Susquehanna River Anadromous Fish Restoration Cooperative
(SRAFRC)

Migratory Fish Management and Restoration Plan for the Susquehanna River Basin

Approved by the Policy Committee
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Cooperators

U.S. Fish and Wildlife Service
National Marine Fisheries Service
Susquehanna River Basin Commission
Pennsylvania Fish and Boat Commission
Maryland Department of Natural Resources
New York State Department of Environmental Conservation

Acknowledgments

This Plan was initially written in 1997 by Mike Hendricks, specifically as a guidance document for future Pennsylvania Fish and Boat Commission (PFBC) activities in Pennsylvania waters of the Susquehanna River basin. It was modified and updated in 2001 by Dick St. Pierre, the Susquehanna River Coordinator (Coordinator) for the U.S. Fish and Wildlife Service (USFWS) to incorporate recent information add new program elements and serve as an anadromous fish restoration plan for the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC). It was updated and revised again during 2006-2010 to address additional migratory fish (anadromous, catadromous, and potadromous) including alewife, blueback herring, striped bass, Atlantic sturgeon, shortnose sturgeon, and American eel.

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Plan writers:

Lawrence M. Miller	U.S. Fish and Wildlife Service
David W. Heicher	Susquehanna River Basin Commission
Andrew L. Shiels &	
Michael L. Hendricks	Pennsylvania Fish and Boat Commission
Robert A. Sadzinski	Maryland Department of Natural Resources
David Lemon	New York State Department of Environmental Conservation

Reviewers:

Richard St. Pierre	U.S. Fish and Wildlife Service, Retired
R. Wilson Laney	U.S, Fish and Wildlife Service
Andrew Kahnle	New York State Department of Environmental Conservation

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Executive Summary

The Susquehanna River once supported large numbers of migratory fish including the American shad (*Alosa sapidissima*), blueback herring (*A. aestivalis*), alewife (*A. pseudoharengus*), and hickory shad (*A. mediocris*), striped bass (*Morone saxatilis*), Atlantic sturgeon (*Acipenser oxyrinchus*), and shortnose sturgeon (*Acipenser brevirostrum*). These stocks have been severely impacted by human activities, especially dam building. In the 1950s, the resource agencies implemented a program to restore access for migratory fish to the upper Susquehanna River basin, focusing on American shad. In response to harvest declines that signaled critically low fish stock levels, the directed American shad fisheries in the Chesapeake Bay region were closed (Maryland in 1980 and Virginia in 1994). The American shad stock in the Susquehanna River improved slowly and made an impressive comeback by 2001 when over 200,000 adult shad were counted at the Conowingo Dam fish lifts. However, since 2001, adult numbers have decreased most likely due to a variety of factors including: poor efficiency of fish passage measures and facilities; low hatchery production in recent years; low numbers of spawning fish accessing quality habitat: poor young-of-year recruitment upstream of Conowingo Dam; ocean and Chesapeake Bay mortality; turbine mortality and predation. The existing and new challenges made it clear that updates were needed to the previous Susquehanna River American shad restoration plan.

The ***Migratory Fish Management and Restoration Plan for the Susquehanna River Basin*** outlined herein will serve as the SRAFRC's restoration guide and management plan for migratory fish resources. This comprehensive watershed plan serves as the lead document that will guide migratory fish management and restoration. The success of this plan is dependent upon stakeholder involvement in a dynamic process of restoration and upstream and downstream passage, water quality monitoring and improvements, and watershed planning coordination. Benchmarks set in this plan should be reviewed periodically thereby maximizing the probability of success using science-based evaluations.

The goal of this plan is to **"*Restore self-sustaining, robust, and productive stocks of migratory fish capable of producing sustainable fisheries, to the Susquehanna River Basin throughout their historic ranges in Maryland, Pennsylvania, and New York. The goals are 2 million American shad and 5 million river herring spawning upstream of the York Haven Dam. Goals for American eel and other migratory species are yet to be determined*".**

The steps to achieve this goal are partitioned into five objectives, each with a series of tasks. The tasks include a brief description along with timelines, costs, potential sources of funding and an assessment of task status. Brief overviews of the five objectives are:

A. Restore access to historic habitats for juvenile and adult migratory fish. This objective calls for development of passage plans and performance measures to achieve specified minimum passage efficiency for American shad, American eels, and other migratory fish species at major basin dams. Specified minimum passage efficiencies are much higher than currently experienced at major Susquehanna River barriers.

B. Maintain or improve existing migratory fish habitat. This objective focuses on essential habitat issues by inventorying blockages and assessing the impact of fish passage impediments through active involvement of SRAFRC in watershed project reviews while supporting monitoring and improving water quality.

C. Enhance migratory fish spawning stock biomass and maximize juvenile recruitment through natural and/or artificial means. This objective includes a variety of tasks designed to directly or indirectly improve migratory fish stocks in the Susquehanna River. Tasks focus on improving current techniques for artificial augmentation of American shad stocks, developing new techniques for augmenting river herring and eel populations, restoring non-Alosine migratory fish, improving instream migration, spawning and rearing habitat, and maintaining existing regulatory framework restricting harvest of migratory fish.

D. Evaluate the migratory fish restoration effort and adjust programs or processes as needed. This objective stresses the importance of data dissemination and analysis. Tasks included in this section will continue to collect baseline data essential to monitor restoration progress while researching and experimenting with technologies to improve survival, reproduction and spawning biomass.

E. Ensure cooperation among all restoration partners while generating support for migratory fish restoration among the general public and potential funding sources. This objective stresses the importance of a watershed approach to restoration and emphasizes the need to include coastal states and ocean waters.

The SRAFRC, through its policy and technical committees, member agencies and partners will rely on this plan as the foundation of its restoration activities while also recognizing that changes in fish stocks, threats, and management techniques will require flexibility and adaptation.

History of Migratory Fish Abundance and Distribution

The Susquehanna River (Figure 1) is the longest river on the East Coast of the United States. It originates at Otsego Lake in Cooperstown, N.Y., drains 27,500 square miles, including nearly one-half of the state of Pennsylvania, and empties into Chesapeake Bay at Havre de Grace, Maryland. Twenty-three percent of the drainage lies within New York, 76 percent in Pennsylvania and 1 percent in Maryland. The mainstem of the river is 444 miles long and its major tributaries include the West Branch (228 miles) and the Juniata River (90 miles). The Susquehanna River provides more than one-half of the freshwater flow to the Chesapeake Bay with an average inflow of 32,000 cubic feet per second.

Early Fisheries

American shad

Native Americans along the Susquehanna River relied on fish as a substantial component of their diet and caught American shad in large quantities long before European colonists arrived in North America (Meehan 1897, Gay 1892). The Native Americans used many methods to catch shad including "*weirs and traps; seines, gill and scoop nets; spears, bows and arrows, gigs; hand, poles and set lines*" (Meehan 1897). In the latter half of the 18th century, colonists from Connecticut settled in the Wyoming Valley and established commercial and subsistence seine fisheries for American shad. Rights to these fisheries were disputed by the Pennsylvania government. These disputes lasted 30 years and were given the term Yankee-Pennamite War (or “shad” wars), which were characterized by the burning of buildings, plundering of produce, and destruction of the seines (Meehan 1897). Eventually, Connecticut gave up its claim to the northern tier of Pennsylvania.

Yankee settlers were allowed to stay and approximately 40 permanent seine fisheries were established between Northumberland and Towanda (Gay 1892). American shad were a dietary staple and an integral part of the local economy. Gilbert Fowler of Berwick wrote in 1881: "*The Susquehanna shad constituted the principal food for all the inhabitants. No farmer, a man with a family, was without his barrel of shad the whole year round*" (Gay 1892). The fisheries in the North Branch (Susquehanna River above its confluence with the West Branch at Northumberland, PA) were economically valuable and the fish were fantastically abundant. Much of the pre-1900 information available comes from a report, written in 1881, by Harrison Wright for the Wyoming Historical and Geological Society and recounted in Gay (1892) and Meehan (1897).

The owner of the soil was the owner of the fishery and rights to the fisheries were bought, sold, and traded. Typically, about 10 men would form a seining company, work the seine, and divide the catch. The catch varied depending on location. Harrison Wright reported that at the eight fisheries near Northumberland, 300 shad was a common haul with some hauls of three to five thousand. Nearly 10,000 shad were taken in a single haul at the Fish Island site. One man received 1,900 shad as his share for one night’s fishing. The fisheries down river from Wilkes-Barre were more productive than those above, with many thousands caught in the area above Berwick during early spring. Excess fish were hauled away to be put on farmland for fertilizer. The annual commercial value of the North Branch shad fisheries in 1881 was estimated at $12,000 with an estimated catch of 150,000 fish. On the North Branch, American shad ranged as far north as Binghamton, N.Y., 318 miles from the mouth of the river and 513 miles from the sea (Stevenson 1897).

On the West Branch Susquehanna River, much less information is available. Gerstell (1998) indicated that substantial shad fisheries occurred in the late 1700s between Lewisburg and Lock Haven, and anecdotal reports suggest shad reached Chest Creek in Clearfield County. However, according to Gay (1892), "*The shad appear never to have gone up the West Branch in such quantities as they did up the North Branch, and the same may be said of the Delaware, or else the fish were of inferior quality, for the dwellers from the banks of both of these streams came to Wyoming Valley for their supply of shad*." On the Juniata River, shad were known to occur as far upstream as Hollidaysburg but most fisheries were located below Lewistown (Gay 1892).

While North Branch fisheries are well reported by Wright, it should be noted that many shad seine fisheries simultaneously occurred on the lower river in Pennsylvania and Maryland during the early decades of the 1800s.

In 1835 gill nets were introduced into the Chesapeake Bay region (Walburg and Nichols 1967), followed by pound nets in 1865 (Stevenson 1897). Pound nets quickly became the gear of choice in the Chesapeake Bay and within ten years over 90% of the shad landed came from these nets. Because of this gear switch, fishermen could target shad in the bay, before they entered freshwater. By 1904, most of the upper river gill net fisheries had been eliminated because of poor catches and low market prices (US Bureau of Fisheries 1909 as cited in Mansueti and Kolb 1953).

River herring

River herring (alewife and blueback herring) were less prominent in the historical literature; however, they did constitute an important historical fishery and were, by all accounts, incredibly abundant. In his treatise on early shad fisheries of the Susquehanna, Gerstell (1998) reported numerous shad fisheries on islands in the lower river and the Conestoga River throughout much of the 1800s, but made no reference to river herring harvest. Wilkinson (1840) reported that herring ran up to Binghamton with the shad. These were probably blueback herring, with alewife limited to the lower Susquehanna (St. Pierre 1979). While herring may have run far upriver, the herring fishery on the Susquehanna River was largely confined to the lower river: "*The bulk of the business is done in the river from the Maryland line southwardly and in the upper Chesapeake Bay*" (Pennsylvania Department of Fisheries 1906). This was also true on the Delaware River, where herring fisheries were confined to the tidal river below Trenton with herring taken occasionally upstream to Lambertville (Pennsylvania State Commissioners of Fisheries 1901).

The Pennsylvania State Commissioners of Fisheries (1898) reported that 1898 was a good year for herring as "*the herring fisheries in the Susquehanna this year were much larger than in former years… for the vastness of the schools in the extreme lower part [of the Susquehanna River] was beyond compare. As it was, the nets in the Pennsylvania section took thousands upon thousands more than could be used, and it is to the credit of the fishermen that, though I made diligent inquiry, I could not hear of a single instance where the surplus fish were not returned unharmed to the river. The Susquehanna River is without question, the finest herring river in Pennsylvania. The catch far outnumbers that of the Delaware and the industry is very large, much greater in fact than on that stream*." "*Enormous*" catches of river herring were also reported in 1899 (Pennsylvania State Commissioners of Fisheries 1900).

Hickory shad

Very little historical information is available on the hickory shad in Pennsylvania. The Pennsylvania Department of Fisheries (1909) reported that "*an unusual number of very small shad or what are probably yearlings, perhaps two year olds were found among the herring …at Washington Park*" on the Delaware River. These small shad, which were "*about the size of a herring or a little larger*", may have been misidentified hickory shad. Horwitz (1986) also thought this species may have been misidentified or confused with the alewife. Henry W. Fowler of the Academy of Natural Sciences of Philadelphia published a checklist of the fishes of Pennsylvania (Fowler 1921) but made no note of hickory shad, despite its description nearly 100 years earlier (1814). Fowler (1921) later reported hickory shad from the Delaware River at Tullytown, Bucks County. No historical records of hickory shad in the Susquehanna River were found, but hickory shad were surely present in abundance.

Atlantic sturgeon

Atlantic sturgeon is native to the lower Susquehanna River and Chesapeake Bay and was historically very abundant in the Chesapeake Bay. Atlantic sturgeon spawn in rivers and mature in the ocean where they can reach maximum lengths greater than nine feet. Spawning usually occurs in flowing freshwater between the salt line and the fall line (United States Fish and Wildlife Service 1998). Such conditions exist in the lower portion of the Susquehanna River from the confluence of Deer Creek to the mouth of the Susquehanna River where it enters Chesapeake Bay.

Newspaper accounts exist of large sturgeon captured in the lower Susquehanna River from 1765 to 1895. Annual landings were reported to range from 136,000 to 181,000 pounds in the 1890s. Overharvest, poor water quality and river blockages are presumed to have led to major declines in the species. Anecdotal evidence suggests that a sturgeon fishery occurred in the lower Susquehanna River at Perryville, MD, but by the 1920s Atlantic sturgeon were infrequently captured in the upper Bay. Due to extremely low numbers and lack of reproduction, Atlantic sturgeon are presently considered biologically extirpated in the Chesapeake Bay (Maryland Department of Natural Resources (MDNR), Fisheries Service 2009).

Shortnose sturgeon

In the 1900 edition of the Report to the Commissioners of Fisheries of the State of Pennsylvania, W.E. Meehan stated; "*Early in the present century sturgeons abounded in the Delaware and Susquehanna Rivers, and until a comparatively few years ago they were still plentiful"*. In his lengthy report he goes into detail about the scale of the sturgeon fishery on the Delaware river and then states the following; "*The story which is told here of the sturgeon fisheries of the Delaware River is the same for that of the Susquehanna River and the great lakes, except that the industry in the Susquehanna is entirely wiped out and there is no regular industry on the great lakes"* (Meehan 1900). The details in Meehan's report suggest that he is primarily referring to Atlantic sturgeon in the Delaware River discussion but could be referring to either Atlantic or shortnose sturgeon on the Susquehanna River.

American eels

Although less is written about American eels, they were also historically very abundant. Fowler (1921) listed the eel as "*abundant throughout all the waters of our state (Pennsylvania)*." A compilation of fresh fish sales for New York City cited sales of eels at 1.5 million pounds in 1880. Among freshwater fish, this was second to sturgeon (2.75 million pounds) and ahead of shad at 1.3 million pounds (Pennsylvania State Commissioners of Fisheries 1883).

Fish baskets or eel weirs, designed to catch out-migrating adult eels and other fish, caused mortality to millions of out-migrating juvenile American shad and were outlawed by

Pennsylvania in 1878 and routinely destroyed by fish wardens in subsequent years (Pennsylvania State Commissioners of Fisheries 1887). Few statistics are available for the catch of eels in fish baskets, largely because they were illegal. However, catches must have been substantial enough to offset the cost and labor involved in making and installing the basket and its rock wing leads, and the other difficulties associated with this illegal activity. Collins (1895) reported 13,725 pounds of eels harvested from the lower Susquehanna River in 1891, using fyke nets or pots. This is compared to over 200,000 pounds of shad harvested. These statistics are surely not reflective of the true abundance of eels at that time, but do present some indication of the commercial value of the fishery.

Regarding the American eel, the Pennsylvania State Commissioners of Fisheries (1898) stated: "*Numerous as are the eels, and readily as they are sold in the markets and sought after as they are by residents along the Susquehanna for winter and table use, the fish is still an inferior article of food and of much less value commercially than the shad*". Despite the fact that the Pennsylvania State Commissioners of Fisheries (1898) desired to *"… get rid of the eels or encourage in every manner possible, consistent with the preservation of the supply of other food fish, the use of any device which would reduce the supply*" they advocated strongly against the use of the fish basket or eel basket because of its destructive nature to juvenile American shad. Destroying fish baskets became one of the primary duties of fish wardens during the 1890s and each warden proudly documented how many baskets were destroyed (Pennsylvania State Commissioners of Fisheries 1898). The amount of illegal fishing was huge, as documented by the destruction of 92 fish dams by the Dauphin County sheriff in 60 miles of river near Duncannon (Pennsylvania State Commissioners of Fisheries 1902).

Eels gained a reputation as voracious predators "*working great injury among much better food fish, particularly game fish. Probably every fish culturist in the state would be glad to see the eels all destroyed, because of their destructiveness*" (Pennsylvania State Commissioners of Fisheries 1900). In Maryland, the American eel was considered destructive of other fish to the point that the legislature passed an act in 1888, appropriating a quarter of the state fish commission's budget for destruction of the eel (Sudler and Browning 1894, cited in Hildebrand and Schroeder 1927). In a two-year period (1892 to 1893), over $3,400 was spent harvesting eels in baited pots but the sale of the captured eels only brought $80, and the practice was discontinued.

For a brief period from 1903 to 1913, eel baskets were made legal in Pennsylvania with restrictions to minimize mortality of other species. A license was required to operate the basket, but reporting of the catch was not mandatory until 1909. Catch, by county, in numbers, pounds, and dollar value was reported in the Department of Fisheries reports for 1909 to 1912 (Pennsylvania Department of Fisheries 1909, 1910, 1911, 1912). By subtracting the catch for counties in the Delaware and Potomac River drainages, it was possible to approximate the catch for the Susquehanna River. The catch of eels in numbers ranged from 53,824 to 336,761 per year with a mean of 157,070. In pounds, the catch ranged from 44,002 to 147,222 with a mean of 88,339. The value of the Susquehanna River eel fishery ranged from $4,503.04 to $13,285.88 with a mean of $8,311.85. Many small eels were captured in the fishery as evidenced by the mean weight of 0.68 pounds per eel. For the four-year period, 1909 to 1912, 90 percent of the statewide catch in numbers and 86 percent of the catch in pounds was harvested in the

Susquehanna River, although Delaware River harvest by New Jersey fishers was not reported.

In 1920, 197,000 pounds of eels, worth $21,000 were harvested in Maryland ranking seventh in both quantity and value (Hildebrand and Schroeder 1927). Alewife herring ranked first (6.7 million pounds), followed by American shad (1.8 million pounds), Atlantic croaker (1.3 million pounds), striped bass (1 million pounds), weakfish (678 thousand pounds), and white perch (317 thousand pounds). These statistics reveal an American prejudice against eating eels despite their firm, flavorful flesh (Hildebrand and Schroeder 1927). This prejudice still exists today as eels are used primarily as bait for sport fish or blue crabs or exported live to Europe or Asia as a food fish.

Striped bass

Historically, the Susquehanna River has had a nominal striped bass fishery.

The Demise of Migratory Fish in the Susquehanna River

Overfishing and pollution from lumbering, mining, and untreated sewage and loss of access to spawning and nursery habitat adversely affected migratory fish. In tributaries, migratory fish runs were blocked by hundreds of milldams. Specific information on the construction of these dams and their impact on migratory fish is difficult to obtain. However, concern for this impact is evidenced in state legislation. For example, the "*Statutes at Large of Pennsylvania*," for 1770 to 1771, chapter DCXXVII, was "*AN ACT DECLARING THE RIVER SUSQUEHANNA AND OTHER STREAMS THEREIN MENTIONED PUBLIC HIGHWAYS, FOR IMPROVING THE NAVIGATION OF THE SAID RIVER AND STREAMS, AND PRESERVING THE FISH IN THE SAME*." This act encompasses the Susquehanna River; the Juniata River to Bedford and Frankstown; the Conestoga River, upstream to Mathias Slough's milldam; and portions of Conodoguinet, Penns, Swatara, and Bald Eagle Creeks. Chapter DCXXIII of the Statutes at Large (same year) regulated the fisheries and provided for fish passage in the lower reaches of Codorus and Conewago Creeks in York County. Act 750, passed by the Pennsylvania Legislature in 1870, declared` the Conestoga River from its mouth to the confluence of Muddy Creek a public highway for the protection of fish.

Dams on the mainstem of the river were first constructed around 1830 to 1835 to feed the new Susquehanna canal system. Canal dams were located on the North Branch at Nanticoke, the Juniata at North's Island, and the mainstem at Duncan’s Island and Columbia (Gay 1892, Meehan 1897). The canal dams completely blocked migratory fish in some years, but allowed passage in others, particularly when the dams were damaged by ice flows. In 1866, the Pennsylvania Legislature passed an act requiring fish passage facilities to be constructed at the dams and appointed a Fish Commissioner (forerunner to what is now PFBC) to ensure compliance. The fishways constructed were largely ineffective, but enough fish passed by way of temporary dam breaches caused by ice damage to create optimism for the success of fish passage measures. By the end of the century, the canal system was abandoned, and breaks in the Columbia Dam re-opened a large portion of the river to migratory fish. Fisheries for migratory species reappeared in the lower Susquehanna and Juniata rivers until the early 1900s and

Pennsylvania harvest at that time amounted to about 200,000 to 400,000 pounds per year (U.S. Fish Commission reports).

Maryland commercial shad and herring fisheries prospered in the upper Chesapeake Bay and lower Susquehanna River between 1890 and 1909. Annual reports of the U.S. Fish Commission, forerunner of the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS), indicated that in Cecil and Harford counties alone, shad catch averaged approximately 4.4 million pounds annually and herring catch ranged from 5 to 10 million pounds (12 to 25 million fish). *Alosa* fisheries in those two counties flanking the lower Susquehanna were engaged by 1,200 persons using 500 boats and fishing as much as 300,000 yards of gill net, 3,200 yards of seines, and 200 pound nets (Walburg and Nichols 1967). Certainly the shad and herring stocks of the upper Chesapeake Bay and Susquehanna River could not sustain this level of fishing effort, and, coupled with loss of spawning habitat in the river due to hydroelectric dam development, Susquehanna stocks crashed.

A low level (8 to 16') hydroelectric dam was constructed in 1904 at Conewago Falls near the village of York Haven (river mile 55). The first of the high dams, the Holtwood or McCalls Ferry project (55') at river mile 25, was completed in 1910. Although a powerhouse fish ladder and a west shore sluiceway were included at Holtwood, both were ineffective in passing American shad. After 1910, American shad fisheries in Pennsylvania disappeared and Maryland harvest in Cecil and Harford counties declined by two-thirds to an average 1.5 million pounds per year. Because of the lack of effective fish passage technology at high dams, it was determined that none would be required at the final two hydroelectric projects in the lower Susquehanna, the 100' high Conowingo Dam (river mile 10) completed in 1928 and the 75' high Safe Harbor Dam (river mile 32) completed in 1931. Except for the lowermost 10 miles of the Susquehanna River, what was once the largest and most productive American shad, river herring, and American eel producing river on the Atlantic Coast was closed to fish migrations and the production and benefit of the migratory fish stocks were lost. Dams affecting fish migration on the Susquehanna River and several of its major tributaries are shown in Figure 4.

In addition to eliminating migratory fish access to upstream spawning and nursery habitat, these dams also altered river habitat in a more permanent way by creating impoundments that inundated and eliminated riverine spawning and rearing habitat in the lower portion of the Susquehanna River. Conowingo, Holtwood, Safe Harbor and York Haven dams inundated 14, 8, 10, and 4 miles of habitat, respectively resulting in the loss of 36 miles of riverine habitat. The Conowingo Reservoir (Conowingo Pool) extends to the Holtwood tailrace and the Holtwood Reservoir (Lake Aldred) extends to the Safe Harbor tailrace, resulting in a 32 mile stretch of impounded water with little flowing water habitat. Above Lake Clarke (the Safe Harbor impoundment) there is 15 miles of free-flowing river to York Haven Dam.

