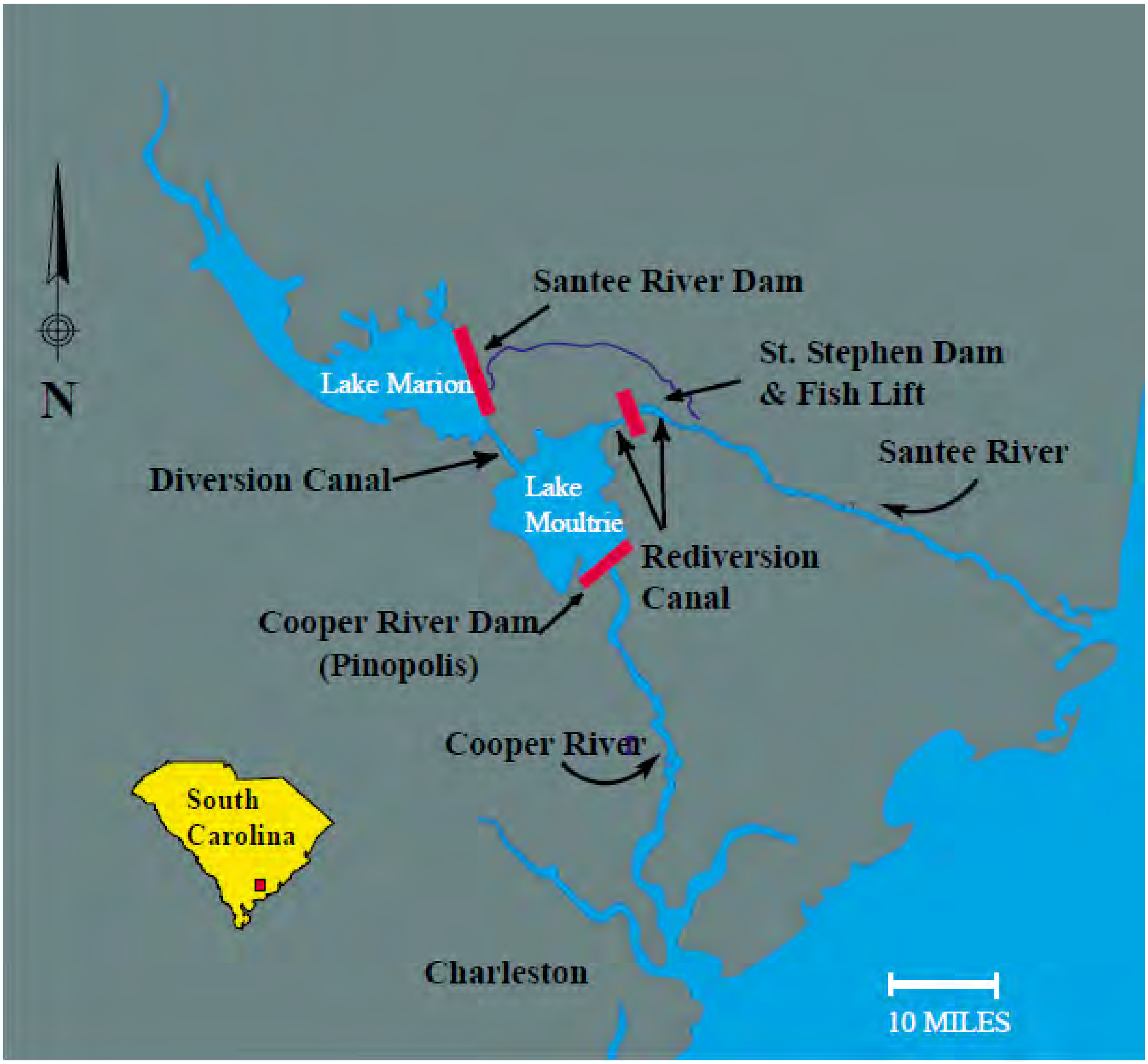


Credit: GoogleEarth

FIGURE 2.6-4: CONCEPTUAL DRAWING OF THE HOLY DAM FISHWAYS, CONNECTICUT RIVER, MASSACHUSETTS.

Credit: City of Holyoke Gas & Electric Department.