Hydroelectric project operations also negatively impacted migratory fish habitat in the areas immediately downstream of the dams. The Susquehanna River hydroelectric projects (with the exception of York Haven) tend to generate power when it is most needed, during the daytime peak use period, and refrain from generation at night when water storage in the impoundment is replenished with incoming river flows. This results in unnatural flow conditions which can vary from flood to drought flow conditions within minutes during any given day. Few aquatic organisms are adapted to these drastic and abrupt fluctuations in flows, and the result is a highly perturbed aquatic ecosystem that is often not suitable for migratory fish spawning, nursery habitat, or fish passage.

From 1966 to 1970, an inflatable dam (the Fabri-Dam also known as the Adam T. Bower Memorial Dam) was built on the Susquehanna River at Sunbury, just below the confluence of the West and North Branches. Owned and operated by the Pennsylvania Department of Conservation and Natural Resources (PA DCNR) this dam is inflated from May to October to provide a pool for recreational boating. As a result, American shad and other anadromous fish, which would normally migrate through this area during May and June, cannot pass upstream beyond Sunbury. The dam construction was permitted in 1966 with a provision for installation of a fishway or fishways upon notice from the PFBC; however, no fishway has yet been built. In 2000, $5 million was authorized by Pennsylvania to design and construct a vertical slot fishway on the east bank at Sunbury. In 2005, final designs were developed for the fishway, and requests for construction proposal were issued. The bids for the fishway construction were received; however the low bid of $7.2 million exceeded the appropriated funds. In 2008, efforts were redirected at developing a less costly nature-like bypass fishway design to be installed at the west bank at a cost that would not exceed the available appropriated funds. To date, the preliminary design for this nature-like fishway is complete and final design, bidding and construction contract award are expected to be complete in 2011.

History of the Anadromous Fish Restoration Effort

Modern attempts to restore anadromous fish to the Susquehanna River began in the 1950s when, at the urging of Pennsylvania sportsmen and the Pennsylvania Fish Commission, the U.S. Congress appropriated funds specifically to study the potential to recover American shad fisheries in dammed rivers. Ensuing studies, many funded by the hydroelectric dam owners/operators on the lower Susquehanna River included: an assessment of the migratory response of American shad placed into riverine habitat upstream of hydroelectric impoundments (Walburg 1954, Whitney 1961), assessment of the suitability of the Susquehanna River for American shad reproduction and survival (Carlson 1968), and the assessment of the engineering feasibility of American shad passage at high dams (Bell and Holmes 1962).

Committees and Settlement Agreements

Anadromous fish restoration was a cooperative venture from the beginning. The Pennsylvania Fish Commission (now Pennsylvania Fish and Boat Commission or PFBC), Maryland Board of Natural Resources (now Maryland Department of Natural Resources or MDNR), New York State Department of Environmental Conservation (NYSDEC) and the USFWS developed an Administrative Committee for American shad studies on the Susquehanna River in February 1963 for the purpose of determining habitat suitability above dams to support American shad reproduction and survival. The $196,000 study was funded by the lower river hydroelectric dam owners/operators during 1963 to 1966. The study results determined that over 300 miles of the mainstem, most of the Juniata, and the lower West Branch were entirely suitable for American shad spawning and rearing (Carlson 1968).

The Administrative Committee reorganized and became the Susquehanna Shad Advisory Committee (SSAC) in 1969 (with policy and technical sub-committees) to initiate a process which would lead to stock rebuilding efforts, and ultimately, fish passage at all four lower Susquehanna River hydroelectric dams. The first five-year settlement agreement among the resource agencies and hydroelectric dam owners/operators was reached in 1970. The settlement agreement called for Philadelphia Electric Company (PECO, now Exelon Corporation) to build an experimental fish lift (trap) at the west side of Conowingo Dam, and the upstream Susquehanna River hydroelectric dam owners/operators which included Pennsylvania Power & Light Company (PPL), Safe Harbor Water Power Corporation (SHWPC), and York Haven Power Company (YHPC), to fund a program to stock up to 50 million American shad eggs annually upstream of the lower Susquehanna River hydroelectric dams.

In 1976, SSAC changed its name to the Susquehanna River Anadromous Fish Restoration Committee (SRAFRC) to better reflect its interest in restoring all anadromous fishes. At this time, the hydroelectric dam owner/operators were afforded two voting memberships on all subcommittees: one for PECO and one for the three upstream dam operators. The 1970 agreement was extended annually from 1976 to 1980. In 1976, direct egg stocking was terminated and using upstream dam operator funds, a hatchery dedicated to American shad production was built by PFBC at Van Dyke, on the Juniata River near Thompsontown, Pa.

In 1980, the Federal Energy Regulatory Commission (FERC) issued long-term federal operating licenses for the four lower Susquehanna River hydroelectric projects, but set aside for later, hearing of all questions related to American shad restoration, fish passage, and instream flow requirements. PPL and SHWPC agreed in April 1981 to fund SRAFRC-approved restoration activities between 1981 and 1985, up to a total of $750,000, in exchange for resource agency approval to add five large new turbine and electric generation units to the Safe Harbor Dam powerhouse. During this period, PECO continued to extend its agreement to operate the West Fish Lift at Conowingo Dam and to transport pre-spawn American shad to upstream spawning habitat.

In 1982, the USFWS established a permanent fishery biologist position in Harrisburg, Pennsylvania with the title of Susquehanna River Coordinator (Coordinator). The Coordinator was charged with chairing the SRAFRC Technical Committee, serving as secretary to the Policy Committee, providing oversight for program activities and contractor performance, developing annual work plans, managing data, and reporting results.

From 1981 to 1984, the FERC held hearings on the outstanding environmental impact issues associated with its 1980 licensing orders for the four hydroelectric projects. These hearings ultimately led to a new settlement agreement with the three upstream licensees (PP&L, SHWPC, and YHPC). The December 1984 settlement agreement provided $3.7 million for SRAFRC-approved restoration activities for a 10-year period through 1994. Upstream licensees also agreed to resolve fish passage issues at their facilities once PECO agreed to construct permanent fish passage at Conowingo Dam.

In response to a FERC order to build a costly second interim fish lift at Conowingo Dam, PECO reached agreement with resource agencies in August 1988 to instead build a permanent fish passage facility at the east end of the Conowingo Dam powerhouse. The initial facility was designed to pass 750,000 American shad and 5 million river herring, with the capability of doubling the capacity by adding a second hopper to the east fish lift. This settlement agreement also addressed instream flow issues in the vicinity of the dam, and included seasonally adjusted continuous flows at the project and dissolved oxygen (D.O.) augmentation to the turbine outflow, as needed, to meet the minimum Maryland D.O. discharge water quality requirement of five parts per million. Following construction of the East Fish Lift ($12 million total cost), the facility began operating for interim trap and transport measures in the spring of 1991. Annual costs associated with trap and transport of American shad and herring from Conowingo Dam were paid by the three upstream hydroelectric dam owners/operators as was required in their 1984 agreement with the resource agencies.

PECO's agreement to build permanent fish passage at Conowingo triggered negotiations with the three upstream hydroelectric project licensees which culminated in the June 1993 settlement agreement to build fish passage facilities at their dams. This agreement called for fish lifts to be operational at Holtwood and Safe Harbor dams by spring 1997, and at York Haven by 2000. In addition to trap and transfer of American shad and river herring from Conowingo, the licensees agreed to provide funding for egg collection and hatchery production activities until upstream fish passage facilities were operational at all dams. In 1997, resource agencies and YHPC owner General Public Utilities-Genco (GPU-Genco) reached a further agreement regarding fish passage at York Haven. This agreement amended the 1993 settlement to allow for construction of a fish ladder with flow augmentation gates and an open weir at the hydroelectric project’s East Channel Dam, rather than the powerhouse fish lift originally agreed to in the 1993 settlement agreement.

In March 1995, the name of the interagency restoration group changed again, dropping the word "Committee" in favor of "Cooperative" thus retaining the acronym SRAFRC. An organizational charter was developed and signed by six resource agencies, now including the NMFS and Susquehanna River Basin Commission (SRBC). The charter defined the roles of the Policy and Technical committees and the USFWS program coordinator.

As part of each settlement agreement with the hydroelectric dam owners/operators for fish passage installation (Conowingo in 1988; Holtwood and Safe Harbor in 1993; and York Haven in 1997), separate fish passage technical advisory committees were developed. These are comprised of resource agency members PFBC, MDNR, and USFWS (and SRBC for Conowingo), and the affected hydroelectric dam owners/operators. These committees meet annually, or as needed, to discuss and agree on operational matters needed to provide safe, timely, and effective upstream and downstream fish passage at the dams.

Restoration Activities

Harvest Restrictions

Throughout the 1950s and 1960s, Maryland reported that commercial American shad landings were fairly constant with an annual harvest of approximately 1.5 million pounds, much of it from the upper Chesapeake Bay. However, harvest declined precipitously through the 1970s to a statewide low of only 18,000 pounds in 1979. In response, MDNR closed its Chesapeake Bay fisheries for American and hickory shad in 1980 and 1981, respectively. Reasons for the sudden collapse of the stocks are unclear but may be related to: (1) the long-term effects of Tropical Storm Agnes in June 1972, which severely flooded the Susquehanna River, dumping 23 years worth of sediments into the upper Chesapeake Bay impacting habitat quality (U.S. Geological Survey (USGS) data); (2) overfishing and unrecorded ocean harvest by foreign fishing fleets prior to the Magnuson Act (1976); and (3) alterations in Conowingo Dam operations (more frequent peaking and the ability to peak at higher flows) following the installation of additional generating units in the mid-1960s. Virginia American shad landings also sharply declined through the 1980s resulting in a closure of their shad fisheries in 1994.

While in-river commercial fisheries subsided, coastal ocean fisheries for American shad increased significantly. From New Jersey to South Carolina, late winter, near-shore gill net fisheries indiscriminately intercepted American shad and some hickory shad prior to their spawning migrations. Atlantic Coast ocean harvest of American shad grew from insignificance to over 2 million pounds annually by the late 1980s and exceeded the total inland harvest. This particularly concerned fishery managers with costly restoration programs underway (such as the Susquehanna) and led the ASMFC to amend its coast-wide American shad plan mandating a closure of ocean fisheries in 2005 (ASMFC 1999).

In recent years, sportfishing for American and hickory shad has grown in importance in many Chesapeake Bay tributaries, particularly the lower Susquehanna River. Maryland, Pennsylvania, and New York allow angling for these species but maintain a zero creel limit (catch/release only) from the Susquehanna and its tributaries.

Current American eel regulations in Maryland (including the lower Susquehanna River) permit commercial and recreational fishing for eels with no restrictions for eels larger than six inches. For eels less than six inches, there is a limit of 25 per person, per day. Commercial harvest of American eels in Maryland peaked at 1.3 million pounds in 1945, and then declined to 110,000 pounds in 1962. Harvest peaked again in 1981 at more than 700,000 pounds, but declined to an average of 100,000 pounds from 1982 to 1988. Between 1989 and 2007, total Maryland eel landings averaged nearly 300,000 pounds annually and now comprise over 40 percent of total Atlantic coastal landings (MDNR landings database, personal communication, Keith Whiteford).

Reported annual eel harvest since 1992 from Susquehanna River and Susquehanna Flats have totaled less than 1,000 pounds. However, an annual average harvest of 20,000 pounds (1992-2007) has been reported for mainstem Chesapeake Bay -North of the Sassafras River. Some of these landings could be harvested from any of the 4 rivers above the Sassafras including the Susquehanna River. Therefore, estimates of landings from the Susquehanna River may range from 3,000-8,000 pounds.

Current regulations in the Pennsylvania portion of the Susquehanna River drainage do not permit commercial harvest of eels but do permit recreational harvest. Eels between 6 and 8 inches may be harvested for bait with a year-round season and a 50 fish creel limit. Eels harvested for food have a minimum size of 8 inches, a year-round season and a creel limit of 50 fish.

Current regulations in the New York portion of the Susquehanna River drainage allow for both commercial and recreational harvest of American eels. Year around eel harvest by recreational anglers is currently allowed subject to a 6-inch minimum size limit and a daily limit of 50. Commercial harvest is also permitted through special licenses issued at the discretion of the NYSDEC. These licenses provide for the use of both eel pots and eel weirs.

Culture and Stocking

Stocking of fertilized American shad eggs in hatching boxes was conducted from 1971 to 1977. Approximately 222 million American shad eggs were stocked in numerous mainstem and tributary sites in the lower and middle Susquehanna River Basins (Table 1). Initial egg collections were from the Susquehanna Flats, but after 1972, other sources from the East Coast and the West Coast, (i.e. Columbia River) were also used. After 1977, direct egg stocking was discontinued and all available eggs were utilized for hatchery culture.

Culture and stocking of hatchery-reared American shad began in 1976 with construction of the PFBC Van Dyke Hatchery. The emphasis was on stocking 18 to 20 day old fry (larvae), but a number of fingerlings were also raised and stocked. American shad hatcheries were commonplace around the turn of the 20th century, but all fish produced at that time were stocked within a few days of hatching as first-feeding fry. Improved methods for culture, feeding, and handling American shad fry were developed at the Van Dyke Hatchery and resulted in increased numbers of shad stocked into the Susquehanna River. By 1984, 12 million cultured American shad fry had been stocked in the Susquehanna River upstream of the four lower hydroelectric dams. From 1985 through 1992, approximately 31 million American shad fry reared at the Van Dyke Hatchery were also stocked in the lower Susquehanna River downstream of the Conowingo Dam. This was done to avoid downstream passage losses at upstream hydroelectric stations, and to support restoration efforts in the upper Chesapeake Bay. Maximum production at the Van Dyke Hatchery was achieved in 1989 when 22.3 million American shad fry were released. Table 2 presents all Van Dyke Hatchery American shad stockings in the river upstream of Conowingo Dam from 1976 to 2008 while Figure 5 indicates fry stocking locations.

PFBC discontinued American shad stocking downstream of Conowingo Dam after 1992 when MDNR's Manning Hatchery began rearing American shad fry. After 1996, MDNR discontinued stocking the lower Susquehanna River because American shad stocks appeared to be self-sustaining in the lower river. Subsequently, stocking was concentrated in other Chesapeake Bay tributaries, principally the Patuxent, Choptank, Patapsco, and Nanticoke rivers. In addition to American shad fry, MDNR also raised fingerling American shad which were released in the Susquehanna River at Havre de Grace, Maryland.

In 1994, staff at MDNR's Manning Hatchery began experimenting with tank spawning of American shad using methods similar to those developed by the Center of Marine Biotechnology (University of Maryland) for striped bass. Adult pre-spawn American shad were collected in the lifts at Conowingo Dam, transported to the Manning Hatchery, injected with hormones to accelerate the onset of spawning, and then were allowed to spawn “naturally” in tanks. In 1995, female American shad produced an average of 30,000 fertilized eggs, comparable to the production expected from traditional strip-spawning methods.

From 1998 to 2002, the USFWS Northeast Fishery Center at Lamar, Pennsylvania, worked with SRAFRC in an effort to develop tank spawning of American shad brood fish transported from Conowingo Dam to Lamar. Numerous combinations of hormones, hormone dosages, sex ratios, tank densities, and sedatives were tested but egg size was small compared to strip-spawned fish, and total viable egg and larval production remained low. Beginning in 2001, a tank spawning system was constructed at the Conowingo West Fish Lift and operated by Normandeau Associates under a SRAFRC contract. This avoided handling and delivery problems experienced at Lamar. While egg production and viability have not been as high as that experienced at Maryland's Manning Hatchery, the West Fish Lift site has been a steady source of eggs from the preferred stock of Susquehanna River fish.

Most American shad eggs for the Susquehanna River restoration program during the 1980s came from the Columbia River (Oregon), and the Pamunkey River (Virginia). Throughout the 1990s, the primary sources of American shad eggs for Van Dyke were the Hudson and Delaware rivers. The Potomac River was added as an egg source in 2006. Total Van Dyke production for the Susquehanna River from 1976-2009 was approximately 200 million American shad fry and fingerlings combined.

Trap and Transport of Pre-Spawn Adults

The longest running restoration activity on the Susquehanna River has been the operation of the fish lifts at Conowingo Dam. The West Fish Lift, a trapping device built and operated by PECO, has operated each spring since 1972. It was designed to capture pre-spawn adult American shad and river herring for transport by tank truck to upstream spawning areas. However, the number of American shad captured during the first ten years of operation (1972 to 1981) was too low to justify the expense of initiating an upstream transport program (Table 1, Figure 6). It was not until 1982 that enough American shad were captured to initiate a trap and transport trucking program from the West Fish Lift. From 1985 through 1990, American shad catches increased steadily from 1,500 to 16,000 fish. In 1991, the new Conowingo East Fish Lift became operational and both lifts were utilized to collect adults for upstream transport. For the 12-year period from 1985 to 1996, over 200,000 adult American shad, collected at Conowingo Dam, were stocked upstream of the four lower Susquehanna River hydroelectric dams (Table 3). In 1997, the East Fish Lift began releasing fish directly into Conowingo Pond. An elevator lifted and deposited all captured fish into an exit trough where the fish would then voluntarily swim past a viewing window. Trained operators would then identify and enumerate all fish passing the viewing window.

In addition to trucking fish from Conowingo, out-of-basin American shad were transplanted to North Branch Susquehanna River to increase the number of spawning fish upstream of the dams. From 1981 to 1987, SRAFRC transplanted nearly 26,000 pre-spawn adults from the Hudson River (New York) and Connecticut River (Massachusetts). These pre-spawn shad were taken from seining the Hudson River near Catskill, N.Y. and from the Holyoke Dam fish lift on the Connecticut River. Radio-telemetry studies (RMC Environmental Services 1986) indicated a tendency for these transported fish to "downrun" rapidly from the release site, and congregate in the York Haven Dam forebay. In addition, few juvenile American shad were collected in the North Branch, indicating unsuccessful spawning of the transplanted fish. Those factors, coupled with increasing numbers of adult American shad observed returning to Conowingo Dam during the mid-1980s, resulted in the decision to terminate the out-of-basin transplant program.

SRAFRC has also attempted trap and transplant of river herring. During 1990 to 2001, river herring were captured at the Conowingo West Fish Lift and transported upstream in an effort to produce naturally spawning runs imprinted to upstream areas. Some 8,864 alewife and 80,402 blueback herring were transported to sites in the Conestoga River, Little Conestoga River, Conodoguinet Creek, Muddy Creek and the Susquehanna River at the Tri-county Marina (Table 4). Since few juvenile river herring were collected during annual monitoring efforts conducted upstream of Conowingo Dam the adult river herring transport effort was deemed unsuccessful and subsequently terminated.

Juvenile American eels were intermittently collected below Conowingo Dam by the PFBC and transported upstream between 1936 and 1980 (Table 5). Approximately 17 million immature eels were transported, including both elvers and yellow phase eels. Perhaps an indication of the success of this transport program can be inferred from a 1966 internal document prepared by the New York State Conservation Department (now NYSDEC). The document addressed a request by an individual from New Berlin, New York who wanted a commercial license that would allow him to build and operate an eel weir on the Unadilla River between New Berlin and South New Berlin, a distance of nearly 400 miles from the mouth of the Susquehanna River. The document further noted that Department biologists believed that the American eel had disappeared from the New York portion of the Susquehanna drainage by about 1953. However, the fact that this individual wanted to expend the time and energy to construct a weir may well indicate that at least a moderate population of eels had become reestablished in the upper portion of the Susquehanna basin by 1966.

Fish Passage at Dams

Beginning in 1972, adult American shad collected in the Conowingo Dam West Fish Lift (West Fish Lift) were transported upstream by truck, released below the dam, or sacrificed for otolith analysis. The Conowingo East Fish Lift (East Fish Lift), operational since 1991, was utilized as a trap and transport facility until 1997. From 1997 to the present, the East Fish Lift has been operated for upstream passage directly into the Conowingo Pond. The current design capacity of the East Fish Lift is 750,000 American shad with expansion capabilities to 1.5 million with the addition of a second lift hopper to the existing structure.

During the 1990s, in hopes of optimizing American shad catches, attraction flow was increased at the East Fish Lift fishway entrance in an effort to deter non-target species (e.g., gizzard shad that migrate upstream at the same time as the American shad and river herring) from entering. The success of this effort has never been evaluated and no other alterations of attraction flow have occurred since 1999 (Ray Bleistine, personal communication, Normandeau Associates).

American shad catch at both Conowingo fish lifts increased dramatically between the mid 1990’s and 2001 (Table 6). However, since 2001 when the catch of American shad peaked at over 200,000, the numbers caught at Conowingo Dam have declined dramatically. Multiple factors, including hatchery production problems, high spring flows not conducive to fish passage or larval survival, cessation of the trap and transfer program, and observed coast-wide declines in American shad stock abundance (ASMFC 2007), are likely contributing causes for the declines in the number of American shad observed at Conowingo Dam.

Fish elevators, each with an ultimate design capacity to handle approximately 2 million American shad and costing a combined $38 million, were completed at Holtwood and Safe Harbor dams in time for the 1997 spring spawning run. These lifts have a design capacity for elevating and passing fish directly into the impoundment upstream of each dam, but are not equipped to trap fish for transport or use in hatchery operations.

In the spring of 2000, a $9 million vertical slot fishway, with a design capacity of 500,000 American shad began operation at York Haven Dam. This fishway, in combination with the three downstream facilities, opened a total of 122 river miles to upstream migration. With the opening of this fishway, diadromous fish had the potential to ascend the Susquehanna River as far upstream as the inflatable dam at Sunbury, Pennsylvania on the mainstem Susquehanna River when the rubber dam is inflated (when the dam is deflated fish may swim to New York waters), and to Warrior Ridge and Raystown dams on the Juniata River. Each fishway at the lower Susquehanna River hydroelectric dams is equipped with a viewing window which allows for the enumeration of the fish species that are passed.

American shad passage on the Susquehanna River has not met expectations. While Conowingo Dam fishway has passed large numbers of shad, its effectiveness has not been adequately assessed, and upstream fishways have had mixed results. Table 6 presents total numbers of shad lifted at each dam. Since the number of shad attempting to pass Conowingo Dam is unknown, a radio telemetry study is required to accurately calculate upstream passage efficiency at this facility. Calculation of upstream passage efficiencies at the other three hydroelectric facilities is based on the counts at each facility relative to the number passed at the adjacent downstream facility. American shad passage efficiencies for Holtwood, Safe Harbor, and York Haven have averaged 32%, 71%, and 11%, respectively, over the period from 1997 through 2009. Clearly, shad passage efficiency at Holtwood and York Haven dams is substantially limiting access to upstream spawning and nursery habitat for migratory fish. The key to increasing wild juvenile recruitment is directly related to passing sufficient numbers of pre-spawn anadromous adult fish into the quality spawning and nursery habitat located upstream of York Haven Dam. Consequently, overall passage efficiencies must be significantly improved to achieve the goal of successful restoration of American shad to the Susquehanna River.

Special Studies and Evaluation

Over the years, many special studies have been conducted by SRAFRC, its cooperators, and partners. Most were funded by the lower Susquehanna River hydroelectric dam operators under terms of settlement agreements. These efforts have included fish culture studies; holding pen and stress analysis studies to improve adult American shad survival and performance after trucking; hormone injection and blood chemistry studies to utilize Conowingo fish lift caught American shad for egg collection; radio telemetry studies to document adult American shad behavior after trucking; migration studies through reservoirs to assist in locating fishway entrances and exits; radio telemetry and hydroacoustic studies to monitor juvenile shad behavior and survival at dams; genetics studies to determine if hatchery-produced shad, originating from out-of-basin sources, have contributed to the existing population; and experimental American eel collections in the Conowingo tailrace.

Downstream Passage

Downstream passage of juvenile American shad past hydroelectric projects has long been an important concern for restoration planning. An accurate estimate of juvenile American shad survival through turbines was made possible by the development of the HI-Z TURB'N Tag (patent No. 4,970,988) by RMC Environmental Services (now Normandeau Associates). Using these balloon tags, RMC estimated juvenile American shad turbine passage survival to be 97 percent at Safe Harbor Dam and 93 percent at Conowingo Dam (RMC Environmental Services 1991, RMC Environmental Services 1994). These projects have large Kaplan and/or fixed blade turbines which operate at lower speeds and with greater water volumes than the older Francis-type turbines found at Holtwood and York Haven dams. Balloon tag studies at Holtwood and York Haven estimated juvenile American shad turbine passage survival at 67 to 80 percent (RMC Environmental Services 1992) and 77 to 93 percent (Normandeau Associates 2001), respectively. This results in a total cumulative juvenile turbine survival estimate ranging from 33 to 53 percent for fish passing through all hydroelectric stations.

Based on these studies, the lower Susquehanna River hydropower projects have agreed to modify their operations to attempt to improve juvenile downstream passage survival. Using selective turbine operation (using only turbines with good fish passage efficiency) coupled with controlled spills (providing an alternative, turbine-free passage route) during peak juvenile American shad migration periods (fall), the York Haven and Holtwood projects have developed protocols to achieve 90 percent downstream passage survival. However, utilization of these new protocols will still result in total lower Susquehanna River, maximum juvenile passage survival of only 66% for fish passing through all 4 hydroelectric projects.

Mortality of post-spawned adult American shad during downstream turbine passage was assessed at Safe Harbor Dam in June 1997 using HI-Z Turb'N Tags (Normandeau Associates 1998). In addition to controls (tagged fish released and recaptured downstream of the turbines), 100 test fish each were passed through turbine Unit No. 7 (Kaplan) and Unit No. 8 (mixed flow). The pooled 48-hour survival estimate was calculated to be 86 percent. It has been postulated that turbine passage survival may be similar at Conowingo Dam's large turbine units. Adult American shad passage survival has not been experimentally measured at either the York Haven Dam or Holtwood Dam, but both are assumed to provide low downstream survival due to the speed of the turbine runner and the close spacing of the vanes of their Francis turbines. Since outmigrating, post-spawn American shad are surface oriented and routinely move during daytime hours only, it has been postulated that some spent adult American shad may be successfully passed downstream of dams during routine or controlled spilling events (e.g., opened trash or spill gates) at some of the hydroelectric projects. As the FERC licenses expire at Conowingo, Holtwood, and York Haven in 2014, the upcoming relicensing process is anticipated to produce refined estimates of juvenile and adult downstream passage survival along with verifiable performance measure requirements.

Adult American Shad Stock Assessment

Monitoring of the adult American shad population in the Upper Chesapeake Bay and Conowingo tailrace has been conducted since 1984 by the MDNR. Each season, approximately 400 to 800 American shad are collected by hook-and-line from the Conowingo Dam tailrace and tagged. Recaptures are documented in the Conowingo Dam fish lifts and trends in population abundance are estimated using modified Petersen tag-recapture methods (MDNR 1985-2009), or alternative models. As might be expected, the American shad population trend in the upper Chesapeake Bay (Table 7) mimics the Conowingo trap and lift catches. Annual estimates have generally increased from a few thousand to almost one million adults in the Conowingo Dam tailrace.

Hatchery Evaluation

Evaluating the contribution of hatchery-reared American shad fry to future adult spawning runs is an important component for tracking restoration success and future restoration strategies. This is especially important as adult American shad abundance increases and the attainment of the goal of a self-sustaining fishery is assessed. Marking of cultured American shad fry is necessary to distinguish them from naturally produced fry. Traditional tags were not suitable for use, because hatchery-reared American shad, stocked as fry, were too small and fragile.

In 1984, small numbers of American shad fry were experimentally marked at the Van Dyke Hatchery by immersion in oxytetracycline (OTC) antibiotics. The OTC chelates to calcium and is incorporated into daily bone growth. Subsequently, the OTC was successfully detected as a fluorescent mark in the fish’s otoliths (ear bones) through ultraviolet light microscopy (Lorson and Mudrak 1987). Since 1985, all American shad produced at the Van Dyke Hatchery have been marked with oxytetracycline.

Refinement of this marking technique (Hendricks et al. 1991) has permitted the development of multiple OTC marks on the otoliths which allowed for differentiation of marked fry batches according to site stocked, life stage stocked, egg source, and other variables. Subsequent research resulted in methods to differentiate hatchery from wild American shad using otolith microstructure without reference to chemical marks (Hendricks et al. 1994). This technology allowed identification of American shad reared in the hatchery prior to 1987 when tetracycline marking became 100% effective. Since development of these techniques, otolith evaluation has become one of the most important tools for tracking the progress of the Susquehanna River American shad restoration effort. OTC otolith marking is now mandated by ASMFC and is used in all American shad culture programs on the Atlantic Coast.

Biomonitoring

Collection of juvenile American shad for otolith analysis is accomplished through an ongoing biomonitoring program. Haul seines, lift nets, and electrofishing gear are used periodically at established stations to monitor abundance, growth, outmigration timing, hatchery contribution, and survival of cultured American shad. Analysis of otoliths from juvenile American shad demonstrated that the relative abundance of wild versus hatchery fish has varied considerably over the years. From 1985 to 1990, the majority of the outmigrating juveniles collected upstream of the lower Susquehanna River hydroelectric stations were of hatchery origin. However, between 1991 and 1994, the contribution of wild, out-migrating juvenile American shad increased to about 50 percent of the sample population. Contribution of wild, outmigrating fish decreased to 10 percent in 1995, but increased again in 1996 to 42 percent. After 1996, however hatchery fish dominated the sample collections in most years. These data suggest that trucking of adult shad from Conowingo Dam to optimal upstream spawning habitat resulted in increased production of wild juveniles.

Since the OTC mark is retained throughout the marked fish's life, similar otolith analysis has been performed on adult American shad returning to the fish lifts at Conowingo Dam (Figure 6 and Table 7). Hatchery contribution to the population of returning adults averaged approximately 77 percent from 1989 to 1995, decreased to approximately 50 percent in the late 1990s, and has averaged 62 percent since 2001. Otoliths were also examined from pound net collections in the Susquehanna Flats during 1993 to 1998. Unlike the stock mixture at Conowingo Dam, the Susquehanna Flats stock includes greater representation of the upper Chesapeake Bay spawning stock, and was dominated by wild (unmarked) fish (67 percent).

Hendricks (2008) partitioned historical lift catches into their component year classes, and adjusted for hatchery contribution in order to determine the total recruitment of hatchery fish to Conowingo Dam by each year class. Comparison to historical hatchery stocking data revealed that over the thirteen year period between 1986 and 2001, one in 306 stocked hatchery fry returned to the Conowingo Lifts as a mature adult. This corresponds to an average survival to adult return of 0.33 percent for hatchery-reared American shad fry stocked into the Susquehanna River.

Genetics Studies

Julian and Bartron (2008) analyzed wild origin adult American shad collected at the Conowingo Dam West Fish Lift to determine origin of parental stocks in the Susquehanna River. They collected tissue samples from American shad from the Susquehanna, Delaware and Hudson stocks, developed a suite of 15 microsatellite markers and utilized these markers to determine origin of wild shad collected at Conowingo Dam. A high degree of genetic diversity was observed in all three stocks, and consequently, assignment of adult shad back to river of collection was poor. However, the authors concluded that the wild population in the Susquehanna River was a mixture of multiple genetic sources, confirming that hatchery-reared fry have contributed to the reproducing stock of American shad in the Susquehanna River.

Summary of Restoration Activities

Over the 38-year period from 1971 to 2009, it is estimated that private hydroelectric company funding for Susquehanna River restoration activities, special studies, and fish passage construction totaled $75 to $85 million. The program to date has shown dramatic results including development and field application of numerous innovative techniques such as massmarking of cultured larvae, and turbine survival measurements using balloon tags. Improvements were also made to existing technologies such as trap and transport of pre-spawn American shad, underwater strobe lights to modify fish behavior, stress reduction techniques for fish handling, and tank spawning. Program partners consider the Susquehanna River restoration effort to be the largest of its type ever undertaken for American shad.

Despite significant efforts, past program goals for the SRAFRC have not been met. Few fish are reaching the optimum spawning habitat located upstream of the hydroelectric dams and, as a result, production of wild, up-river juvenile shad has been poor in most years. Within the Susquehanna River system, stocks of diadromous species are under significant threats including predation, turbine mortality, poor water quality, habitat degradation, and poor lift efficiencies. Threats outside the system include predation and commercial fishery bycatch. These threats must be addressed on a coast-wide basis. Successful restoration of diadromous fish in the Susquehanna River is dependent on resolving all of these issues.

Tributary Habitat Restoration

Migratory fish restoration in the Susquehanna River Basin also includes reopening smaller tributary waters blocked by dams, most of which were built more than 50 to 100 years ago. These dams were originally built to supply water to historic mills and other industries which no longer exist. As part of the U. S. Environmental Protection Agency's (USEPA's) Chesapeake Bay Program (CBP) a Fish Passage Work Group was established. Under the direction of the work group's PFBC and MDNR fish passage coordinators, several dozen blockages in the Susquehanna Watershed have already been removed or retro-fitted with fishways. Typical removals cost $25,000 to $50,000 while fishways average between $100,000 and $300,000. Federal funds from the CBP are matched 1:1 with non-federal dollars and/or in-kind services from local and state governments and Non-Governmental Organizations (NGOs). These projects typically include habitat restoration components, and in some limited cases, pre- and post-removal monitoring studies.

In 1993, the PFBC used CBP funds through NMFS to contract with the USGS Pennsylvania Cooperative Fish and Wildlife Research Unit to inventory and assess blockages on Susquehanna River tributaries downstream from the confluence of the Juniata River. The three-year effort identified 198 blockages on 15 tributaries. Several of these stream sections, as well as portions of the Juniata River and West Branch Susquehanna River, were evaluated for potential American shad and river herring reproduction by the USGS Northern Appalachian Research Lab (Wellsboro, PA) through a separate study funded by USGS. Over a two-year period, researchers examined habitat quality in transects located at three-mile intervals for approximately 540 river miles on six tributaries. These included the Juniata River, Conodoguinet Creek, West Conewago Creek, Conestoga River, Swatara Creek, and West Branch Susquehanna River (Kocovsky et al. 2008).

As part of these studies, USGS also measured zooplankton type and abundance, substrate type, water temperature, salinity, cover, and flow (Stier and Crance 1985). Habitat Suitability Index (HSI) values ranged from 0 (unsuitable) to 1 (optimal habitat) for measurable variables at various life stages of American shad, blueback herring, and alewives. Preliminary results indicate that for summed life-stage components for American shad (but particularly larvae); highest HSI values (> 0.5) were measured in Swatara, Conestoga, and Conodoguinet creeks, the upper Juniata River above Lewistown, and the West Branch Susquehanna River below Lock Haven. For blueback herring, only the Juniata River and Conodoguinet Creek rated above 0.5. For alewives the Conestoga River and Swatara Creek rated highest. In terms of boosting habitat use values for river herring, dam removals should be afforded highest priority in the West Conewago and Swatara creeks for blueback herring; and in the West Conewago and Conodoguinet creeks for alewives.

In order to prioritize stream sections for restoration activities, tributaries have been further classified by PFBC into three categories: (1) highly suitable for restoration; (2) moderately suitable; and (3) unsuitable. Most tributaries and river sections that enter the Susquehanna River downstream of the Juniata were categorized by PFBC Area Fisheries Managers based upon their subjective knowledge of those areas. Tributary evaluations typically considered resident fish and invertebrate abundance and diversity, presence/absence of pollution tolerant species, spring-summer flow, and water quality characteristics such as temperature, D.O., and clarity. Results of the PFBC classifications for Pennsylvania waters are listed in Table 8. Small river tributaries upstream from the confluence of the Juniata River that may merit future evaluation include Penns Creek, Loyalsock Creek, Pine Creek, Bald Eagle Creek, Towanda Creek, and Tunkhannock Creek.

The Chesapeake Bay Connection

The CBP is a unique regional partnership that has been directing and conducting water quality and ecosystem restoration efforts in the Chesapeake Bay watershed since the signing of the historic 1983 Chesapeake Bay Agreement. Program partners include the states of Maryland, Pennsylvania, and Virginia; the District of Columbia; the Chesapeake Bay Commission (a tri-state legislative body); the USEPA (representing the federal government); the SRBC; the Interstate Commission on the Potomac River Basin and various local governments and NGOs participating in advisory groups.

Since its inception, one of the CBP’s highest priorities has been the protection and restoration of the Bay’s living resources including fish, oysters, crabs, and other aquatic life and wildlife. This is accomplished through numerous programs which address habitat restoration; nutrient, toxics, and sediment reductions; and research and education. Further agreements, amendments, and directives since the CBP’s inception have guided the program through the 1990s, and in 1994, the Executive Council declared the tributary strategies, which includes migratory fish restoration, as the top priority for the program.

The 2000 Chesapeake Bay Agreement recommitted the Living Resources Subcommittee to cooperatively achieve the restoration and protection of the Chesapeake Bay’s living resources through the development of policy plans that recognized the dynamic nature and complexities of the Bay. The 2000 Agreement broadened the management perspective from single-system to ecosystem functions and recognized the need for a balanced and integrated approach.

In July 1989, the CBP Executive Council adopted a Chesapeake Bay Alosid Management Plan. The plan has been periodically reviewed with subsequent updates to the implementation table. The goal of that plan is: "*To rebuild the American shad, hickory shad, and river herring stocks within the Chesapeake Bay, protect the stocks and their habitats, and provide for the long-term ecological, economic, and social benefits from these resources*."

Objectives to achieve this Bay-wide goal include:

1. Follow guidelines recommended by the ASMFC in its coast- wide fishery management plan.

2. Restore *Alosa* stocks to Bay tributaries through stocking efforts, habitat enhancement, and controls on fishing mortality.

3. Determine criteria for a restored stock and define tributary-specific restoration targets.

4. Improve the quality and quantity of data necessary for stock assessments.

5. Work cooperatively with habitat restoration and fish passage projects to protect and restore *Alosa* habitats.

6. Once restored, maintain spawning stock sizes which minimize the possibility of low reproductive success.

7. Define a process for making decisions on when to open a limited fishery and/or fisheries in the Chesapeake Bay.

Alosines have been slated for the development of an ecosystem-based fishery management plan (EBFMP) that will begin in 2010.

On May 12, 2009, President Barack Obama signed an Executive Order that recognized the Chesapeake Bay as a national treasure and called on the federal government to lead a renewed effort to restore and protect the nation's largest estuary and its watershed. The Chesapeake Bay Protection and Restoration Executive Order established a Federal Leadership Committee that will oversee the development and coordination of reporting, data management and other activities by agencies involved in Bay restoration. The committee will be chaired by the Administrator of the USEPA and include senior representatives from the departments of Agriculture, Commerce, Defense, Homeland Security, Interior, Transportation and others. This effort establishes a Federal commitment to the Chesapeake Bay and a renewed emphasis on restoring the living resources of the bay.

The migratory fish restoration effort on the Susquehanna River is a recognized component of the CBP. All SRAFRC partner agencies are actively involved in various subcommittee and workgroup activities. The CBP has invested millions of federal, state, and private sector dollars on habitat improvement initiatives in the Susquehanna River Basin related to achieving CBP goals. These activities also directly affect migratory fish restoration (e.g., tributary fish passage and dam removals, nutrient and sediment reduction strategies, forested buffers and wetland enhancements, community watershed initiatives).

The ***Migratory Fish Management and Restoration Plan for the Susquehanna River Basin*** incorporates many habitat-related elements of the CBP tributary strategies. It also recognizes the desirability and necessity of including objectives of the Chesapeake Bay Alosid Management Plan within the framework of the Susquehanna Plan. This ecosystem-wide approach will ensure that fishery management agencies from all Chesapeake jurisdictions adequately address stock rebuilding and habitat improvement concerns voiced by the CBP and SRAFRC partners.

Current Status of Susquehanna River Migratory Fish Stocks

American shad

Juvenile abundance

Abundance of juvenile American shad in the Susquehanna River is reflected by a number of indices: seine surveys in the upper Chesapeake Bay and at Columbia and a lift-net survey in the Holtwood forebay.

Juvenile American shad abundance in the upper Chesapeake Bay has been estimated since 1959 by MDNR from the Estuarine Juvenile Finfish Survey. Except during one flood year, no hatchery-origin fish were detected in this survey (Figure 8). Thus, this index reflects reproductive success in the Susquehanna River below Conowingo Dam and in the Susquehanna Flats.

Juvenile American shad indices for stocks above Conowingo Dam include a seine survey at Marietta and a lift-net survey in the Holtwood Dam forebay (Figure 9). Lift-net CPUE peaked in 1985 and has declined since. Seine CPUE peaked during the mid-1990s and has declined since. Wild juvenile American shad were most abundant from 1992 to 2001. During this time period, more than 10,000 adults were transported or passed above Safe Harbor Dam annually and their spawning success may account for observed peaks in relative wild juvenile American shad abundance.

Push-netting was conducted from 1997 to 2003 in Conowingo Pool to assess natural reproduction of Alosines passed above dams. In 6,224 minutes (104 hours) of push-netting, only 12 juvenile American shad were collected, suggesting that there was little natural reproduction below Holtwood Dam (Carney 1998, Carney 1999, Carney 2000, Carney 2001, Carney 2002, Carney and Hendricks 2003, Hendricks and Carney 2004). A total of two alewife and 136 blueback herring (134 in 2001) were also collected, suggesting that these species did not reproduce below Holtwood, except, perhaps for blueback herring in 2001.

Adult abundance

Relative abundance of adult American shad in the lower Susquehanna River is measured by six independent surveys. All indices showed similar trends, an increase through the late-1990s followed by a steep decline. Adult indices include Conowingo Dam fish lift passage counts and catch per unit effort (CPUE), commercial pound net CPUE from the Susquehanna Flats, CPUE from MDNR tagging in the Conowingo tailrace, a population index generated from tag recaptures, and a creel survey index.

Two of these indices utilize fish lift catches: the annual total catch of American shad from both lifts at Conowingo Dam since 1972 (Figure 6); and the geometric mean (GM) CPUE (Figure 10, Sadzinski and Jarzynski 2009).

Three of these indices utilize tagged fish to estimate abundance of adult American shad. MDNR recorded American shad caught in pound nets in the Susquehanna Flats from 1988 to 2001 (Sadzinski et al. 2002). The geometric mean CPUE of American shad caught per-pound-net-day was calculated in the upper bay (Figure 11). Beginning in 1984, MDNR tagged American shad caught by angling in the tailrace and generated a geometric mean CPUE from this catch (Figure 12, Sadzinski and Jarzynski 2009). In addition, a modified Petersen population estimate was originally used to estimate total Conowingo Dam tailrace abundance (Figure 13). However, because of poor recapture data for some years, a surplus production model based on this index and the total catch of American shad at Conowingo Dam has been used to calculate a more reliable population estimate (Sadzinski and Jarzynski 2009). In general, this estimate is lower than the Petersen estimate.

The final index of adult abundance is an angler survey in the Conowingo tailrace. CPUE from roving-intercept (since 2001) and logbook (since 1999) surveys have also confirmed sharp decreases in American shad stock abundance, although the number of anglers sampled during these surveys was often small (Tables 9 and 10, Sadzinski and Jarzynski 2009).

Recaptures of American shad at Conowingo Dam represent the only index of catchability (efficiency) for that site but likely produce a minimum recapture rate due to handling stress and tag loss. Table 11 indicates the number of recaptures at Conowingo Dam (both lifts) from 1984 to 2009. The average percent of recaptures from 1984 to 2009 is 22.3 percent but is highly variable and apparently is not related to stock size because in 2008, only 6.2 percent of the tagged fish were recaptured at Conowingo Dam, the lowest for the time series. Variation in the recapture rate is likely a combination of flow conditions, age structure (younger fish are generally captured at the dam), water temperature and weather. In addition, American shad of both hatchery and wild origin produced downstream of Conowingo Dam may home more to the lower river and may be less susceptible to capture at the Conowingo Dam fish lifts. Thus, recapture rates can also be affected by shifts in the percentage of adult American shad originating from stocking or wild reproduction upstream of Conowingo Dam.

Stock decline

Suspected causes for the recent decline in stocks of adult American shad in the Susquehanna River include decreased hatchery production since 2000, predation, poor fish passage effectiveness, turbine mortality, poor environmental conditions in some years (e.g., high flows), and bycatch in offshore commercial fisheries. Similar declines have been observed coastwide and ocean harvest may well prove to be the most important factor driving the decline (ASMFC

2007).

Bycatch mortality

Cieri et al. (2008) and Kritzer and Black (2007) have noted significant catches of river herring in select ocean trawl fisheries that are targeting other ocean fish species. In addition, immature American shad are difficult to distinguish from river herring, immature American shad may also comprise a significant portion of this reported herring bycatch in the ocean trawl fisheries. The mid-water ocean trawl fishery has increased significantly since the late 1990s and may be catching significant numbers of non-target anadromous species. These ocean losses are likely contributing to the American shad and river herring reductions observed during their spawning migrations. American shad can be a predominant species caught in ocean trawls (Matt Cieri personal communication, Maine Department of Marine Resources) and ocean bycatch estimates are presently being calculated. The directed commercial American shad ocean fishery was closed in 2005 in an effort to protect critically low stocks. However, a significant increase in recruitment resulting from this closure has not occurred as evidenced by the Susquehanna River stock which has continued to decline to alarming levels. Significant decreases in American shad abundance have also been noted for many other major river systems on the east coast (ASMFC 2007).

Predation

Predation models for adult American shad in the Susquehanna River have shown that the biomass of striped bass in the upper Chesapeake Bay is insufficient to significantly impact the adult stock, especially for the short time period of spatial overlap during the American shad spawning run (Sadzinski MDNR personal communication).

Predation on juvenile American shad by striped bass could be significant because both species share similar habitat in the Chesapeake Bay during the summer when striped bass stocks are at very high levels. This may account for the high percentage of adult hatchery-origin fish caught at Conowingo Dam in most years (Figure 6). As juveniles, hatchery-reared shad are less susceptible to striped bass predation in the Bay because their peak outmigration is in November, when water temperatures cool and striped bass migrate to deeper water. In contrast, wild juvenile shad produced in the river below Conowingo dam are available to striped bass throughout their entire early life phase.

Fish passage efficacy

Fish passage numbers at Susquehanna River hydroelectric dams are shown in Table 6 and Figure 7. American shad passage efficiencies for Holtwood, Safe Harbor, and York Haven have averaged 32%, 71%, and 10%, respectively, over the period from 1997 through 2009. These efficiencies were calculated by dividing passage at the dam in question by passage at the next downstream dam. This calculation does not account for drop-off between dams. A better method of calculating passage efficiency would be to compare the number of shad passed to the number of shad present in the tailrace immediately downstream of the dam, however, the number of shad in tailrace waters is unknown. Despite this, SRAFRC partners believe that shad passage efficiency is poor at Holtwood and York Haven dams, and is substantially limiting access to upstream spawning and nursery habitat for migratory fish. Studies are ongoing in 2010 (and perhaps 2011) at both Conowingo and York Haven Dams as part of federal relicensing actions to better estimate fish passage efficiency.

Alterations to hydroelectric project operations and fish lift attraction flows have been made in an attempt to improve passage of anadromous fish by excluding gizzard shad. This has not excluded the capture of over fifty species of fish in some years (Table 12) and may not be effective in improving anadromous fish passage. Saturation of the lifts at Conowingo Dam by gizzard shad appears to be occurring (R. Sadzinski, MDNR personal communication). Annual gizzard shad passage at the Conowingo East Fish Lift has ranged from 400,000 to 2.5 million between 1985 and 2009.

<u>Conclusion</u>

In conclusion, as a result of cooperative anadromous fish restoration efforts from 1976 to 2009, significant advances were made in techniques for shad culture and tagging, and for the handling and transport of both adult and juvenile American shad. American shad abundance increased exponentially below Conowingo Dam culminating in the catch of over 200,000 adult American shad in the Conowingo lifts in 2001. After 2001, this trend reversed and stocks are now struggling to compensate for losses.

Because of poor fishway efficiencies and poor spawning habitat in the accessible river reach downstream of Safe Harbor Dam, lifting American shad above Conowingo Dam has demonstrated few measurable results in terms of juvenile recruitment and adult spawning run fish. There has been little detectable spawning between Conowingo and Safe Harbor dams and American shad passed at Conowingo but not passing Holtwood or Safe Harbor dams do not contribute significantly to juvenile production. The recent decline in American shad abundance in the Susquehanna River may be attributed to turbine mortality of adults and juveniles, poor fish passage effectiveness, predation of adults and young-of-year, decreased hatchery contribution, poor environmental conditions during spawning, and mortality in commercial fisheries (both in the ocean and the Chesapeake Bay).