FIGURE 2.6-5: MAP OF THE SANTEE-COOPER SYSTEM, SOUTH CAROLINA.

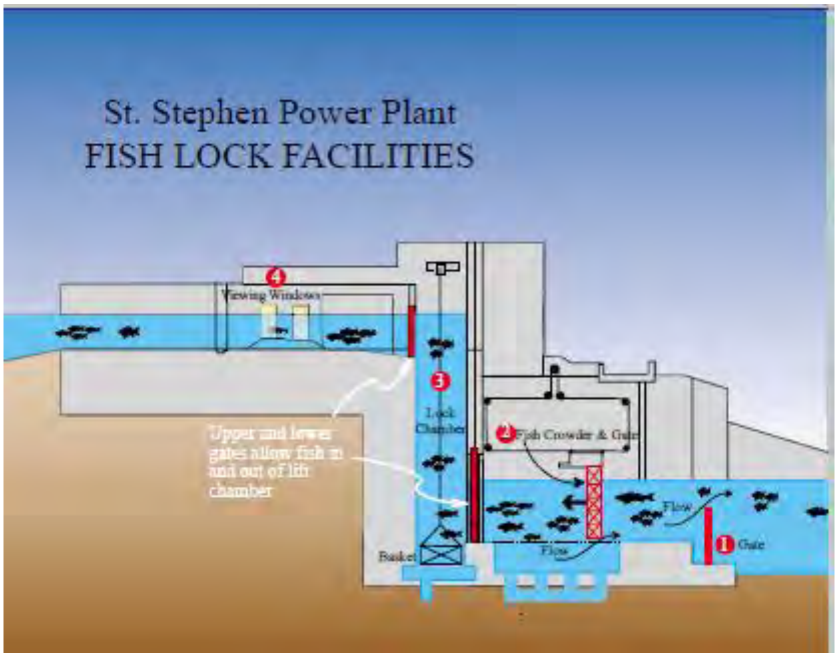


Credit: South Carolina Department of Natural Resources.

FIGURE 2.6-6: AERIAL IMAGE OF ST. STEPHEN DAM, REDIVERSION CANAL, SOUTH CAROLINA.