River herring (Alewife and blueback herring)

River herring catches at the Conowingo Dam fish lifts have varied dramatically since the West Fish Lift began operating in 1972, ranging from zero to more than 300,000 (Tables 3 and 4). Since 2002, catches have been consistently low. This is concurrent with a coastwide decline in river herring populations (ASMFC 2009). In response, ASMFC adopted Amendment 2 to the Interstate Fishery Management Plan for Shad and River Herring to eliminate directed harvest in those fisheries that could not demonstrate sustainability. The states of North Carolina, Massachusetts, Rhode Island and Connecticut have already put a moratorium on river herring harvest.

There has been little fishery dependent or independent river herring data collected either from the lower Susquehanna River or Susquehanna Flats. Both species appear to be excluded from capture by the two fish lifts in some years even though angler catches and numbers observed in the tailrace are substantial (R. Sadzinski, MDDNR personal communication). Consequently the status of alewife and blueback herring below Conowingo Dam is unknown.

Hickory Shad

Hickory shad commercial and recreational fisheries were closed in 1981 out of concern for stock abundance and misidentification with American shad. In the Maryland portion of the Susquehanna River, hickory shad were likely caught as bycatch but because they run earlier than the other anadromous species, their exploitation was likely less than targeted species. Hickory shad stocks have increased significantly providing an exceptional recreational catch-and-release fishery in the lower Susquehanna River region.

Hickory shad are not caught in the fish lifts at Conowingo Dam in proportion to their abundance because of their apparent aversion to existing fishways. The best indices for hickory shad are angler-based- roving creel survey and volunteer logbooks. In addition, characterization data are collected from MDNR's aquaculture program in the Susquehanna River and Deer Creek. These data, collected since 1997, show steady angler catches of hickory shad, at times exceeding 30 fish landed per hour in the lower Susquehanna River and Octoraro and Deer creeks. Age and length data from MDNR surveys show hickory shad stocks have a robust age structure with a high percentage of repeat spawning and varied lengths.

Gizzard shad

In the Chesapeake Bay, commercial watermen catch large numbers of gizzard shad in spring using pound and fyke nets. Figure 2 shows the commercial landings of gizzard shad, but it should be noted that market conditions highly influence landings (i.e., when price is low, gizzard shad are often immediately discarded at the fishing site with no records kept), especially after mid-April when the market is saturated with this species.

Gizzard shad have increased in abundance in the Chesapeake Bay area since the 1970s, and their abundance may be correlated to decreased water quality. Increased adult gizzard shad abundance may also be linked to increased reproductive success resulting from fish passage into ideal habitat upstream of the lower Susquehanna River dams. Another factor could be a recent trend of warmer winters resulting in reduced winter kill. Although gizzard shad numbers have increased, this increase is not reflected in annual commercial landings because of variable market demands.

In the Susquehanna River, it is speculated that gizzard shad may be excluding other anadromous fish species from entering the fish lifts due to overcrowding. Catches of gizzard shad at the Conowingo Dam West Fish Lift (Figure 3) averaged 200,000 from 1972 to 1980 and increased to an average of 1.4 million from 1981 to 1990. From 1997 (the year the East Fish Lift was added) to 2009, the lifts captured almost 850,000 gizzard shad each spring. These high catches occurred despite operational changes that increased flows at the fish lift entrances in hopes of excluding gizzard shad and allowing the larger, stronger-swimming American shad to enter and pass. However, restricting gizzard shad access to the fish lift may be leading to large numbers of gizzard shad clogging the area immediately in front of the entrance. Visual observations suggest that the lifts are saturated with gizzard shad which congregate in and around the lifts (R. Sadzinski MDNR Personal Communication). Existing fish passage capacity for the Conowingo Dam East Fish Lift (750,000 American shad) may have been reached due to the abundance of gizzard shad which are similar in shape and size to American shad. Additional management techniques such as installation of a second lift bucket or increasing lift frequency may be required to increase passage capacity of the East Fish Lift.

Atlantic sturgeon

Atlantic sturgeon is listed as endangered by the Commonwealth of Pennsylvania. Maryland does not list it as endangered or threatened but did close the fishery in 1996. However, adult sturgeon observations are occasionally reported. Commercial fishermen and research biologists reported observing large sturgeon near the mouth of the Susquehanna River from 1978 to 1987 (United States Fish and Wildlife Service 1998). According to the MDNR Fisheries Service, in 2007, a large female sturgeon was captured by a waterman in Maryland waters for the first time since 1972 (Richardson 2008).

The MDNR Fisheries Service along with the USFWS and others initiated an Atlantic sturgeon restoration and stocking program in 1996 (3,275 stocked in Nanticoke River). From 1996 through 2007; 2,093 subadult (less than 5 feet in length) sturgeon have been captured and reported as part of a waterman bycatch reporting reward program. Approximately 73 percent of those juveniles were of wild origin, providing evidence that reproduction may be occurring somewhere in or near the Chesapeake Bay. Captures of wild and stocked juveniles occur primarily in the middle Chesapeake Bay and to date none have been recorded in the Susquehanna River. Efforts are underway to culture and stock Atlantic sturgeon juveniles in the Potomac River; however, no stockings have been made in the Susquehanna River.

Opportunities for restoration of this species to the Susquehanna River would be dependent on obtaining sufficient numbers of juveniles for imprint stocking or if numbers of adults or juveniles increase to levels where fish begin to seek unoccupied spawning and foraging habitat areas and relocate to the lower Susquehanna River.

Shortnose sturgeon

The shortnose sturgeon is listed as endangered under the Federal Endangered Species Act of 1973 and is currently listed as state endangered by Pennsylvania and Maryland. Shortnose sturgeon was documented in the Susquehanna River in the 1980s and near the mouth of the river in 1997 (National Marine Fisheries Service 1998). The cooperative Atlantic sturgeon tagging program in the Chesapeake Bay also has reports of shortnose sturgeon in their database. The data demonstrate that the upper Chesapeake Bay appears to be suitable habitat for this species. However, since most fish reported have been subadults, it is unlikely that any reproduction is occurring at this time. It has been postulated that occurrences of shortnose sturgeon in the upper Chesapeake Bay are due to individuals from the Delaware River stock entering the Bay through the Chesapeake–Delaware Canal. Currently, there is no shortnose sturgeon restoration effort underway in the Susquehanna River or Chesapeake Bay.

Opportunities for restoration of this species within the flowing sections of the Susquehanna River are limited by very low numbers of individuals and perhaps the inability of the current fish passage technology to effectively attract and move this species upstream. A review of the Conowingo East and West Fish Lift records reveals that from 1972 through 2009 no shortnose sturgeon were recorded in the lifts. Although shortnose sturgeon numbers are also low in the

Delaware River, they are occasionally caught by anglers in the flowing water sections of the river (A. Shiels, PFBC, personal communication). It is possible to pass shortnose sturgeon through certain fish lifts. At the Holyoke Dam on the Connecticut River from 2001 through 2008, a total of 13 shortnose sturgeon were recorded passing through the fish lift (United States Fish and Wildlife Service 2009).

American eel

American eel catches at the Conowingo Dam Fish Lifts have dropped dramatically from over 90,000 in 1974 to less than 1,000 since 1993. This trend appears to be coastwide. Over-harvest and dam construction are serious threats (ASMFC 2000). Eels are harvested as glass eels, elvers, yellow eels and silver eels to support regional and European food markets, domestic trotline bait, and as small bait eels for domestic sport fisheries. Glass eels and elvers are harvested for culture to marketable size in Asia and have been sold for up to $600 per pound on the international market. Factors that contribute to the impacts of over-harvest include: American eels mature slowly, requiring 7 to 30+ years to attain sexual maturity; glass eels aggregate seasonally to migrate; yellow eel harvest is cumulative over multiple years, on the same year class; and all eel fishing mortality is pre-spawning mortality. ASMFC (2000) identified lack of long term data as a hindrance to management of the species. There are few long-term data sets from fish ladders, impingement sampling, research collections, and monitoring programs. Where available, most of the data are of short duration and data collections were not standardized between management agencies. In addition, changes in year-class strength are not easily recognized because most samples include eels of similar sizes but from an unknown number of year classes.

American eels were proposed for listing as an endangered species in 2004 but, after evaluation, were not listed (http://www.fws.gov/news/NewsReleases/showNews.cfm?newsId=73C49E66-CA1E-2EC5-22EBD499912EC3E3 accessed August 31, 2009).

Striped bass

Striped bass are the most popular sportfish in the Chesapeake Bay. Overharvest of striped bass during the late 1970s and early 1980s led to the closure of the fishery from 1985 to 1989. In 1990, the commercial and recreational fisheries were reopened with limited harvest. Permitted harvest was incrementally increased through the late 1990’s and remains limited. Striped bass management on the East Coast is under the jurisdiction of ASMFC. Commercial landings data need to be interpreted in light of strict annual quotas.

ASMFC’s 2006 coastwide striped bass assessment indicated that stock size is 10 percent higher than the average stock size for the previous five years. Female spawning stock biomass (SSB) is estimated at 55 million pounds and is well above the SSB target and threshold levels of 38.6 and 30.9 million pounds, respectively. During the last five years, fishery-independent sampling by MDNR using gill nets in the upper Chesapeake Bay has shown very high abundance levels relative for the time series (Figure 14). In general, striped bass populations are presently at very high levels in the Chesapeake Bay and tributaries.

Maryland accounts for approximately one-half of the total commercial striped bass harvest on the east coast (Figure 15). As an overharvest precaution, Maryland utilizes a quota-based harvest management system coordinated by ASMFC. There are significant seasonal and gear restrictions and quotas by gear type. In the last five years, commercial harvest has averaged approximately 2 million pounds (Figure 15). It should be noted that recreational discard mortality in Maryland during the last ten years generally exceeds 1 million fish annually, as indicated by the 2008 estimated mortality (Table 13, from Durell et al. 2009).

The upper Chesapeake Bay juvenile striped bass geometric mean for the 54-year time series averaged 5.8 but during the last five years it has averaged 4.8. When adult stock abundance is very high, juvenile production is largely environmentally driven (Figure 16).

There has been a dramatic decline in striped bass catches at the fish lifts at Conowingo Dam since 2002 (Figure 17). This decrease may be reflective of several factors such as a shortened lifting season compared to past years and the increased attraction flow from the lifts, possibly excluding striped bass. In addition, most of the striped bass typically observed in the lifts are less than twelve inches in length (Ray Bleistine, Normandeau Associates, personal communication) and, therefore, the recent decline in catches may reflect the recent drop in juvenile production in the upper Chesapeake Bay.

Migratory Fish Management and Restoration Plan

Goal

In 1979, SRAFRC partners adopted a "*Strategic Plan for the Restoration of Migratory Fishes to the Susquehanna River Basin*". That plan offered broad strategies and numeric goals. Based in part on information derived from other rivers with stable American shad populations, St. Pierre (1979) calculated probable habitat carrying capacities of two million adult American shad and five million adult river herring (alewife and blueback herring) in the free-flowing reaches above York Haven, PA. These computations used an area-density estimate of 48 American shad per acre for the mainstem up to Sunbury and the entire Juniata River up to present day blockages.

The river herring target was based on St. Pierre's (1979) estimate for American shad and the assumption that five river herring were equivalent to one American shad. This target will be re-visited, recognizing that lower river habitat has changed markedly from free-flowing riverine habitat to hydroelectric power project impoundments that are more like lakes. As such, considerable uncertainty exists regarding the desirability and use of this altered habitat in the lower river by the target restoration species.

Historic commercial catch rates in Maryland were used to describe changes in abundance of *Alosa* species prior to and after hydroelectric dam development in the Susquehanna River Basin. Available records (ASMFC 1985) indicate that prior to 1910 Maryland American shad landings averaged 4.4 million pounds (approximately one million fish), but after that date, declined to less than one million pounds (~250,000 fish). Maryland river herring landings averaged 18 million pounds (45 million fish) during the 1880s through 1908 but decreased to approximately 7 million pounds (17 million fish). Following completion of Holtwood Dam in 1910, migratory fish were prevented from accessing nearly all their prime spawning habitat. Other factors in addition to habitat availability (e.g., fishing effort, market demands) affected historic shad and river herring commercial landings. However, the evidence indicates that a substantial portion of the observed decrease in these landings was directly related to the significant loss of spawning habitat in the Susquehanna River and its tributaries upstream of Holtwood Dam.

A restored American shad stock in the Susquehanna River would provide substantial economic and ecological benefits. Economic benefits would be realized by Maryland watermen as commercial fisheries in the Chesapeake Bay are reopened, and even more so by the sport fishing industry in all three basin states as increased recreational fishing opportunities are realized. The ecosystem benefits realized from restoration of the ecological functions and values of a restored Susquehanna River American shad stock would affect not only the river and Chesapeake Bay but also the waters of the Atlantic Coast through which these species migrate on an annual basis.

Creel survey data from the nearby Delaware River American shad sport fishery indicate that anglers may catch several shad, but generally only harvest one fish per four-hour fishing day. Typical economic assessments of anadromous sport fisheries suggest a per day value (willingness to pay) of $50 to $75. A fully restored Susquehanna River American shad run could produce 500,000 angler days valued at $25 to $37 million annually (http://www.nj.gov/drbc/creel02c.pdf accessed September 8, 2009).

Based on the foregoing, the goal for this management plan is to:

Restore self-sustaining, robust, and productive stocks of migratory fish capable of producing sustainable fisheries, to the Susquehanna River Basin throughout their historic ranges in Maryland, Pennsylvania, and New York. The goals are 2 million American shad and 5 million river herring spawning upstream of the York Haven Dam. Goals for American eel and other migratory species are yet to be determined.

Objective A: Restore access to historic habitats for juvenile and adult migratory fish.

This objective calls for development of passage plans and performance measures to achieve specified minimum passage efficiency for American shad, American eels, and other migratory fish species at major basin dams. Specified minimum passage efficiencies are much higher than currently experienced at major Susquehanna River barriers.

> **Task A1:** Develop and implement upstream passage plans and performance measures at all four lower river hydroelectric dams to ensure that each facility passes at least 75 percent of the adult American shad passed at the next downstream facility, or at least 85 percent of the adult American shad reaching project tailwaters. Incorporate upstream passage plans and evaluation requirements in FERC licenses. Recommend or conduct evaluation studies as necessary. Require additional fish passage capacity, as needed, to meet fish passage targets. Report fish passage results annually.

Priority: 1
Implementation: FERC relicensing, 401 certification, and Susquehanna River Technical Committee (SRTC) for Conowingo and Fish Passage Technical Advisory Committees for Holtwood, Safe Harbor and York Haven; in cooperation with dam owners.
Status: In conjunction with FERC licensing and compliance.
Cost: SRAFRC-Overhead to be borne by SRAFRC member agencies. Hydro owner costs depend upon measures needed to improve fishway performance to target levels.[1]
Funding: SRAFRC member agencies and Dam Owners.
Lead: Fish Passage Technical Advisory Committees (FPTAC) and SRTC.
Timeline: Upon completion of FERC relicensing in 2014at Conowingo, Holtwood and York Haven dams. Upon agreement with Safe Harbor by 2015.

Task A2: Develop and implement downstream passage plans and measures for adult Alosines at the four lower river hydroelectric dams to ensure at least 80 percent survival at each dam. Incorporate adult downstream passage plans and evaluation requirements in FERC licenses.

Priority: 1
Implementation: Fish passage technical committees for hydroelectric dams (SRTC for Conowingo and FPTAC for Holtwood, Safe Harbor, and York Haven) will meet annually to review and revise (as needed) downstream passage plans and operational measures to maximize survival (FERC requirement).
Status: Ongoing.
Cost: SRAFRC-Overhead to be borne by SRAFRC member agencies. Hydro owner costs depend upon measures needed to improve fishway performance to target levels.
Funding: SRAFRC member agencies and Dam Owners.
Lead: FPTAC and SRTC
Timeline: Upon completion of FERC relicensing in 2014 at Conowingo, Holtwood and York Haven dams. Upon agreement with Safe Harbor by 2015.

Task A3: Develop and implement juvenile downstream passage plans and performance measures at all four lower river hydroelectric dams to ensure 95 percent survival of juvenile alosines at each facility. Incorporate juvenile downstream passage plans and

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[1] Agency costs will be time and overhead associated with: FERC licensing consultation; assessment of impacts related to hydroelectric project operation; development of protection, mitigation and enhancement (PM&E) terms and conditions; negotiation of agreement with Safe Harbor; and post licensing/agreement compliance verification. Hydroelectric project owner implementation costs are difficult to estimate at this time and would likely be associated with lost generation due to required spillage and/or differentials in generation revenue from turbine shutdowns or restricted operation during the passage season. There may also be capital costs associated with potential installation of fish passage and protection facilities and out year annual operation and maintenance costs for these facilities.

evaluation requirements in FERC licenses. Include operational measures at all hydroelectric dams as needed to enhance downstream passage survival of juvenile alosines.

Priority: 1
Implementation: FERC relicensing, 401 certification, SRTC for Conowingo and Fish Passage Technical Advisory Committees for Holtwood, Safe Harbor and York Haven; in cooperation with dam owners.
Status: In conjunction with FERC licensing and compliance.
Cost: SRAFRC-Overhead to be borne by SRAFRC member agencies. Hydro owner costs depend upon measures needed to improve fishway performance to target levels.
Funding: SRAFRC member agencies and Dam Owners.
Lead: FPTAC and SRTC
Timeline: Upon completion of FERC relicensing in 2014 at Conowingo, Holtwood and York Haven dams. Upon agreement with Safe Harbor by 2015.

Task A4: Develop and implement upstream passage plans at FERC-licensed dams to ensure adequate passage of American eels. Incorporate upstream passage plans and evaluation requirements in FERC licenses. Recommend or conduct evaluation studies as necessary. Report eel passage results annually.

Priority: 1
Implementation: FERC relicensing, 401 certification, and SRTC for Conowingo and Fish Passage Technical Advisory Committees for Holtwood, Safe Harbor and York Haven; in cooperation with dam owners.
Status: In conjunction with FERC licensing and compliance.
Cost: SRAFRC-Overhead to be borne by SRAFRC member agencies. Hydro owner costs depend upon measures needed to implement fish passage and meet target levels. Measures for upstream eel passage cost much less compared to those for other species.
Funding: SRAFRC member agencies and Dam Owners.
Lead: FPTAC and SRTC
Timeline: Upon completion of FERC relicensing in 2014 at Conowingo, Holtwood and York Haven dams. Upon agreement with Safe Harbor by 2015.

Task A5: Develop and implement downstream passage plans and performance measures for silver eels at FERC-licensed dams to ensure at least 85 percent survival at each hydroelectric development. Incorporate downstream passage plans and evaluation requirements in FERC licenses, 401 certifications, and other regulatory proceedings and settlement agreements. Establish operational measures at all FERC hydroelectric projects, to ensure survival of silver eels passing downstream. Where needed require installation of fish passage facilities and associated measures.

Priority: 1
Implementation: During FERC relicensing, 401 certification, and during annual consultations with the SRTC for Conowingo and FPTAC for Holtwood, Safe Harbor and York Haven in cooperation with dam owners.
Status: Ongoing in conjunction with FERC re-licensing and annual fish passage

review and consultation.
Costs: SRAFRC-Overhead to be borne by SRAFRC member agencies.
Hydro owner costs depend upon measures needed to implement fish passage and meet target levels.
Funding: SRAFRC agencies and Project Owners.
Lead: SRAFRC and the FPTAC and SRTC.
Timeline: Upon completion of FERC relicensing in 2014 at Conowingo, Holtwood and York Haven dams. Upon agreement with Safe Harbor by 2015.

Task A6: Develop targets for upstream passage of migratory fish at all non-FERC licensed dams.
Priority: 3
Implementation: SRAFRC Technical Committee with input from water development project owners, and water resource regulators.
Status: Ongoing.
Cost: SRAFRC-Overhead to be borne by SRAFRC member agencies.
Dam owners- minimal costs for participation in planning process.
Funding: Resource agencies.
Lead: SRAFRC
Timeline: When migratory fish are detected at the project.

Task A7: Provide adequate upstream passage (safe, timely, effective, and efficient) for migratory fish at all non-FERC licensed dams.
Priority: 3
Implementation: Water development project owners, and water resource regulators.
Status: Ongoing.
Cost: SRAFRC-Overhead to be borne by SRAFRC member agencies. Dam Owners- unknown, several thousand to one million dollars per site, depending on site characteristics.
Funding: Water development owners, resource agencies, National Fish and Wildlife Foundation, NOAA, and non-governmental organizations.
Lead: SRAFRC agencies.
Timeline: Within four years of when migratory fish are detected at a project.

Task A8: Develop and update, as needed, fishway and migratory fish protection operating plans for non- FERC-licensed water resource development projects.
Priority: 3
Implementation: Convene a meeting of the SRAFRC TC and appropriate experts to develop a technical guide for use by water developers and regulatory agencies.
Status: Approximately 10 existing fishways do not have operating plans.
Costs: SRAFRC- Overhead to be borne by SRAFRC member agencies.
Dam owners - minimal, participation in planning process.
Funding: Resource agencies and water developers.
Lead: SRAFRC
Timeline: Issue guidance by 2012 (One day meeting and follow up

drafting/editing of guidance document).

Task A9: Minimize delays at fishways to foster adult spawning fish migration to the upper limits of historical spawning habitat in the watershed.

Priority: 1
Implementation: Review of passage effectiveness at dams and other blockages. For FERC-licensed dams this will occur during upcoming licensing and compliance proceedings.
Cost: SRAFRC **-**Overhead to be borne by SRAFRC member agencies. Dam Owners **-** unknown, several thousand to one million dollars, depending on site characteristics.
Funding: Water project developers and resource agencies.
Lead: SRAFRC
Timeline: For FERC licensed dams, by 2014. For non-FERC projects upon agreement with dam owner and availability of funding.

Task A10: Advocate free-flowing streams (dam / barrier removal) as a preferred alternative to reconstruction of damaged or unneeded dams, and encourage regulatory agencies to require fish passage at any new or rebuilt dams.

Priority: 1
Implementation: Convene a meeting of the SRAFRC TC and appropriate experts to develop a position statement with supporting documentation. Participate in project permit review process and public hearings. Establish new fish passage advisory committees, as needed, including USFWS, PFBC, NYSDEC, MDNR, Pennsylvania Department of Environmental Projection (PA DEP), U.S. Army Corps of Engineers (USACE), and SRBC.
Status: Ongoing.
Cost: SRAFRC- Overhead to be borne by SRAFRC member agencies.
Funding: SRAFRC partners
Lead: SRAFRC
Timeline: Position statement by 2012. Permit review process ongoing.

Task A11: Complete fish passage facilities at both the east and west sides of the inflatable dam at Shikellamy State Park in Sunbury, PA. The confluence of the West Branch and mainstem Susquehanna River occurs just upstream of the inflatable dam. As a result, water flowing from the West Branch tends to hug the west shore and water flowing from the Susquehanna River tends to hug the east shore downstream from the inflatable dam. Thus, anadromous fish homing to the West Branch will migrate up the west shore of the Susquehanna River and concentrate on the west side of the inflatable dam. Conversely, fish homing to the Susquehanna River will concentrate on the east side of the inflatable dam. Passage facilities and measures at the inflatable dam need to ensure that migratory anadromous fish homing to both the West Branch and mainstem Susquehanna River can pass in a safe, timely, and effective manner.

Priority: 1
Implementation: PA Department of Conservation and Natural Resources (PA DCNR), Bureau of State Parks owns and operates the inflatable dam for

recreational boating. PA DCNR, PFBC, USFWS, and SRBC have participated on the Shikellamy Shad Advisory Committee (SSAC). Maintain contact with DCNR and local legislators to ensure adequate funding is available to complete these projects. Revive the SSAC to facilitate implementation, monitoring, and oversight of fish passage.