Credit: GoogleEarth

FIGURE 2.6-7: CONCEPTUAL DRAWING OF ST. STEPHEN FISH LOCK, REDIVERSION CANAL, SOUTH CAROLINA

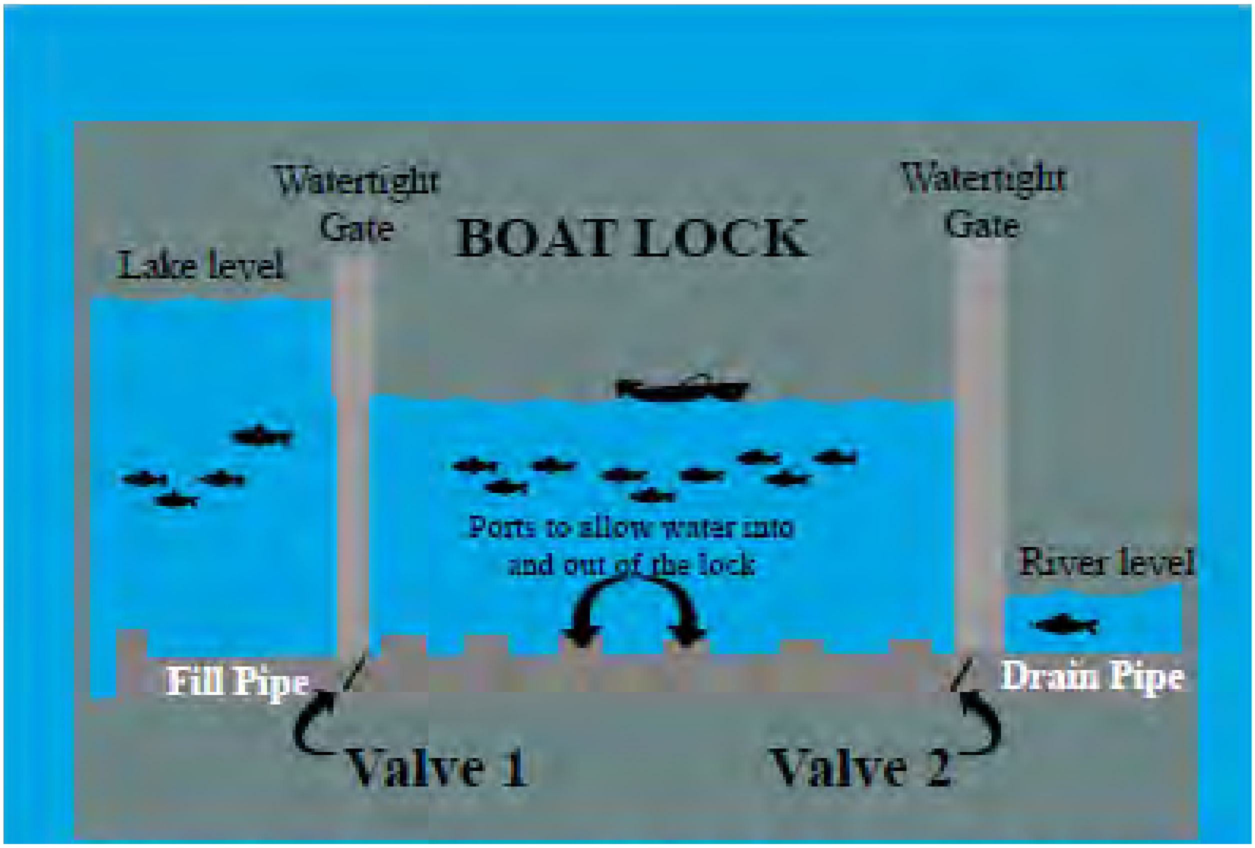


Credit: South Carolina Department of Natural Resources

FIGURE 2.6-8: AERIAL VIEW OF PINOPOLIS DAM AND LOCK, COOPER RIVER, SOUTH CAROLINA.

Credit: GoogleEarth

FIGURE 2-6.9: CONCEPTUAL DRAWING OF PINOPOLIS NAVIGATION LOCK.



Credit: South Carolina Department of Natural Resources

3.0 ANALYSIS OF AVAILABLE HABITAT BELOW CONOWINGO DAM

Exelon conducted a study to analyze project operational impacts on shortnose sturgeon habitat availability as part of the Instream Flow Habitat Assessment below Conowingo Dam Study (Study 3.16). The Instream Flow study analyzed the occurrence and suitability (velocity, depth, and substrate) of habitat conditions as a function of flow for the spawning, fry, and juvenile and adult life stages of shortnose sturgeon. Habitat suitability criteria have been determined and habitat availability below Conowingo dam assessed by development of a 2-D hydraulic model using bathymetry, substrate roughness, water surface elevations and water velocity. Habitat models were constructed using results of the 2-D model and habitat suitability criteria to quantify optimal habitat. The effects of project operations on habitat suitability will be assessed by analysis of persistence of habitat among simulated flow levels. Results of that study were provided as part of the Conowingo 3.16-Instream Flow Habitat Assessment below Conowingo Dam study report.

3.1.1 Response to Comments

The Initial Study Report (ISR) for Conowingo Hydroelectric Project, FERC Project No. 405, relicensing was filed with FERC Feburary 22, 2011. Agency comments on the ISR were filed on April 27, 2011, and Exelon's responses to those comments were filed on May 27, 2011. Comments and response pertinent to RSP 3.22 included:

MDNR Comment 1:

> Analysis of habitat types below Conowingo Dam seems to be preliminary. In the context of the title of the study it is difficult to determine how habitat types are being analyzed. Habitat in this study appears to refer to the water column and its flow characteristics. However, an analysis of that nature should be characterized as hydraulic habitat. Nevertheless, an analysis of habitat cannot be conducted solely on hydraulic characteristics, based on the description of the study. The analysis also concludes that in general, suitable habitat is limited for all life stages of shortnose (and presumably Atlantic) although there is are no physical habitat characteristics presented in this study. It seems unlikely there is no gravel in this region given the visible habitat seen in some of the figures.

Exelon Response:

> The analysis of sturgeon habitat was completed as part of Study 3.16-Instream Flow Habitat Assessment below Conowingo Dam.