Status: Design and modeling contract was let by Pennsylvania DGS in late 2001 for construction of vertical slot fishway on the East bank capable of passing 500,000 American shad. Construction bids exceeded available funds. Construction has been delayed due to escalating costs and insufficient funds. In 2007, discussions were renewed and in 2008, PA
DCNR agreed to obtain a cost estimate for a "nature-like" fishway consisting of a rock-lined channel going around the existing dam structure on the west bank. In 2009, authorization was received by the design consultant to formulate plans for a nature-like bypass channel fishway. Design was completed in 2010.

Cost: SRAFRC- Overhead to be borne by SRAFRC member agencies.

DCNR- $4.5 million for West side by-pass, $9 million for East side vertical slot fishway.

Funding: Commonwealth of Pennsylvania ($4.5 million committed for west bank fishway; east bank fishway currently unfunded.).

Lead: SRAFRC

Timeline: West bank, 2012. East bank, when funding is secured.

Task A12: Reconstruct the existing, ineffective fish ladder at Pennsylvania Department of Conservation and Natural Resources (PA DCNR) owned Hepburn Street Dam on the West Branch Susquehanna River at Williamsport according to the design plan developed by the USFWS in 2009.

Priority: 2

Implementation: SRAFRC in cooperation with the PA DCNR.

Status: The dam is owned by the PA DCNR and operated by Bureau of Forestry. A final design and an opinion of probable construction cost for a fishway upgrade were completed in 2009 by an engineering firm under contract to the USFWS. Additional funding will be needed for construction and implementation of improved fish passage.

Costs: Staff resources to investigate and secure funding. Permitting and construction costs $5.9 million.

Funding: Seeking funding from state and federal grants and appropriations.

Lead: SRAFRC and PA DCNR.

Timeline: Anticipate fund raising initiative in 2012, construction in 2014.

Task A13: Construct a fishway at the Grant Street Dam on the West Branch Susquehanna River in Lock Haven according to the new design plan developed by the USFWS in 2009.

Priority: 2

Implementation: SRAFRC in cooperation with the City of Lock Haven, PA.

Status: City of Lock Haven, PA owns and operates the Grant Street Dam. A final design and an opinion of probable construction cost for a fishway were completed

in 2009 by an engineering firm under contract to the USFWS. Additional funding will be needed for construction and implementation of improved fish passage.
Costs: Staff resources to investigate and secure funding. Permitting and construction costs $1.5 million.
Funding: Funding is needed to construct Grant Street fishway. Seeking funding from state and federal grants and appropriations.
Lead: SRAFRC in cooperation with the City of Lock Haven, PA.
Timeline: Anticipate fund raising initiative in 2012, construction in target 2014.

Task A14: Construct a fishway at the First Quality Tissue paper mill dam on Bald Eagle Creek, Mill Hall, PA.
Priority: 1
Implementation: SRAFRC and PFBC in cooperation with the City of Lock Haven, PA.
Status: First Quality Tissue, LLC owns and operates a dam at Mill Hall, PA on Bald Eagle Creek a major tributary to the West Branch Susquehanna River. A final design and an opinion of probable construction cost for a fishway were completed in 2009 by an engineering firm under contract to the USFWS. Funding is currently in place through a congressional appropriation to the USFWS Partner for Fish and Wildlife Program, and a subsequent grant to the PFBC for construction and implementation of fish passage. The PFBC contracted with First Quality Tissue, LLC in 2010 to build the fishway. Construction is expected to be complete in fall 2011.
Costs: Staff resources to implement funding logistics and review installation of the fishway. Permitting and construction costs $600,000.
Funding: Funding already available to build Bald Eagle Creek fishway.
Lead: SRAFRC, USFWS, PFBC and First Quality Tissue, LLC.
Timeline: Construction of the new fishway is expected to be complete in fall 2011.

Task A15: Implement fish passage at three Susquehanna River dams in New York State.
Priority: 3
Implementation: Complete formal designs and cost estimates for construction of Denil and/or "Nature-like Fish Passage Channels" at all three dams. Evaluate cost and projected effectiveness of both designs to determine which plan is to be implemented. Owners of both dam are potentially interested in creating a whitewater recreation facility at both of these dams so fish passage plans will need to be sensitive to this possibility. A fish passage design is also needed for a third dam, formerly known as Goudey Station Dam, on the Susquehanna River at Binghamton but nothing has been done to date. Goudey Station Dam poses a fish passage barrier under "normal" early summer flows but is passable under higher flows.
Status: USFWS fish passage designers are expected to provide conceptual plans and preliminary cost estimates for Denil fish ladders at both Rockbottom Dam on the Susquehanna River and Chase-Hibbard Dam on the Chemung River by January 2011. Funding is needed to develop final designs and an opinion of

probable construction cost for construction of "nature-like" fish passage channels at both of these dams. Funding is also required to develop plans for Goudey Station Dam.
Cost: Design (Nature-like Passage Channels) - $10,000-$30,000 each
Construction - $300,000 each
Funding: Unfunded
Lead: SRAFRC / NYSDEC
Timeline: All designs completed by January 2013. Funding secured for construction by 2015. Construction completed at all three dams by 2018.

Task A16: Provide for adequate fish passage at Oakland Dam in Susquehanna County Pennsylvania.

Priority: 2
Implementation: SRAFRC to work with FERC, the dam owners, and interested parties to ensure adequate fish passage at the site.
Status: A powerhouse was installed at this dam in 1982 via a FERC license exemption. Fish passage was to be addressed as part of the FERC order. A fish ladder was installed in the middle of the dam, but was not designed to accommodate migratory fish passage needs, and was never tested for effectiveness for resident riverine fish passage. Fish entrainment and turbine passage impacts were never adequately addressed regarding safe downstream passage of fish. The powerhouse was damaged by floodwater in 2000 and has been offline since then. The fish ladder structure failed in 2007 resulting in a partial breach of the dam. The FERC exemption was transferred to River Bounty and it is attempting to develop plans and secure financing to repair the dam, install fish passage, and put the power station back online. River Bounty has consulted with PFBC and USFWS regarding fish passage needs, and the agencies are assessing existing and future fish passage at the site. In the current breached condition, upstream fish passage may be adequate for larger fish species at some river flows, but the breach does not appear to allow passage of all fish. Fish entrainment in turbines is not currently a problem due to the powerhouse being offline. If the dam is repaired, and the station put back in service, adequate fish passage facilities and measures will be required.
Costs: Agency staff resources to work with FERC, the dam owners, and interested parties to ensure adequate fish passage is implemented at the site. Capital, operation and maintenance costs for fish passage are unknown at this time.
Funding: SRAFRC partner agencies for the consultation and the dam owner/hydro project operator for capital, operation and maintenance costs for fish passage.
Lead: SRAFRC, PFBC, and USFWS.
Timeline: Upon agreement with dam owner or via FERC process. FERC decision on dam status expected by 2012.

Objective B: Maintain or improve existing migratory fish habitat.

This objective focuses on essential habitat issues by inventorying blockages and assessing the impact of fish passage impediments through active involvement of SRAFRC in watershed project reviews while supporting monitoring and improving water quality.

Task B1: Inventory tributary blockages, assess quantity and location of habitat, set priorities, and reopen blocked habitat for migratory fish through dam removals and fish passage development.

Priority: 3
Implementation: MDDNR, PFBC and NYSDEC in respective waters.
Status: Numerous barrier removals and passage projects have been completed with additional removals proposed and planned. Some dam removals already completed or proposed within the Maryland, Pennsylvania and New York portions of the Susquehanna Basin. A blockage inventory was completed in 2009 for New York portions of the Basin. A blockage inventory is also complete in Maryland. In Pennsylvania, a blockage inventory is completed on Susquehanna River tributaries up to, but not including, the Juniata River.
Cost: SRAFRC-Inventory: $50,000. Dam Owner-Removal or fish passage construction unknown, varies site to site.
Funding: ASMFC, CBP and others.
Lead: SRAFRC
Timeline: Inventory: 2015. Removal or fish passage: upon agreement with owner and securing funding.

Task B2: Assess and mitigate the impacts of hydroelectric projects and their operation on migratory fish spawning and rearing habitat within the project area immediately downstream and upstream of the project.

Priority: 1
Implementation: Impacts to migratory fish spawning and rearing habitat associated with the construction and operation of the hydroelectric project will be assessed during FERC licensing and compliance proceedings at each project. When impacts are identified, appropriate protection, mitigation and enhancement measures will be developed to avoid, minimize, or mitigate these impacts. Recommend/require that appropriate measure be implemented through agreement or regulatory measures.
Status: Ongoing via FERC licensing.
Costs: Staff resources to work with FERC, the dam owners, and interested parties to ensure adequate migratory fish habitat protection, mitigation and enhancement measures will be implemented at each project. Capital, operation and maintenance costs for fish habitat measures are unknown at this time.
Funding: SRAFRC member agencies for assessment and development of mitigation measures and hydropower developers for capital and operation and maintenance costs for fish habitat, protection, mitigation and enhancement measures.
Lead: SRAFRC member agencies
Timeline: Assessment of impacts and development of mitigation measures 2010-

2012. Implementation of mitigation upon completion of FERC relicensing in 2014 at Conowingo, Muddy Run, Holtwood and York Haven hydroelectric projects, and upon agreement with Safe Harbor.

Task B3: Advocate avoidance, minimization, or mitigation of impacts to migratory fish migration, spawning, rearing, or habitat associated with construction, maintenance and operation of dams or other developments that require agency consultation, a permit, or license.

Priority: 1
Implementation: Participate in project permit/license consultation and review process, and associated public hearings. Establish permanent or ad hoc SRAFRC advisory committees, as needed to engage in permit and licensing proceedings.
Status: Ongoing, as needed.
Costs: SRAFRC-Overhead to be borne by SRAFRC member agencies.
Capital and operation and maintenance costs for fish habitat measures are unknown at this time and would be borne by the project proponent.
Funding: SRAFRC, project permit/licensee applicant, project sponsor and affected resource agencies.
Lead: SRAFRC member agencies.
Timeline: As needed.

Task B4: Advocate Policy level actions that maintain existing designated uses and support additional water quality improvements within the Susquehanna River Basin.

Priority: 1
Implementation: States and EPA are required to maintain water quality for designated uses under the Clean Water Act. EPA is developing a Total Maximum Daily Load (TMDL), or “pollution diet” for the Chesapeake Bay, and is also requiring states to develop and execute Watershed Implementation Plans under the Chesapeake Bay TMDL. The Chesapeake Bay TMDL will benefit both the bay and local watersheds in the Susquehanna River Basin. Maintenance and improvement of water quality by state, federal, local, and private interests is also addressed under SRBC’s Comprehensive Plan for the Water Resources of the Susquehanna River Basin.
Status: State and local water quality activities are ongoing. The Chesapeake Bay TMDL is scheduled for completion by the end of calendar year 2010. SRBC’s comprehensive plan was updated in 2008.
Costs: SRAFRC overhead to be borne by SRAFRC member agencies.
The total amount of funding for activities conducted by state, federal, local, and private entities has not been determined, and will depend on the magnitude of water quality improvements required under the Chesapeake Bay TMDL and state Watershed Implementation Plans.
Funding: Water developers, state and federal agencies.
Lead: States and EPA.
Timeline: Ongoing with the Chesapeake Bay TMDL to be completed in calendar year 2010.

Objective C: Enhance migratory fish spawning stock biomass and maximize juvenile recruitment.

This objective includes a variety of tasks designed to directly or indirectly improve migratory fish stocks in the Susquehanna River. Tasks focus on improving current techniques for artificial augmentation of American shad stocks, developing new techniques for augmenting river herring and eel populations, restoring non-Alosine migratory fish, improving instream migration, spawning and rearing habitat, and maintaining existing regulatory framework restricting harvest of migratory fish.

Task C1: Supplement wild production with hatchery culture and stock larval American shad in order to re-establish and rebuild mainstem and tributary stocks. Annually stock 10 million or more hatchery-reared American shad larvae. Distribute larvae in mainstem and tributary areas according to available habitat.

Priority: 1
Implementation: Van Dyke hatchery will use several egg source options, preferably Susquehanna River tank spawning (see Task C2) and including out-of-basin strip spawning to produce 15 million viable eggs.
Status: Ongoing.
Costs: SRAFRC- Operation and maintenance $175 thousand annually.
Funding: Current funding through operational expenditures from PFBC and Sportfish Restoration Act.
Lead: SRAFRC
Timeline: On-going.
Augmentation of naturally spawning stocks with hatchery-reared American shad will be discontinued when the following conditions are met:

1. The hatchery contribution to numbers of adult American shad passing Conowingo Dam is less than 25 percent for three consecutive years; and

2. Natural spawning of American shad has been confirmed for three consecutive years in the North Branch above Wilkes-Barre, the West Branch above Williamsport, the Juniata River above Lewistown; and

3. Suitable tributaries (i.e., those stocked for five or more years) have been colonized by runs of American shad.

Task C2: Relocate the Van Dyke Hatchery to a location in Centre County, near Benner Spring.

Priority: 2
Implementation: PFBC and SRAFRC
Status: Seeking funding.
Cost: SRAFRC- $1.5 million Capital expenditures for construction of new rearing facility. Operation and maintenance $175 thousand annually.
Funding: Current funding of operational expenditures from PFBC and Sportfish

Restoration Act. Potential sources for capital include, mitigation funding, settlement funding, private sector contributions, federal and state grants and direct appropriations, donations, SRAFRC member agencies.
Lead: PFBC
Timeline: 2015.

Task C3: Consider trap and transport of adult American shad from Conowingo Dam fish lift(s) to above York Haven Dam while upstream fish passage is being improved at the Conowingo, Holtwood and/or York Haven hydroelectric projects.

Priority: 1
Implementation: Consistent with the FERC and other regulatory agency review processes for permitting and licensing, project operational impacts on adequate fish passage will be assessed and appropriate protection, mitigation and enhancement measures will be developed by the natural resource agencies. Any new measures to enhance fish passage effectiveness will take the form of terms and conditions in any new FERC license and associated permits issued for these hydroelectric projects. It may take a number of years after licensing before the terms and conditions can be fully implemented and the fish stocks respond to improved fish passage. In the interim, trap and transport of adult American shad to the river reach upstream of the York Haven project may be a viable interim passage measure to move restoration efforts forward over the next several years while existing volitional upstream fish passage facilities and measures are being assessed and improved. Through the FERC licensing consultation process Exelon has been requested to assess the logistics and cost of utilizing the West Fish Lift as an interim measure to increase fish passage at the project via trap and truck measures and provide a summary report to the agencies.
Status: Upstream volitional passage of spawning American shad through the lower Susquehanna River hydroelectric projects has been poor with less than 10% of the fish that pass the first dam (Conowingo) making it past the fourth dam (York Haven). Poor lower river passage is believed to be due to the cumulative effects of fish passage inefficiencies at each hydroelectric project. The potential inefficiencies and resulting causes are currently being investigated or addressed as part of the FERC licensing process at Conowingo, Muddy Run, Holtwood, and York Haven. Safe Harbor exhibits relatively high upstream passage efficiency and does not appear to be a significant problem at this time.
In addition, Exelon has committed to conducting a trap and transport assessment and prepare a report of its findings as part of the FERC relicensing process. The SRAFRC will review the study, assess the feasibility of a trap and transport program, and develop an implementation plan if deemed feasible.
Costs: SRAFRC-overhead to be borne by SRAFRC member agencies. The Exelon study is estimated to cost $40,000. Capital, operation and maintenance costs for trap and transport operations are unknown at this time, pending completion of the Exelon assessment and these costs would be borne by the hydroelectric project owners until the inefficiencies in there fish passage facilities and measures have been adequately addressed.
Funding: SRAFRC member agencies for FERC consultation, review of the

Exelon study, development on an action plan, and regulatory and agreement compliance. Hydroelectric project owners for capital, and operation and maintenance costs for trap and transport operations.
Lead: SRAFRC member agencies.
Timeline: Exelon study report to be completed early 2011. SRAFRC agency assessment and action plan development by end of 2011. Regulatory conditions and any settlement agreements developed by mid-2012. Implementation of trap and transport operations as soon as possible following a decision to move forward.

Task C4: Develop a reliable source of Susquehanna River American shad eggs to replace out-of-basin sources and to enhance genetic integrity of the program.
Priority: 1
Implementation: Refine tank spawning techniques using adult American shad from the West Fish Lift at Conowingo Dam to collect sufficient eggs to stock 10 million or more larvae annually. Develop a dedicated, temperature controlled anadromous fish tank-spawning facility near Conowingo Dam with sufficient capacity to meet annual production goals.
Status: Ongoing studies and trials at Conowingo Dam under contract to SRAFRC. Seeking funding for tank-spawning facility.
Cost: SRAFRC- $2 million capital investment plus $300 thousand annual operation and maintenance.
Funding: Potential sources include, mitigation funding, settlement funding, private sector contributions, federal and state grants and direct appropriations, donations, SRAFRC member agencies.
Lead: SRAFRC
Timeline: Secure funding 2014, design and permitting 2015, construction 2016, Operational spring 2017.

Task C5: Investigate strategies to increase river herring abundance in the Susquehanna River basin upstream of Conowingo Dam using hatchery-reared fry or by transplanting adults.
Priority: 2
Implementation: SRAFRC to prepare a feasibility study of raising river herring fry and/or transplanting adult river herring to river reaches upstream of migration impediments.
Status: Culture of river herring is being conducted by state and federal agencies on other rivers. Trap and transport of river herring (i.e., mainly alewife to upstream ponds and lakes) has resulted in establishment of viable runs on rivers in New England (e.g., Maine’s Sebasticook River). SRAFRC will review these programs for applicability to restoration of river herring stocks in the Susquehanna River.
Costs: SRAFRC-Overhead to be borne by SRAFRC member agencies**.**
Funding: SRAFRC member agencies.
Lead: SRAFRC
Timeline: This study could be conducted in 2013 following the bulk of FERC

licensing activities.

Task C6: Investigate culture and marking techniques for river herring for stock restoration in the Susquehanna River Basin.

Priority: 3
Implementation: PFBC or USFWS at existing culture sites. Egg sources and collection procedures (tank or strip spawning) to be developed.
Status: Under consideration in Pennsylvania once funds are located.
MDNR and USFWS have had successful efforts with strip-spawned herring.
Cost: SRAFRC**-** $40,000
Funding: Unfunded.
Lead: SRAFRC
Timeline: Pending funding.

Task C7: Implement trap and transport of eels from the lower river to upstream sites while eel passageways are being constructed and evaluated.

Priority: 1
Implementation: American eel passage is being assessed during the ongoing FERC relicensing consultations via field and desktop studies. When complete, the study results will be reviewed by the SRAFRC agencies to develop and assess options to improve upstream eel passage.
Status: Eel trap and transport is currently being conducted by the USFWS from its trapping operations below Conowingo Dam in cooperation with Exelon Corporation. Past trap and transport efforts for eels have documented increased populations of juvenile and adult eels in the river reaches into which they were placed. SRAFRC is currently assessing American eel restoration alternatives for the Susquehanna River basin, including trap and transport.
Costs: SRAFRC**-**Overhead to be borne by SRAFRC member agencies. Costs for a trap and transport operation are yet to be developed but will likely run $50,000 - $100,000 per year.
Funding: SRAFRC member agencies and hydroelectric project owners, and large water users with the potential for entrainment issues.
Lead: SRAFRC, the FPTAC and SRTC.
Timeline: The FERC licensing studies are currently underway. SRAFRC agency assessment and action plan by 2012. Regulatory conditions and any settlement agreements developed by mid-2012. Implementation of trap and transport operations as soon as possible following a decision to move forward.

Task C8: Maintain closures or restrictions on commercial and recreational fisheries for American shad in those waters of the Susquehanna River Basin and Chesapeake Bay, which could take Susquehanna fish until or unless it is shown that harvest would not impair Susquehanna River restoration.

Priority: 1
Implementation: Maryland has maintained a closure of its Chesapeake Bay American shad fisheries since 1980 and Virginia since 1994. Pennsylvania and New York have no future plans to allow commercial harvest in the Susquehanna.

Status: American shad stocks in the upper Bay remain low.
Costs: SRAFRC- Overhead to be borne by SRAFRC member agencies.
Funding: Potential sources include, mitigation funding, settlement funding, private sector contributions, federal and state grants, direct appropriations, and donations.
Lead: ASMFC, CBP, and SRAFRC
Timeline: On-going.

Task C9: Manage the existing or developing commercial and recreational fisheries for migratory fish through effort and harvest regulation.
Priority: 1
Implementation: Through state regulation. Guidance provided by ASMFC and SRAFRC.
Status: Ongoing.
Costs: SRAFRC- overhead to be borne by SRAFRC member agencies.
Funding: Resource agencies.
Lead: Resource agencies, ASMFC, and SRAFRC
Timeline: On-going.

Task C10: Investigate the potential for restoring migratory striped bass, Atlantic sturgeon, and shortnose sturgeon to historic levels upstream of Conowingo Dam.
Priority: 2
Implementation: SRAFRC.
Status: Exelon is currently monitoring the lower Susquehanna River downstream of the Conowingo River for use by ultrasonic tagged sturgeon and striped bass as part of its relicensing studies. Fish counts at all fishways at the lower Susquehanna River hydroelectric projects observe for sturgeon or striped bass, passage, however, these fish species have not been documented to readily utilize the upstream passage facilities. The effectiveness of existing downstream passage also needs to be addressed.
Costs: SRAFRC-Overhead to be borne by SRAFRC member agencies. Costs of restoration efforts and fish passage needs will be estimated for the SRAFRC assessment report.
Funding: SRAFRC member agencies.
Lead: SRAFRC
Timeline: Assessment to be completed by 2012.

Objective D: Evaluate the migratory fish restoration effort periodically and adjust programs or processes as needed.

This objective stresses the importance of data dissemination and analysis. Tasks included in this section will continue to collect baseline data essential to monitor restoration progress while researching and experimenting with technologies to improve survival, reproduction and spawning biomass.

Task D1: Monitor and regulate sport fishing for migratory fish in the Susquehanna River (MD, PA and NY) to ensure adequate stock rebuilding.

Priority: 1

Implementation: Conduct angler use and harvest surveys. Resource agencies will annually review migratory stock status in their portions of the Susquehanna River Basin and make recommendations regarding sport fishing seasons and creel limits, where applicable.

Status: Maryland sport fisheries and commercial fisheries were closed to harvest in 1980 and Pennsylvania and New York both have a zero creel limit on American shad in the Susquehanna River Basin. A significant catch-and release sport fishery for American shad has developed below Conowingo Dam in Maryland. Successful, but smaller scale catch-and-release American shad fishing also occurs below Holtwood, York Haven, and Sunbury Dams. Amendment 3 to the ASMFC American shad and River Herring Management Plan requires all states to close American shad fisheries unless they can demonstrate that the fishery is sustainable. Recreational catch and release fisheries are permitted under Amendment 3.

Cost: Angler use and harvest surveys: Maryland- $3,000, Pennsylvania-$10,000 to $100,000

Funding: Resources agencies and other sources.

Lead: SRAFRC

Timeline: Conducted annually as part of the states'ASMFC monitoring requirements and reported and discussed at annual SRAFRC meetings.

Task D2: Monitor and annually report adult upstream fish passage at all dams.

Priority: 1

Implementation: Analyze fish migration and behavior using fish passage counts, PIT tagging, telemetry, and other appropriate techniques. Several of these requirements are mandated by the ASMFC as part of Amendment 3 to its Fishery Management Plan for Shad and River Herring (ASMFC, 2010), and Interstate Fishery Management Plan for American Eel (ASMFC, 2000). Annual fish passage counts at the four lower Susquehanna River hydroelectric project fishways are currently being conducted by the project owners as part of the operation of the fishways. The counts are reported to the SRAFRC and included in annual reports.

Status: Radio telemetry studies of adult American shad upstream and downstream migration were conducted at Muddy Run and Holtwood in 2008 and at Conowingo and York Haven in 2010 and may be continued into 2012. Results of the first year of study should be available in early 2011. An assessment of the installation of PIT tag detectors at all fishways has been requested of all hydroelectric operators as part of the annual fish passage technical review and/or as part of the ongoing FERC licensing consultation process. These PIT tag assessments should be available in 2011 or 2012.