4.0 DOCUMENTATION OF STRANDING BELOW CONOWINGO DAM

Exelon conducted a Downstream Flow Ramping and Fish Stranding Study (Study 3.8). The study assessed areas below Conowingo Dam for their potential for fish stranding under several minimum flow-generation combinations. Field crews examined potential stranding sites after peaking generation periods on 12 occasions: April 9, May 6, 13, 18, June 11, July 7, August 11, September 1, October 27, November 3, 10, 17. No sturgeon were observed. See Study 3.8 for details.

5.0 MONITOR FOR USE OF THE SUSQUEHANNA RIVER BELOW CONOWINGO DAM BY SHORTNOSE AND ATLANTIC STURGEONS

5.1 Introduction and Background

A number of Atlantic and shortnose sturgeons in the Delaware River tagged with active acoustic transmitters (Vemco, 69 kHz) may be currently at large. In 2009, Delaware Department of Natural Resources and Environmental Control tagged 21 young-of-year Atlantic sturgeon; the transmitters for 12 of those were expected to be active at least to summer 2010, but the battery life of nine transmitters was expected to have been exceeded by mid-March 2010 (Fisher 2009a, b). Young-of-year Atlantic sturgeon are generally thought to remain in the estuarine portion of their natal river for months to years before making marine migrations, but the potential movement among systems by early juvenile fish is increased due to the hydraulic linkage of the upper Chesapeake Bay and Delaware Bay estuaries via the Chesapeake and Delaware (C&D) Canal. Fisher (2009a, b) using supplementary data from a network of researchers employing arrays of Vemco data logging receivers, documented overwintering by juvenile Delaware River Atlantic sturgeon in the James River, VA. Approximately 46 Atlantic sturgeon tagged in the Delaware River (Matt Fisher, Delaware Department of Natural Resources and Environmental Control, personal communication) and 51 tagged in the Atlantic Ocean offshore of Delaware (ACT database, Dewayne Fox, Delaware State University, personal communication), and more than 100 tagged in the James River, Virginia as well as coastal migrants from other studies coast wide could be available to use the Susquehanna River. Additionally, a number of shortnose sturgeon have been tagged in the Delaware River (Hal Brundage, Environmental Research Consulting), but it is unclear whether any still have active tags. Welsh et al. (2002B) reported movement of shortnose sturgeon tagged in the Chesapeake Bay to the Delaware River system via the C&D Canal. They did not document movement of Delaware River tagged fish down the C&D Canal to Chesapeake Bay, but suggested that two-way movement could not be ruled out, citing genetic evidence that the fish collected in Chesapeake Bay were of Delaware River origin. Simpson (2008) did document movement of tagged sub-adult Atlantic sturgeon down the C&D Canal to Chesapeake Bay from the Delaware River.

The objective of this study was to monitor the Susquehanna River for sonic transmitter tagged sturgeons at large in the system that could potentially use habitats in the Susquehanna River.

5.2 Materials and Methods

Two transects consisting of three stations each were deployed pursuant to the FERC Study Plan Determination and a subsequent meeting with NMFS personnel (February 16, 2010). The deployment of the two transects to provide cross-river coverage in the tidal portion of the river and near the downstream extent of the Conowingo Project influenced zone (vicinity of Deer Creek) was discussed and generally agreed upon. Transects were selected based on ideal location in the tidal portion of the lower river while considering logistics of deployment and download as well as effects on navigation and the potential for vandalism. All receivers were deployed with an anchor and buoy system that was permitted by the U.S. Coast Guard (USCG Form 2554, Private Aids to Navigation). According to the Coast Guard permit, all buoys were yellow in color (indicating a research buoy) and two locations in the tidal transect had yellow strobes during nighttime hours.

The tidal transect was located near Perryville, Maryland and just downstream of the Interstate 95 bridge crossing. The non-tidal transect was located near Port Deposit, Maryland, just downstream of Spencer Island and approximately 2 km downstream of the mouth of Deer Creek. This transect was chosen because it was downstream of the Project influence, therefore providing a monitoring gateway for tagged fish entering the Project area. This area also represents a current velocity reduction where tag reception would be optimized relative to the higher velocity zone upstream.