Costs: SRAFRC**-**Overhead to be borne by SRAFRC member agencies. Costs for radio telemetry studies are estimated at $280,000 to $300,000 per project per year. Costs for PIT tagging studies will be estimated during the FERC licensing

process.
Funding: SRAFRC resource agencies and hydroelectric project owners.
Lead: SRAFRC
Timeline: Fish passage counts conducted annually by fishway owners and reported in the annual SRACRC report. Radio telemetry studies in 2010, 2011, and 2012. PIT tag studies would begin following FERC relicensing or sooner.

Task D3: Determine hatchery and wild stock composition of pre-spawn adult American shad returning to Conowingo Dam annually.
Priority: 1
Implementation: Analyze up to 200 random otolith specimens from West Fish Lift collections. Take steps to ensure annual operation of Conowingo West Fish Lift. Sample adult American shad from tailrace (MDNR) for otolith analysis (PFBC).
Status: Ongoing.
Cost: $1,500 annually for analysis of 200 otoliths.
Funding: Currently funded by PFBC and MDNR. Future funding to be determined.
Lead: SRAFRC
Timeline: Samples collected annually as part of annual West Lift operations, analyzed by the PFBC, and reported in annual SRAFRC report.

Task D4: Monitor presence of adult migratory fishes at selected sites and areas of targeted restoration efforts including the base of non-FERC dams and in stocked tributaries, using electrofishing or other collection methods.
Priority: 3
Implementation: PFBC has conducted some surveys using Area Fisheries Managers and their staff and contracts for other surveys.
Status: Electrofishing surveys have not been conducted in recent years due to poor fish passage performance at Holtwood and York Haven dams.
Cost: $5,000 per site.
Funding: PFBC, Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA), NYSDEC, and PA. DCNR.
Lead: PFBC/SRAFRC/NYSDEC
Timeline: The need for monitoring migratory fish presence is dependent upon the number of shad successfully passing York Haven Dam and will be assessed annually as part of the SRAFRC consultation and reporting process. New York to implement monitoring when more than 10,000 American shad are known to be upstream of York Haven Dam and when reliable passage is available at the inflatable dam in Sunbury.

Task D5: Monitor abundance of American eels at priority passage barriers. Monitor relative abundance at these sites to determine appropriate siting for eel passage. Document and report to SRAFRC annually, any collections of American eels in the Susquehanna River Basin that occur during routine fishery survey activities conducted by

MD, PA, NY, or SRBC.

Priority: 2
Implementation: Develop survey techniques. Prioritize barriers for monitoring.
Status: Limited effort ongoing at Conowingo.
Cost: $1,000 - $5,000 per site
Funding: Water developers and Resource agencies.
Lead: SRAFRC
Timeline: When eel passage has been implemented at all impassable barriers. To be assessed and reported annually as part of the SRAFRC process.

Task D6: Monitor juvenile *Alosa* including relative abundance, growth, and outmigration timing and maintain or improve existing juvenile surveys.

Priority: 1
Implementation: Conduct summer-fall net, electrofishing, and/or impingement collections for juvenile *Alosa*. Sites to include the West Branch Susquehana River and Susquehanna River, Juniata River, Columbia/Marietta, Holtwood, Peach Bottom Atomic Power Station, Conowingo, Susquehanna Flats, and other sites as needed.
Status: Ongoing.
Cost: $20,000 annually per site.
Funding: Resource agencies and water developers.
Lead: SRAFRC
Timeline: To be completed on an annual basis and assessed and reported as part of the SRAFRC process. Two sites to be assessed in 2010. Additional sites will be added as the shad population expands into additional areas.

Task D7: Annual review of restoration and monitoring activities.

Priority: 1
Implementation: The SRAFRC compiles and reports the collective restoration activities of the member agencies, hydroelectric operators, and other migratory fish restoration partners annually.
Status: Ongoing.
Costs: Overhead to be borne by SRAFRC member agencies. Hydroelectric operator costs are unknown at this time.
Funding: SRAFRC member agency hydroelectric operators, and other migratory fish restoration partners.
Lead: SRAFRC
Timeline: To be completed on an annual basis and assessed and reported as part of the SRAFRC process.

Task D8: Determine if differences exist in passage behavior at Conowingo Fish Lift between hatchery reared returning adult American shad and non-hatchery fish. Determine the rate at which fish move upriver through the lifts and determine if there are differences between hatchery and wild fish.

Priority: 2
Implementation: Compare hatchery contribution between tailrace random

sample and Conowingo Fish Lift sample. Utilize P.I.T. tagging to track upstream movement and migratory behavior through the system.
Status: P.I.T. tagging to be initiated as part of FERC re-licensing process.
Cost: $1,500 annually for 200 additional otolith specimens.
Funding: Water developers (P.I.T. tagging), SRAFRC and resource agencies (shad collection and otolith processing).
Lead: SRAFRC
Timeline: To be completed on an annual basis and assessed and reported as part of the SRAFRC process. Otolith processing- 2011, P.I.T tagging- 2014.

Objective E: Ensure cooperation among all restoration partners while generating support for the restoration of migratory fish among the general public and potential funding sources.

This objective stresses the importance of a watershed approach to restoration and emphasizes the need to include coastal states and ocean waters.

Task E1: Meet all ASMFC stock characterization requirements for diadromous fishes migrating to the Susquehanna River each year.
Priority: 1
Implementation: Obtain and process biological data from diadromous fishes as per ASMFC and other resource management plans. Monitor age and size structure, mortality, spawning history, and sex ratios in the annual runs.
Priority: 1
Status: Ongoing with annual reports provided to SRAFRC and ASMFC.
Costs: $60,000 annually
Funding: Currently funded by PFBC and MDNR. Future funding to be determined.
Lead: MDNR and PFBC
Timeline: On-going.

Task E2: Coordinate restoration activities among regulatory and resource agencies. (e.g., NMFS, ASMFC, SRBC, CBP, utility interests, and other stakeholders).
Priority: 1
Implementation: Continue to report biological and fishery information to ASMFC and NOAA. As appropriate, continue state and federal participation on SRAFRC Policy and Technical committees; fish passage advisory committees; SRBC Water Resources Program, CBP fish passage work group, Non-Tidal Habitats workgroup and Living Resources Subcommittee; ASMFC American shad and river herring and American eel Technical committees and management boards; and Mid-Atlantic Fishery Management Council.
Status: Ongoing.
Costs: Overhead to be borne by SRAFRC member agencies.
Funding: SRAFRC member agencies.
Lead: SRAFRC
Timeline: To be completed on an annual basis and assessed and reported as part

of the SRAFRC process.

Task E3: Advocate through the Mid-Atlantic Fishery Management Council (MAFMC) and New England Fishery Management Council (NEFMC) for minimization of bycatch and discard mortalities.

Priority: 1
Implementation: The ASMFC American shad and river herring fishery management plan, amendments 2 and 3, address bycatch and discards in state and inshore waters. The MAFMC and NEFMC may also regulate small mesh fisheries which capture river herring and American shad in the Exclusive Economic Zone (EEZ).
Status: ASMFC Amendments 2 and 3 require reporting of bycatch and discard mortalities. MAFMC is preparing Amendment 14 to the Atlantic Mackerel, Squid, and Butterfish Management Plan, and NEFMC is preparing Amendment 5 to the Atlantic Herring Management Plan.
Cost: SRAFRC- Overhead to be borne by SRAFRC member agencies.
Funding: None required.
Lead: SRAFRC Agencies, ASMFC, Fishery Management Councils
Timeline: Ongoing.

Task E4: Expand public education and information initiatives.

Priority: 2
Implementation: PA Angler and Boater magazine, NYSDEC "Conservationist" magazine, electronic media, brochures, presentations, coordination of news releases, and provide fish viewing at dams, where appropriate. Work with the Chesapeake Bay Foundation, the Alliance for the Chesapeake Bay, State Conservation Districts, CBP Communication Subcommittee, sportsmen's clubs, sports writers, and others to promote the program. Engage the public through participation in stocking, tours, media events, and public forums.
Status: Ongoing.
Cost: SRAFRC- Minimal, dependent upon activity.
Funding: Agency and other sources.
Lead: Agencies/SRAFRC
Timeline: To be completed on an annual basis and assessed and reported as part of the SRAFRC process.

Task E5: Develop and promote funding partnerships with local, state, federal governments, water developers, and NGOs with an interest in migratory fish restoration in the Susquehanna.

Priority: 1
Implementation: Contact appropriate Congressional offices, National Fish and Wildlife Foundation, Fish America Foundation, American Rivers, The Nature Conservancy, CBF, and others and propose co-funding opportunities to meet financial needs of the program.
Status: New initiative. In most cases, need to locate non-federal matching funds.
Costs: - Overhead to be borne by SRAFRC member agencies. Program needs up

to $500,000 per year plus capital improvements at, or full replacement of, the Van Dyke hatchery (est. $1.5 million).
Funding: SRAFRC member agencies.
Lead: SRAFRC
Timeline: To be completed on an annual basis and assessed and reported as part of the SRAFRC process.

Adaptive management and future plan revisions

The Susquehanna River is a productive system with a long history and tremendous potential for sustaining migratory fish stocks. Because alosines will fill what is now an open ecological niche, their numbers should expand rapidly once substantial natural reproduction is confirmed, downstream passage success is maximized, and adverse removals from the stock (e.g., ocean fisheries) are eliminated. This restoration effort is in a transition phase. For over 30 years, utility companies jointly or individually provided most of the financial support for restoration activities. With completion of permanent fish passage facilities, most of that required financial support is gone and SRAFRC partners must develop new ways to maintain or advance the program.

It is expected that the American shad hatchery effort in Pennsylvania will soon shift its focus from out-of-basin to in-basin egg sources, necessitating reliance on tank spawning. Brood fish for this effort must come from the West Fish Lift at Conowingo Dam. However, that facility is over 30 years old and future maintenance needs and costs are unknown. Development of river herring culture at Van Dyke or elsewhere will require new research, space, egg sources, and funding. USEPA funds for the Chesapeake Bay fish passage program are stretched thin by ever-decreasing federal budgets; as such, other funding sources must be developed. SRAFRC's contributed funds account that supported West Fish Lift operations, adult herring transfers, and much of the tank spawning costs since 1997, is now depleted.

The tasks listed in this Management and Restoration Plan must be adaptive and somewhat generic in nature in order to avoid re-writing the plan annually as new data are generated. SRAFRC will continue to develop and approve annual work plans which guide the restoration process while striving toward accomplishment of all stated tasks. Management of the Susquehanna River migratory fish restoration program will conform to basic guidance and requirements of the CBP and ASMFC Alosa and American Eel Fishery Management plans.

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Figures and Tables

Figure 1. The Susquehanna River with sub-basins.

Figure 2. ***Commercial landings of gizzard shad in Maryland and the corresponding juvenile indices from the upper Chesapeake Bay and the Potomac River***

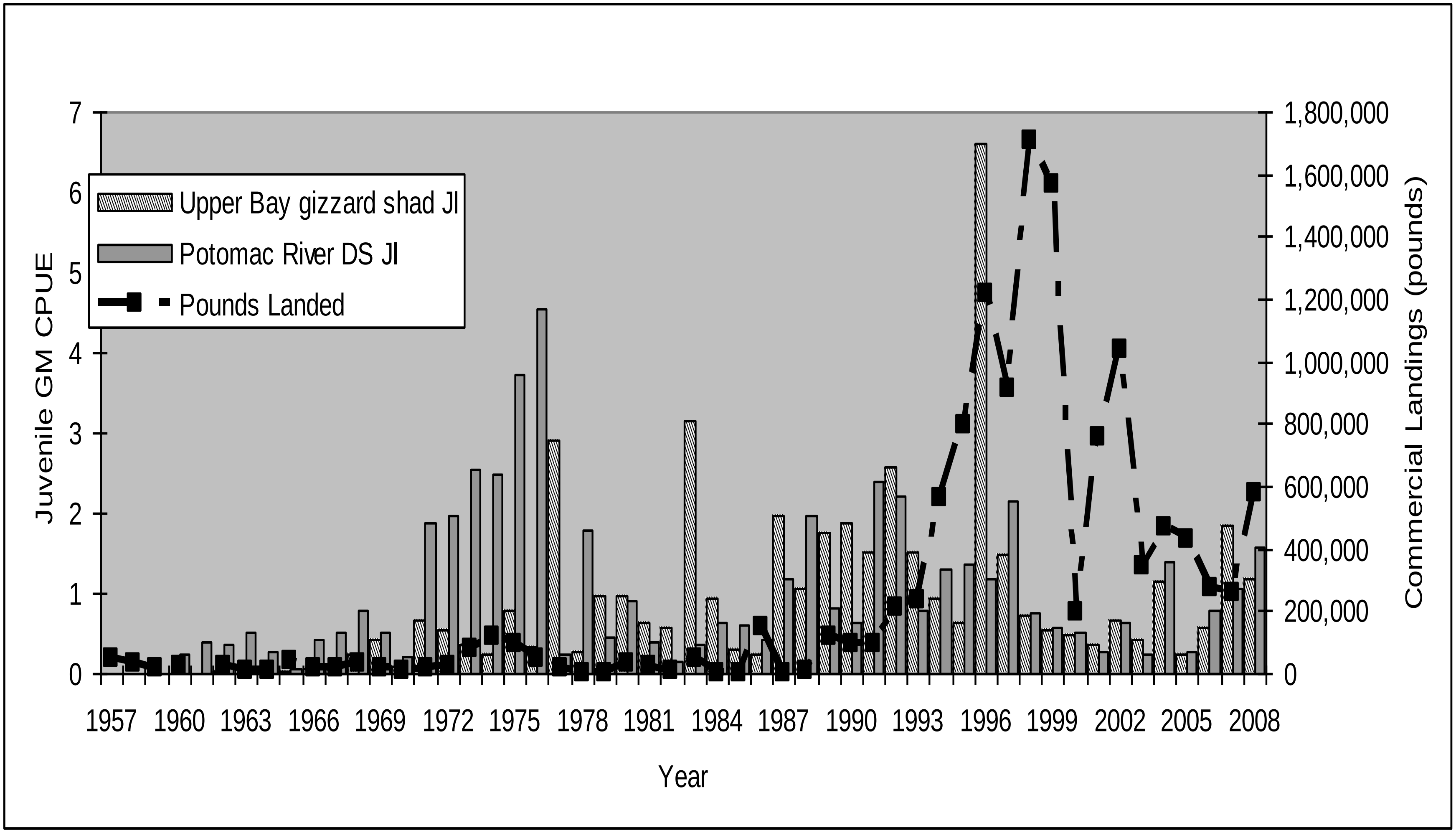

Figure 3. Commercial gizzard shad landings in Maryland and catch of gizzard shad at Conowingo Dam, 1972-2008

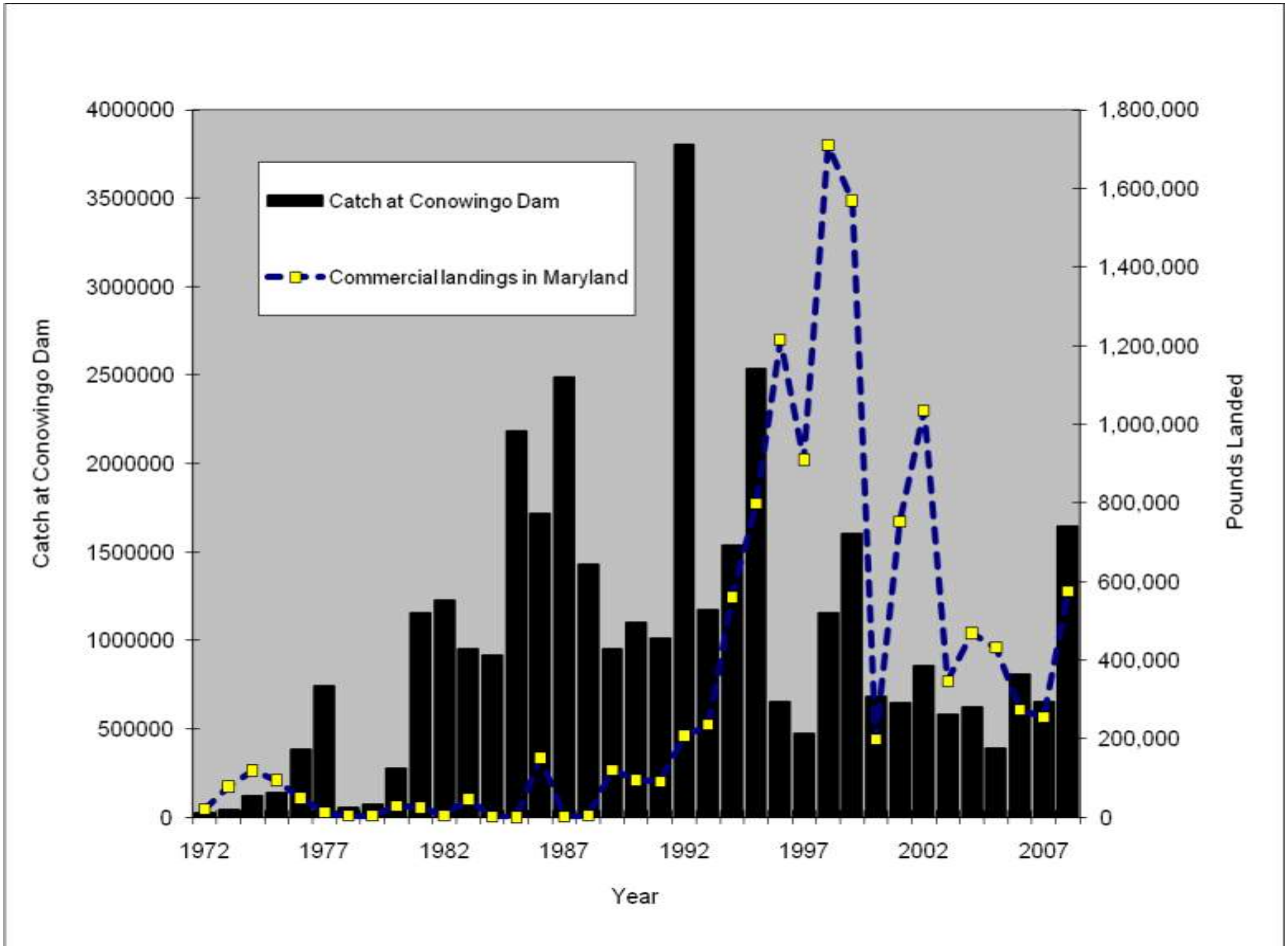

Figure 4. The Susquehanna River with dams and migratory fish passage.

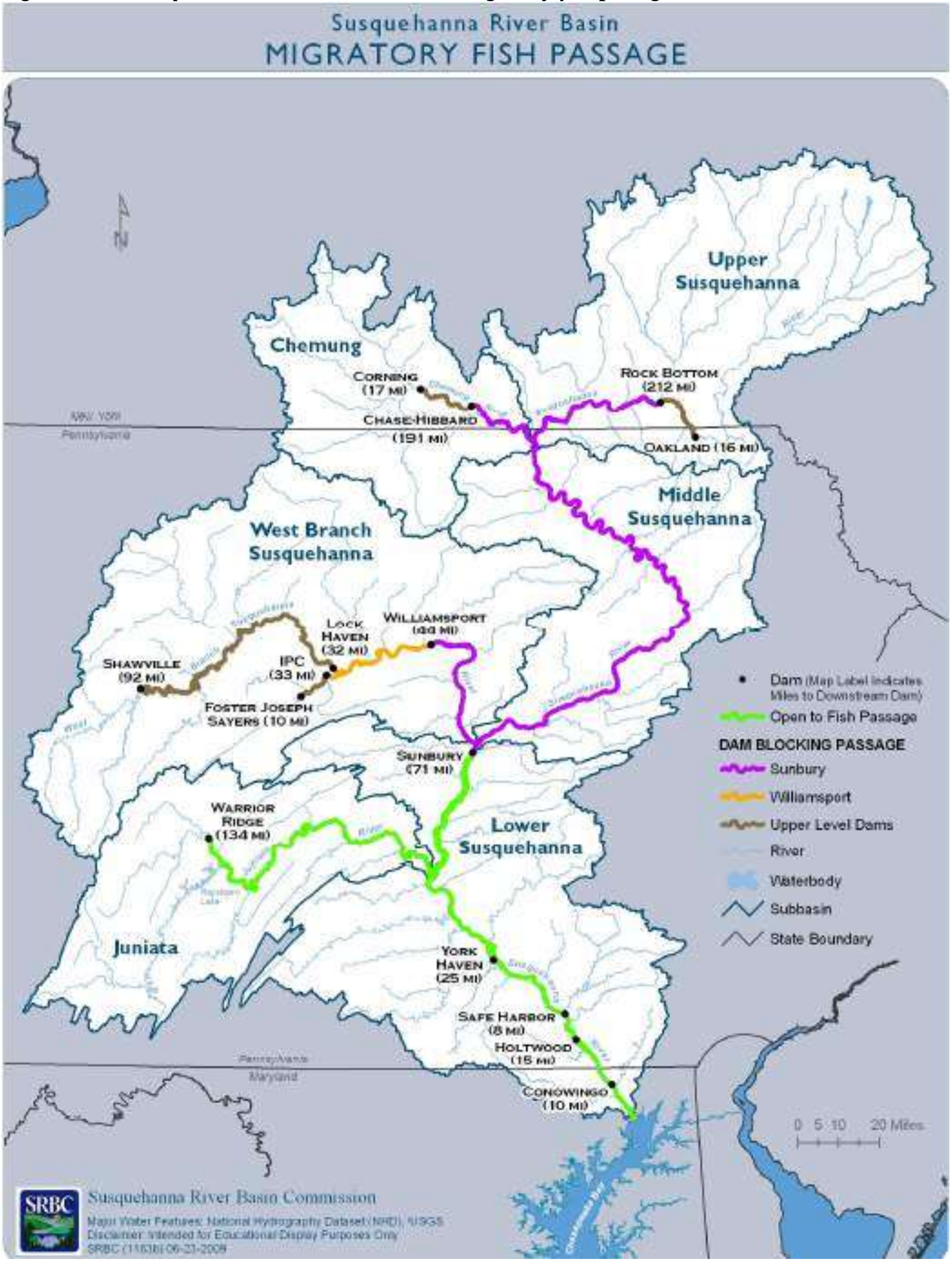

Figure 5. The Susquehanna River with American shad stocking sites.