A final site visit and station range finding was done on March 17, 2010 when river discharge was greater than 200,000 cfs (i.e., during spring freshet, Figure 5.2-1). Receiver reception range was evaluated by deploying a Vemco VR2W data-logging sonic telemetry receiver (Figure 5.2-2A) at the pre-selected stations and placing a transmitter at a variety of discrete distances from the station at a known time. Range finding was done using the weakest tag type used in the Delaware River Atlantic Sturgeon studies, V7-2L (Figure 5.2-2B), with a power output of 136 dB (Matt Fisher, Delaware Department of Natural Resources and Environmental Control, personal communication). Range finding resulted in positive reception varying from 200 – 400 m under ambient conditions with a relatively low powered tag. Final station locations were selected based on those results (Table 5.2-1, Figure 5.2-3) and were deployed on March 24 when river discharge was still relatively high, but had receded to less than 100,000 cfs (Figure 5.2-1).

During spring, data from the receivers were manually downloaded biweekly and during summer, downloads were done monthly. In fall, 2010 data downloads were done frequently in conjunction with a separate study for silver-phase American eel emigration. Downloaded data were compiled into a database in Vemco Vue V.1.6.4 software and reviewed for logged tag identification codes. When data were logged, the codes were cross-checked with an Atlantic Coast sturgeon tagging database (see Eyler et al. 2009) and critically reviewed to eliminate spurious codes resulting from noise or signal collision. If a logged code did not appear on the ACT database and was recorded only once, or if it was recorded only once and known transmitters were also logged around the same time, it was assumed to be spurious data and was discarded. Spurious data can occur as the result of ambient noise, such as boats engines, or from signal collision when real tags are within range. Signal collisions can occur when multiple transmitters are present in range, or from an echoing signal from a single transmitter. If a logged code was determined to be potentially real, it was cross checked with the ACT database or with Vemco to determine validity and source.

5.2.1 2011 Monitoring

Per informal coordination with NMFS via teleconference on March 2, 2011, it was decided to redeploy the acoustic telemetry receiver arrays were re-deployed for the 2011 season. The deployment locations and monitoring and download methodology were as for 2010. Initial deployment was done on April 4, 2011 when water temperature was 7.5 °C.

5.3 Results

Data-logging receivers were deployed on March 24, 2010; the first data downloads were done on April 2 and continued biweekly through June 28, and then monthly through October 28. During November, downloads were done on a sub-weekly basis due to an ongoing silver-phase American eel emigration study. Water temperature as of November 8 was 8.8°C.

Excluding test tags used for range finding and sonic transmitter tagged American eels released into the Susquehanna River during fall 2010, only three valid codes were logged. Those were recorded April 1 – 24, 2010 and were determined to be from striped bass tagged out of state in an unrelated study. Those records were submitted to the appropriate researcher. No other tags were logged, and therefore no sturgeon tags were logged.

5.3.1 2011 Monitoring Results

Data-logging receivers were deployed on April 4, 2011 when water temperature was 7.5°C. An exceptionally high freshet period () led to serious concerns for equipment loss and damage; however, and the receivers were removed on April 28, 2011. Water levels were rising rapidly at that time, and daily average discharge exceeded 300,000 cfs by April 29, 2011. The reveivers were then re-deployed on May 9, 2011 when discharge levels had receded. The receivers were then monitored until September 8, 2011 when flood waters resulting from Tropical Storm Irene resulted in rapidly rising river discharge that was approached 800,000 cfs on September 9, 2011. The receivers were then re-deployed on September 16, 2011. Another discharge event began on September 29, 2011 with discharge exceeding 200,000 cfs. The reciervers were not retrieved in that event, and on October 6, 2011 it was discovered that the receiver for the tidal transcect, station C (see Table 5.2-1, Figure 5.2-3) was missing. Although range-finding excercises demonstrated that the receiver at tidal transect station B redundantly covered the area of the receiver at station C, that location is closest to the most likely corridor of migration for sturgeos using the Susquehanna River – the deep channel along the east side of Garrett Island. As a result, the receivers for the non-tidal transect were removed on October 19, 2011 and one of those was used to replace the missing receiver for station C, and only the tidal transect stations were maintained for the remainder of the study. On December 9, 2011 monitoring was terminated for the season and all remaining receivers were retreieved. Data were downloaded between 9 and 12 times for each receiver throughout the season.