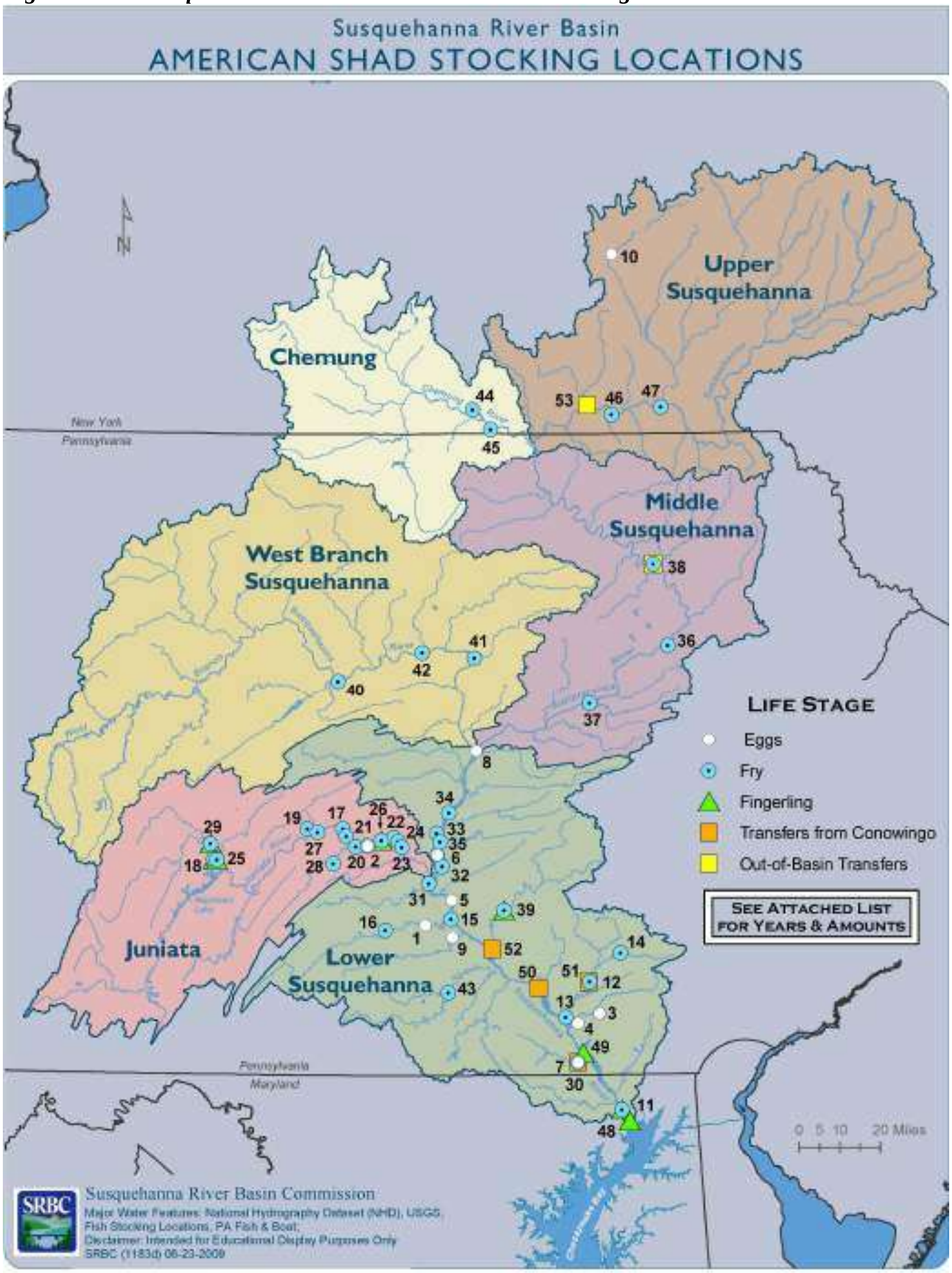

Figure 6. Catch of American shad at the Conowingo dam fish lifts.

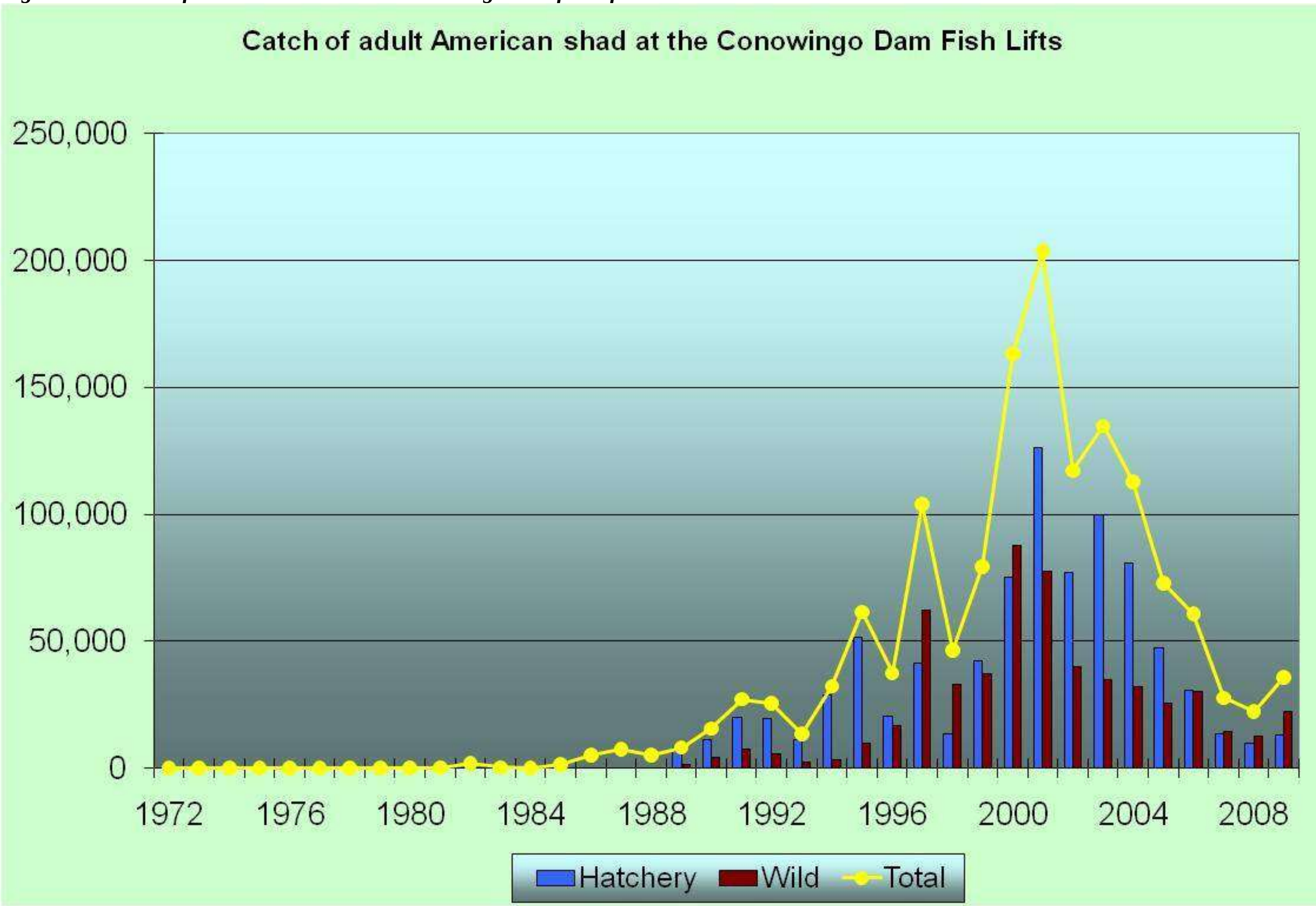

Figure 7. American shad passage at Susquehanna River dams

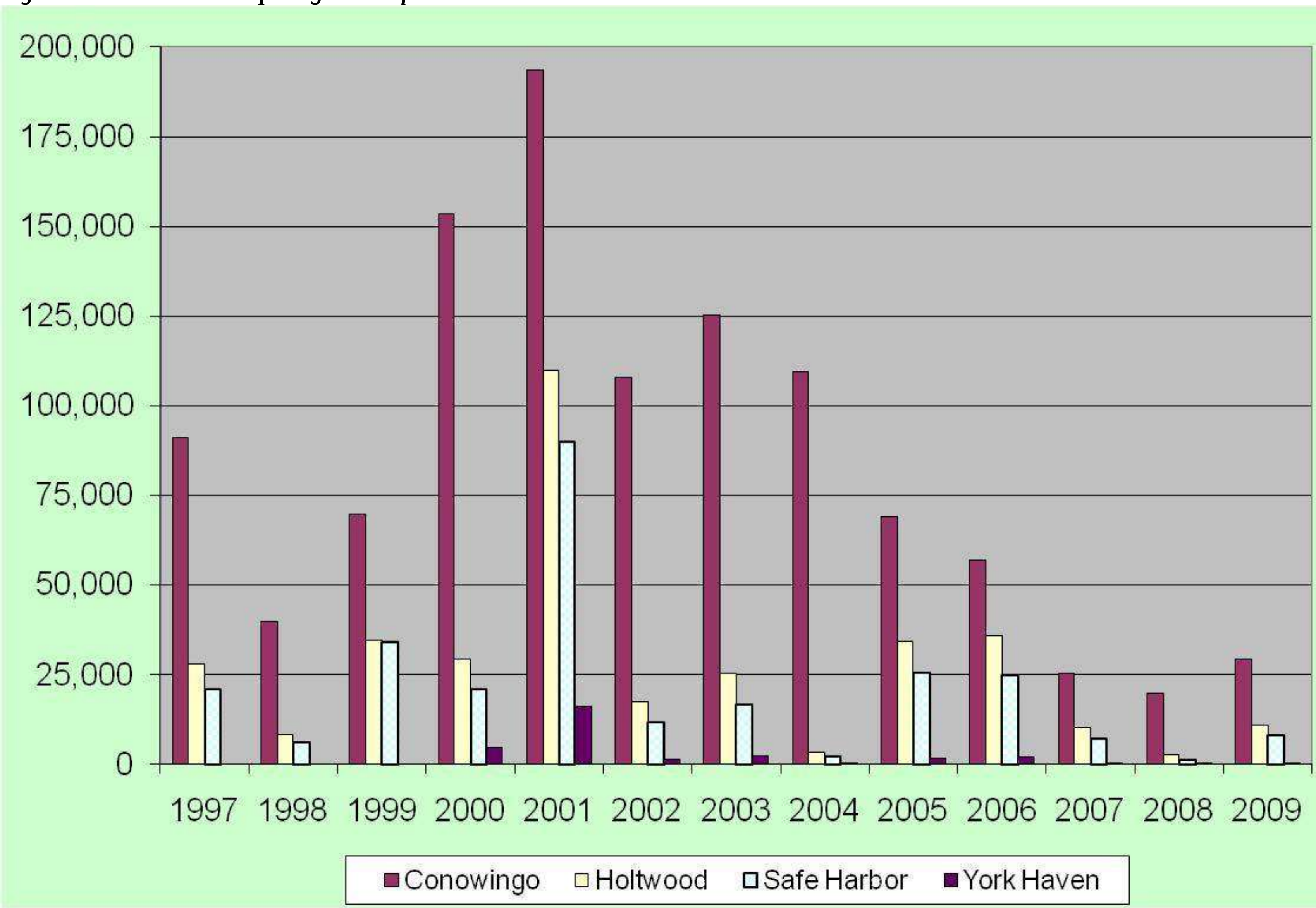

Figure 8. Upper Chesapeake Bay juvenile American shad geometric mean CPUEs (catch-per-seine-haul), 1959-2009.

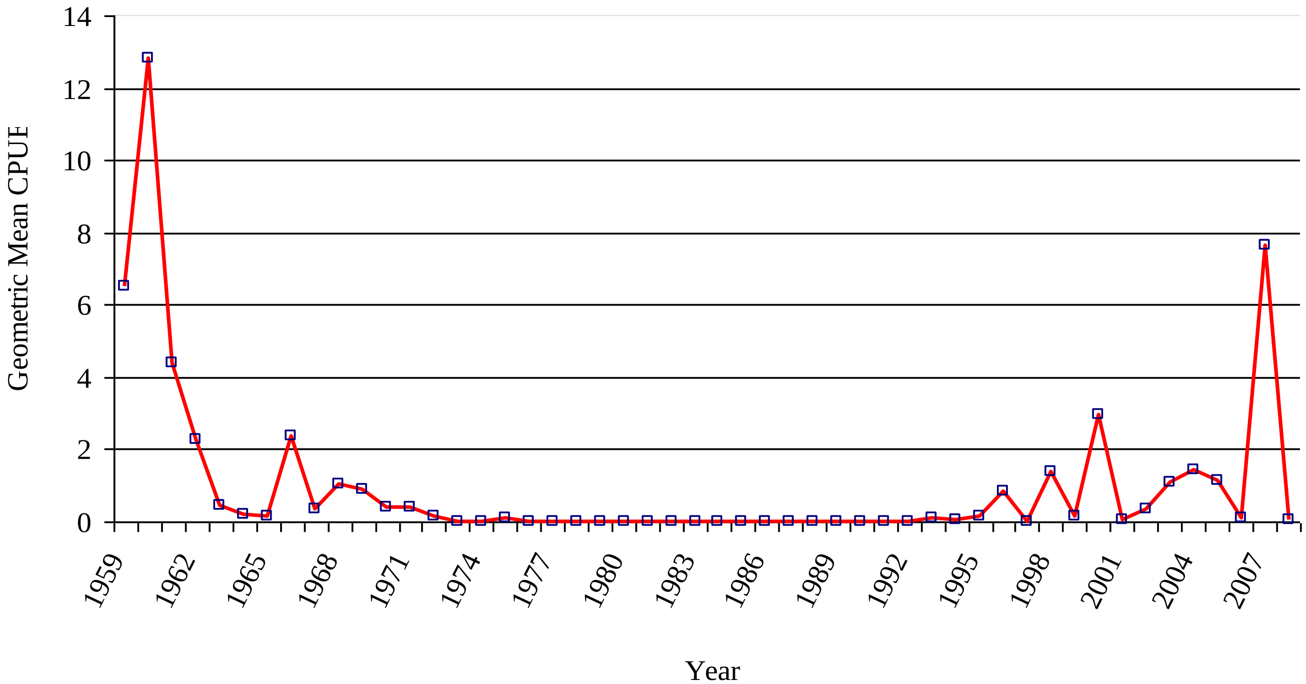

Figure 9. Abundance of juvenile American shad above Holtwood Dam, Susquehanna River.

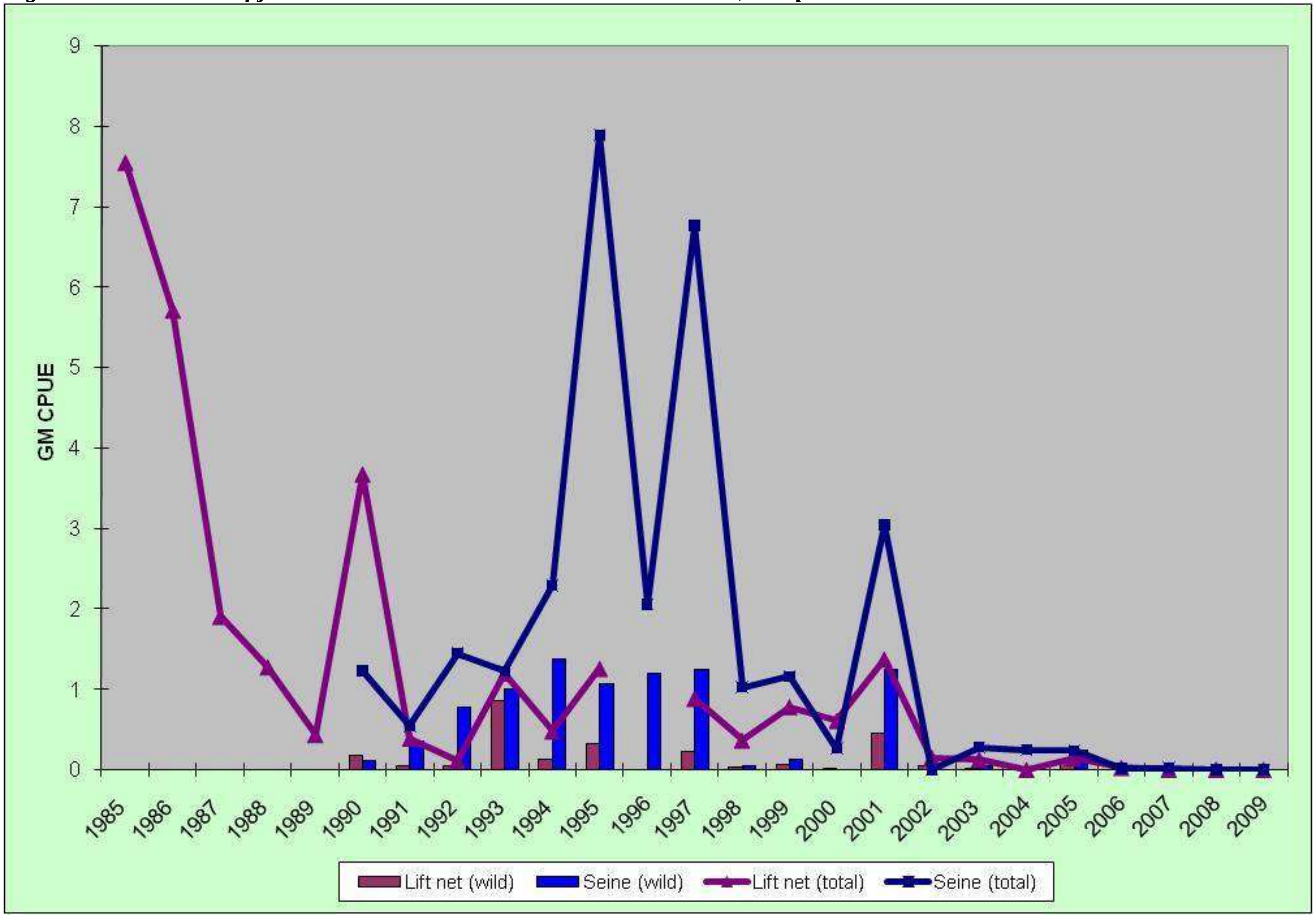

Figure 10. Geometric mean CPUE (catch-per-lift-hour) of American shad from the lifts at Conowingo Dam, 1980-2009.

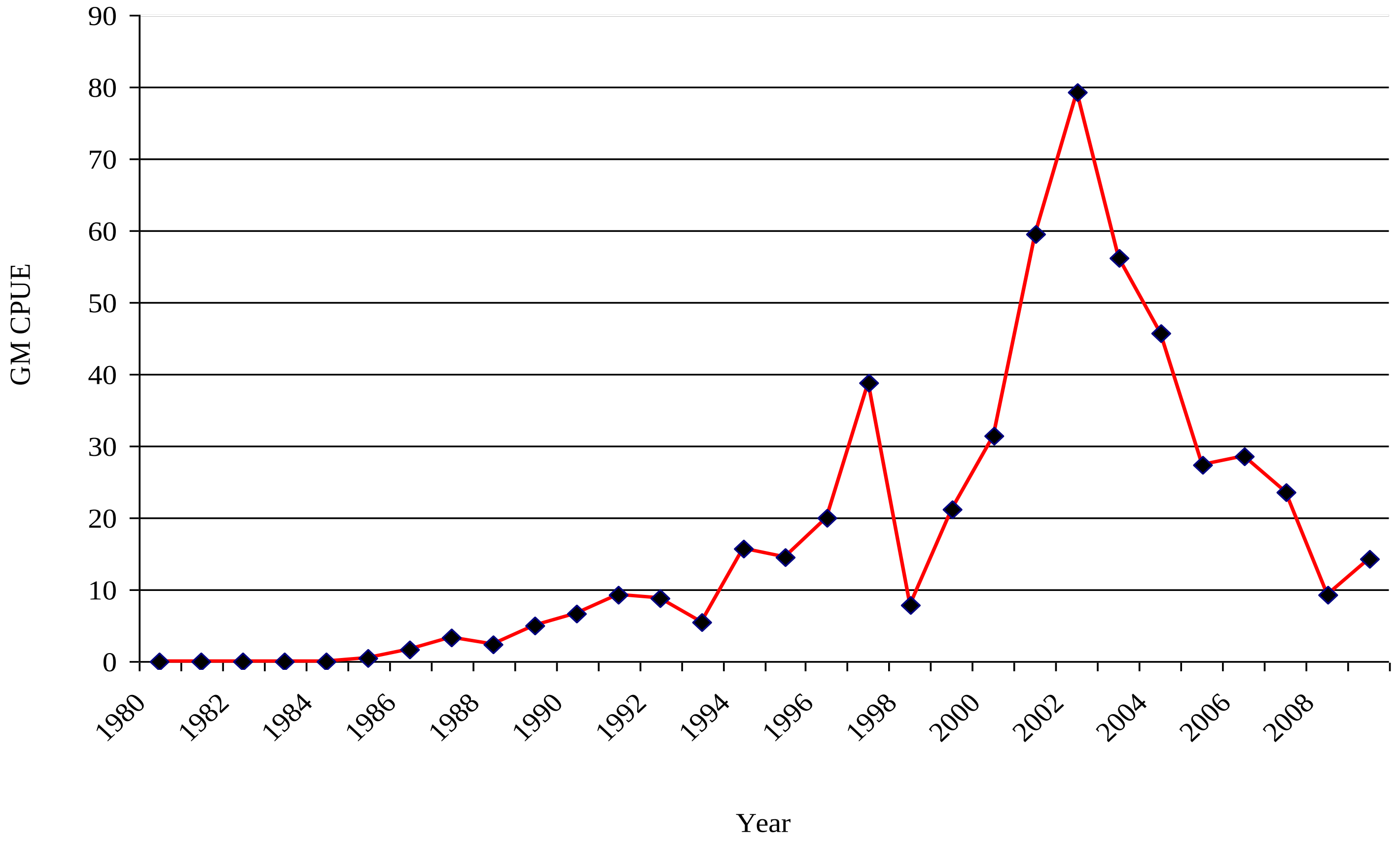

Figure 11. Pound net geometric mean CPUE (catch-per-pound-net-day) from the Susquehanna Flats, 1988-2001.

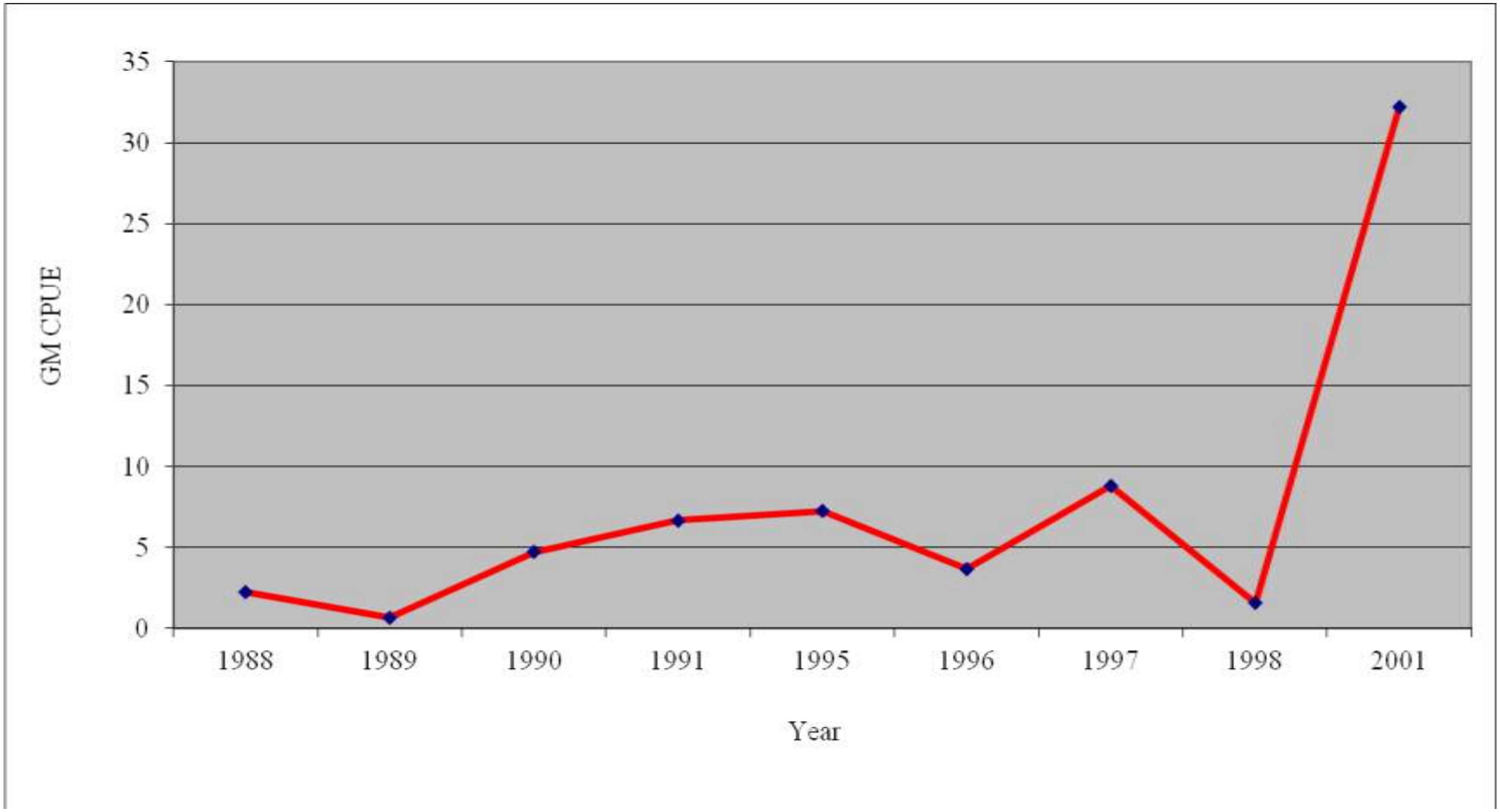

Figure 12. Geometric mean CPUEs (catch-per-angler hour) from Conowingo Dam tailrace hook and line sampling, 1984-2009.