As in 2010, no tags associated with shortnose or Atlantic sturgeon were logged during the study. Valid codes were logged for test tags, tags used for American eels during fall 2011, and two transmitters from unrelated studies. Interstingly, those two transmitters, logged between April 8 – 10, 2011, were two of the same transmitters (striped bass) that were logged during spring, 2010. The records were submitted to the appropriate reasearcher.

5.4 Discussion and Conclusions

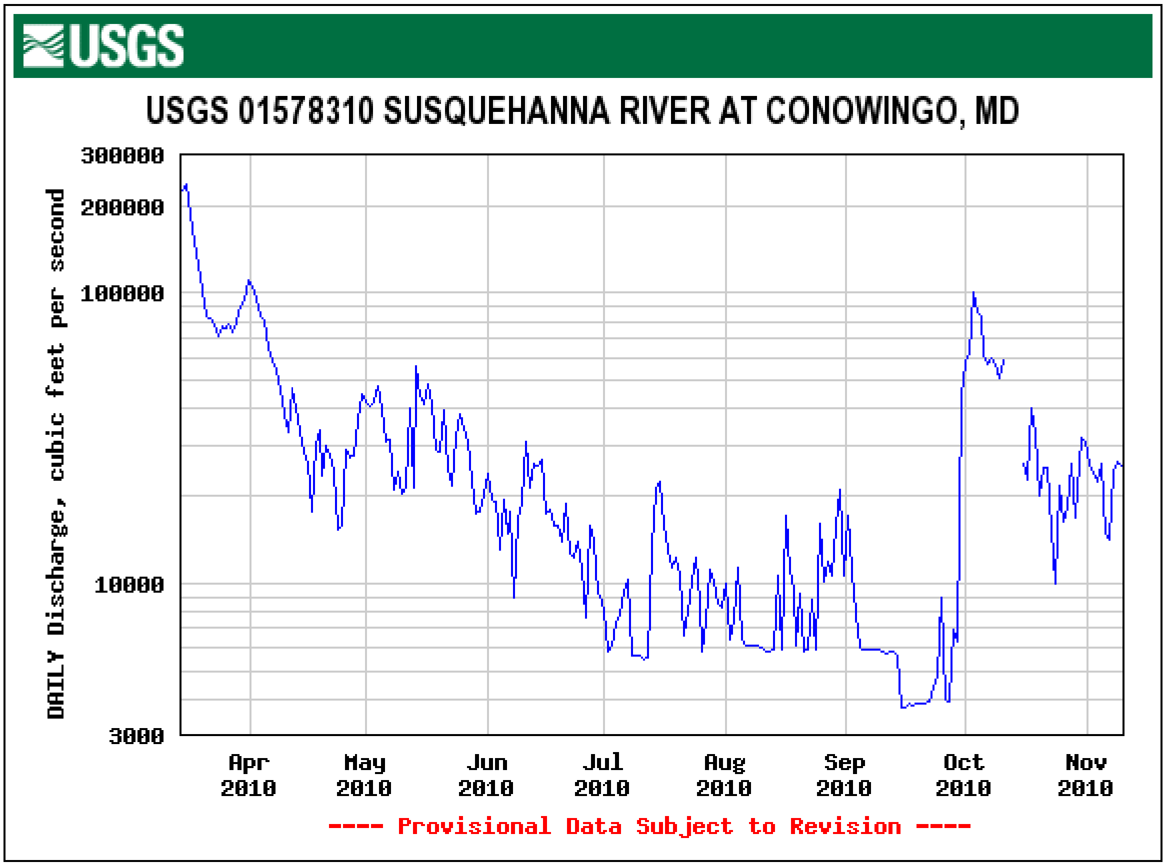
No tagged sturgeon were detected using the Susquehanna River during the study period. It is important to note that this result demonstrates only that no fish with active transmitters used the Susquehanna River during the study period; however the potential for untagged fish or fish with inactive transmitters to have used the river is real but unknown.

TABLE 5.2-1: DATA-LOGGING SONIC RECEIVER LOCATIONS

Station identification	Latitude	Longitude	Depth (m)
Tidal-A	39.57473	76.10313	4.6
Tidal-B	39.57486	76.09658	5.2
Tidal-C	39.57869	76.09129	6.1
Non-Tidal-D	39.60195	76.12717	3.0
Non-Tidal-E	39.60415	76.12458	3.0
Non-Tidal-F	39.60559	76.12214	3.0

Coordinates are presented in decimal degrees format.

FIGURE 5.2-1: SUSQUEHANNA RIVER DAILY AVERAGE DISCHARGE DURING SONIC TELEMETRY MONITORING STUDY, 2010.



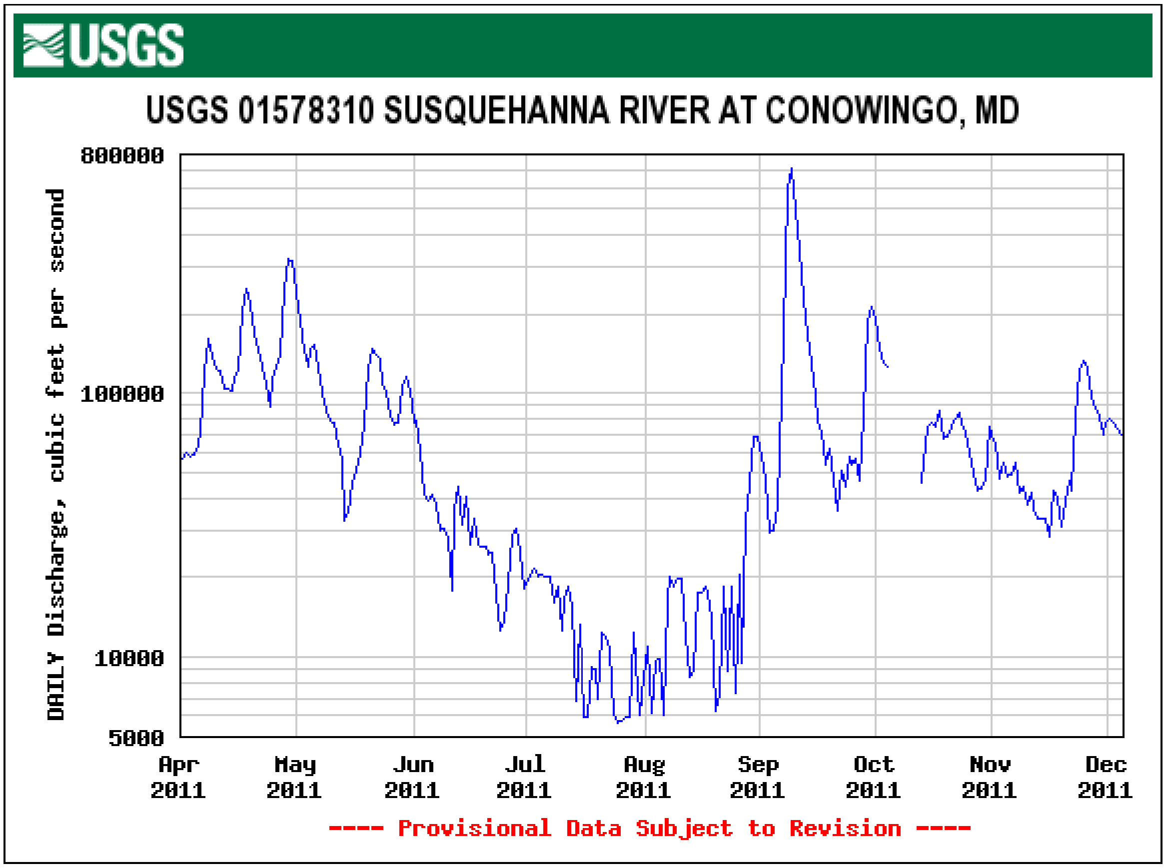
Data are from USGS Gauge 01578310, http://waterdata.usgs.gov/usa/nwis/uv?01578310.

FIGURE 5.2-2: VEMCO SONIC TELEMETRY EQUIPMENT

A. Model VR2W receiver, B. Model V7 transmitter (left). Photographs courtesy of Vemco.

FIGURE 5.2-3: RECEIVER DEPLOYMENT LOCATIONS

FIGURE 5.2-4: SUSQUEHANNA RIVER DAILY AVERAGE DISCHARGE DURING SONIC TELEMETRY MONITORING STUDY, 2011.



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