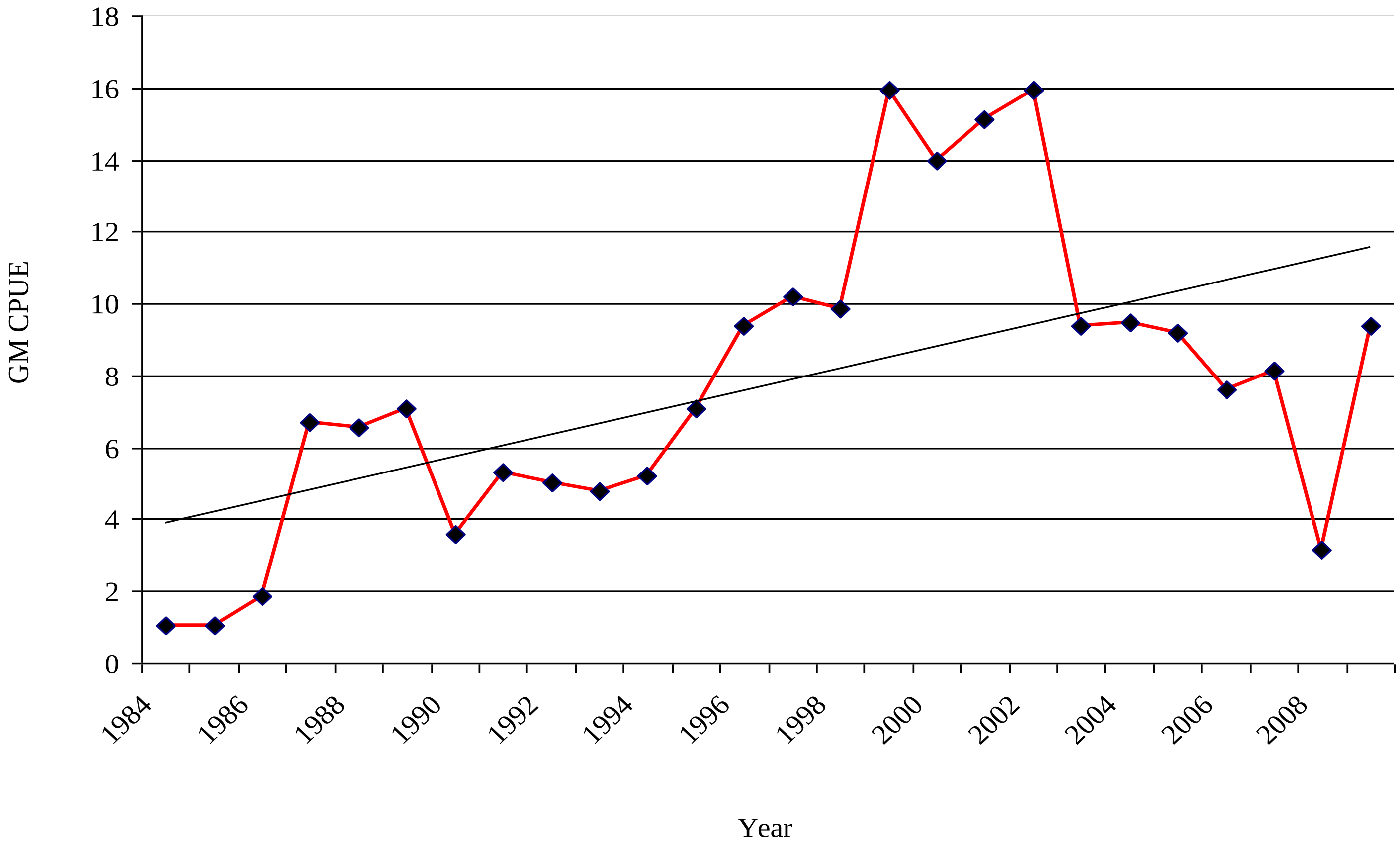

Figure 13. Conowingo Dam tailrace population estimates of American shad, 1985-2009.

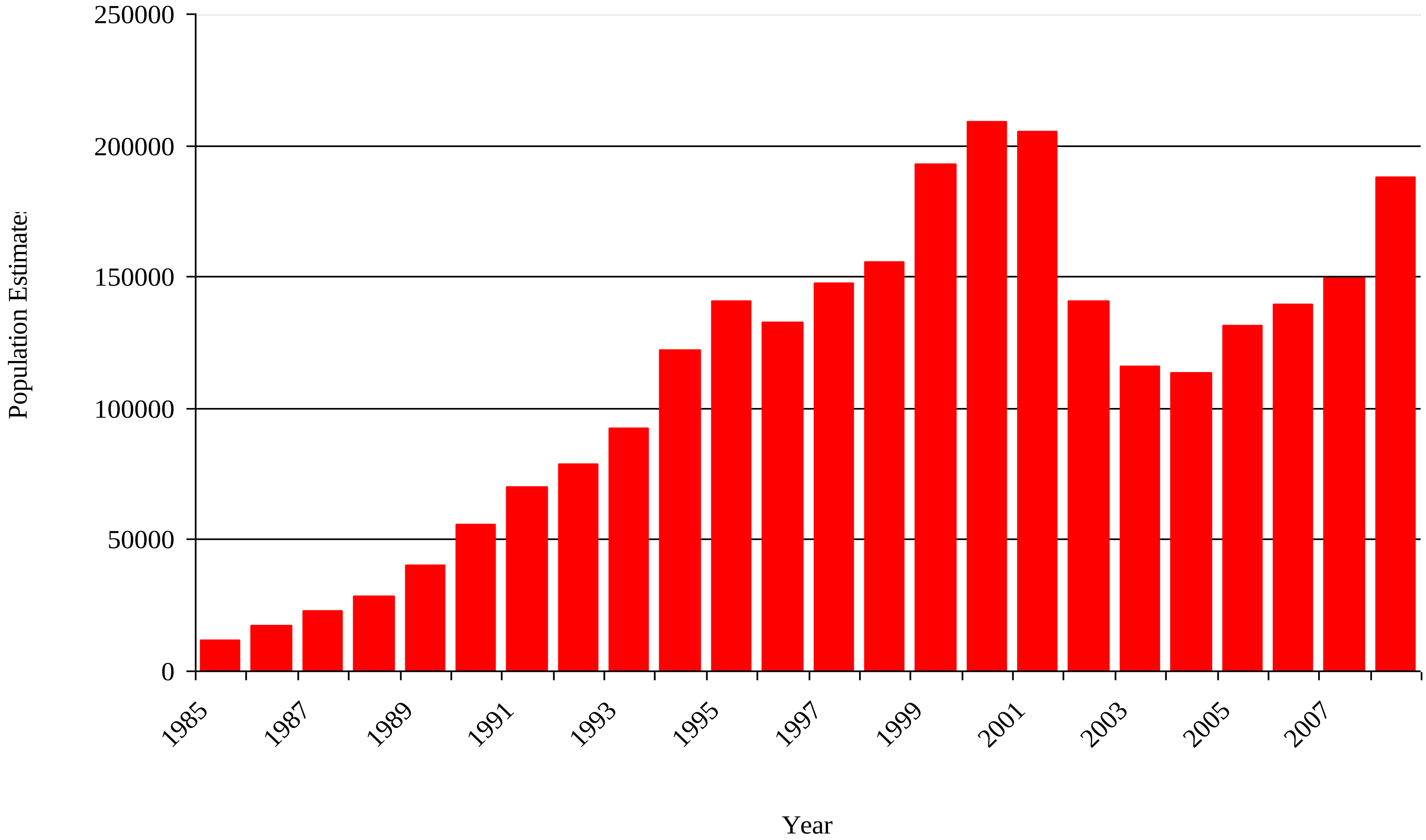

Figure 14. Striped bass gill net catch per unit effort from the upper Chesapeake Bay.

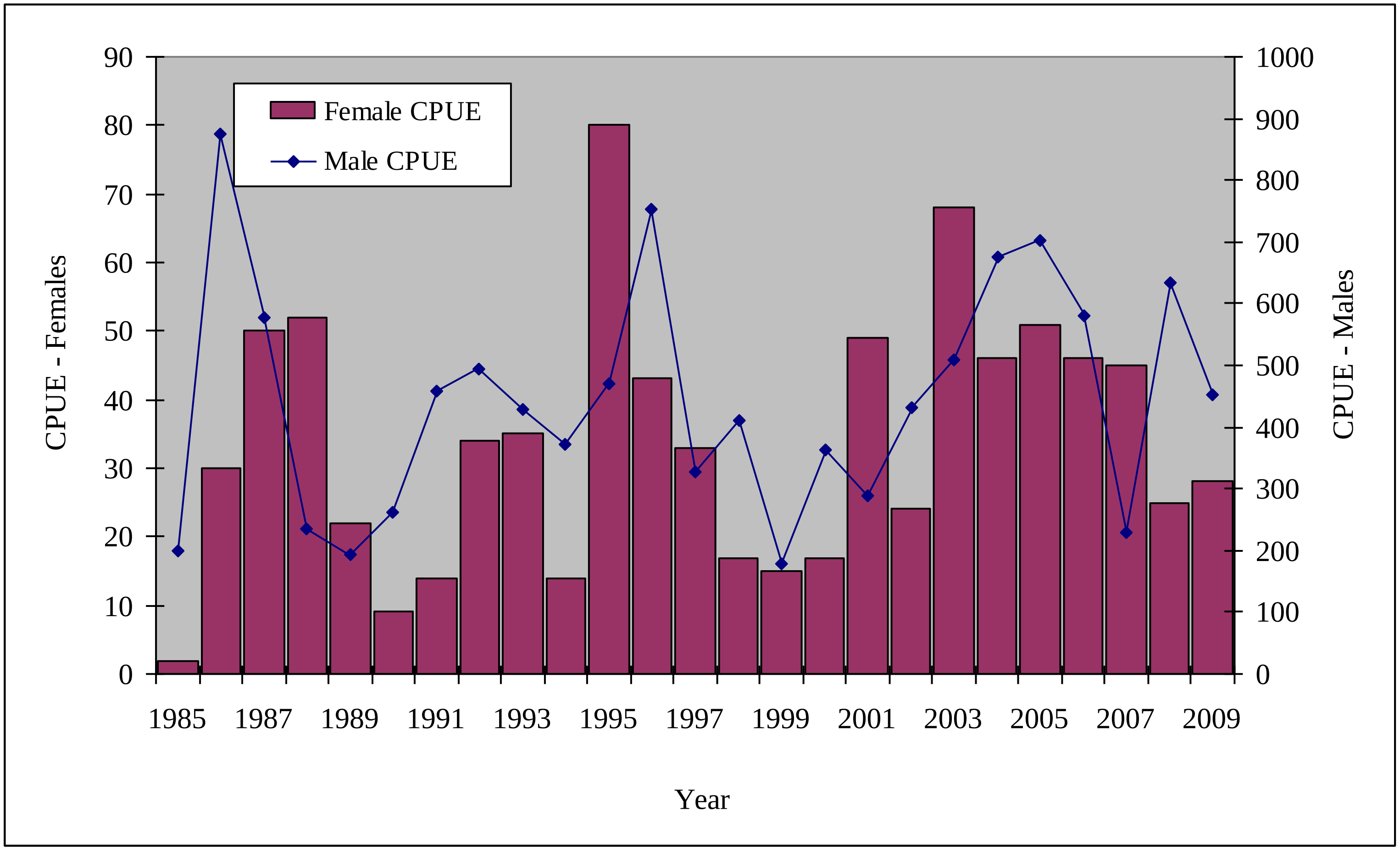

Figure 15. Annual commercial striped bass landings in Maryland's Chesapeake Bay.

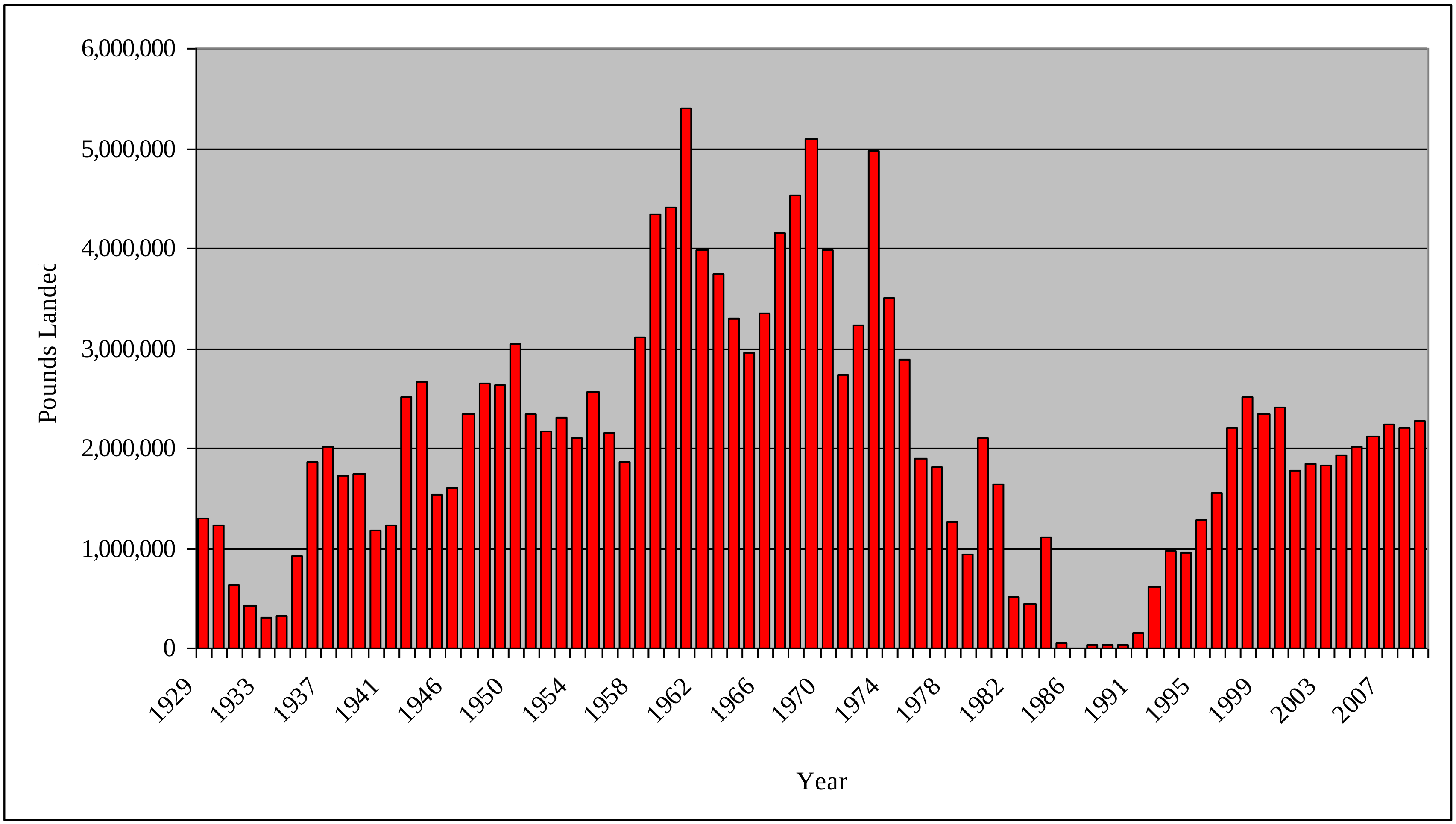

Figure 16. Juvenile striped bass index for the upper Chesapeake Bay.

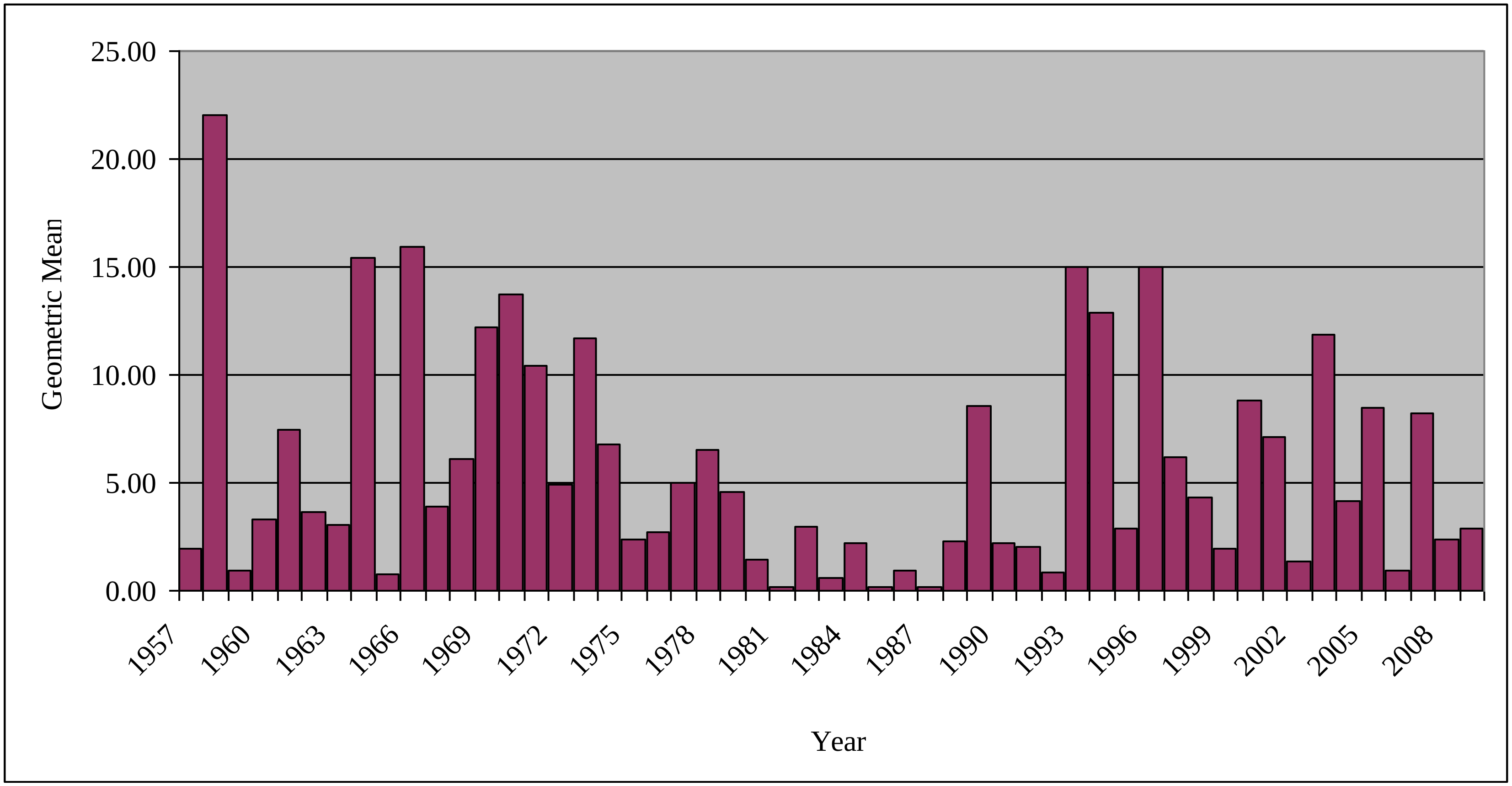

Figure 17. Annual catch of striped bass from Conowingo Dam's fish lifts and associated catch-per-operating-hour of striped bass from the west lift.

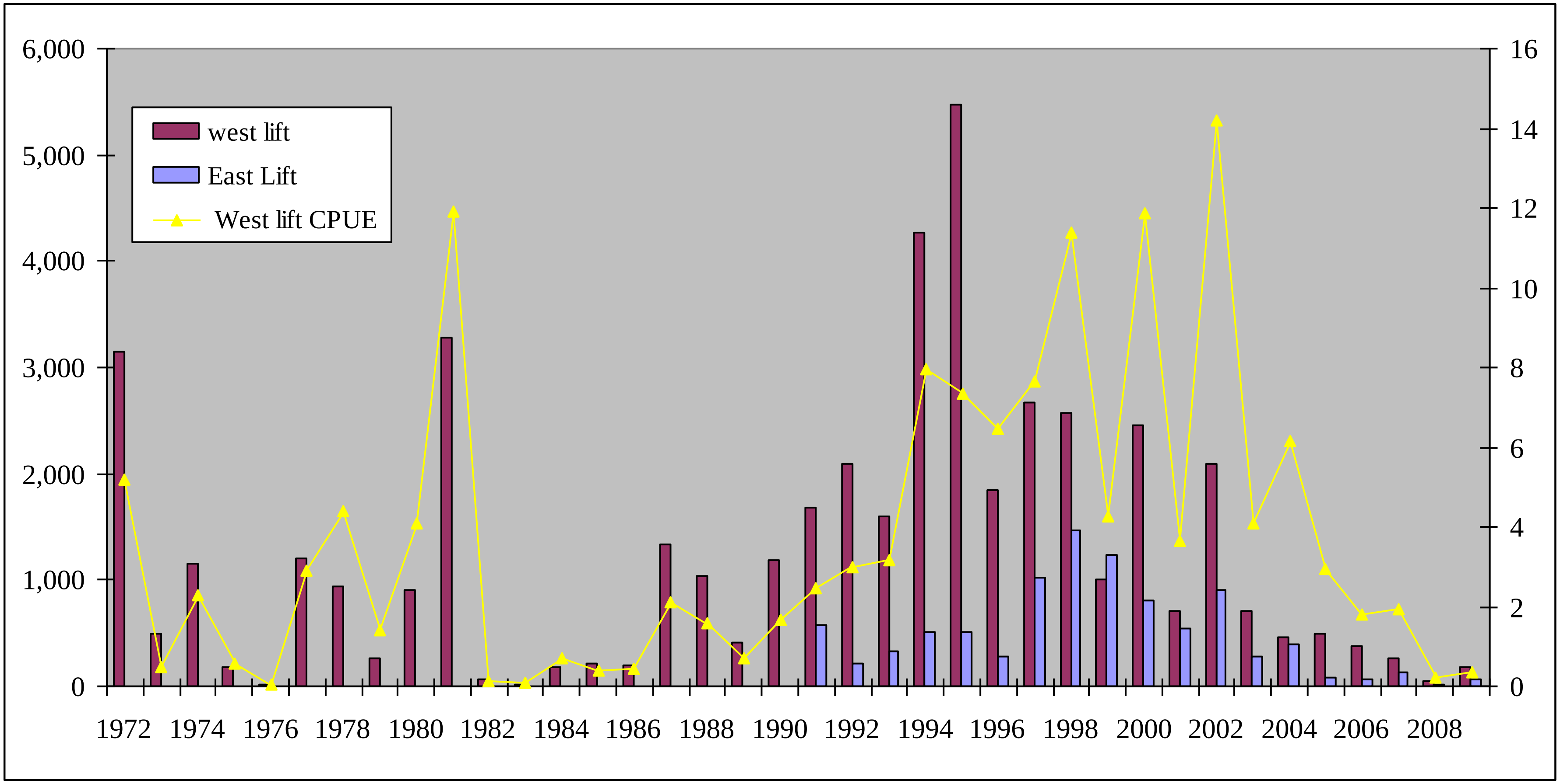

Table 1. Summary of American Shad egg, larvae, fingerling, and adult stocking activities in the Susquehanna River above dams, 1971-2009.

Year	Eggs planted (millions)	Hatchery fry/fing. (millions)	Pre-spawn adults (out-of-basin)	Adults from Conowingo Dam Fish Lifts		
				Catch	Hauled	Passed
1971	8.4	-	-	-	-	-
1972	7.1	-	-	182	-	-
1973	58.6	-	-	65	-	-
1974	50	-	-	121	-	-
1975	33.2	-	-	87	-	-
1976	54	0.78	-	82	-	-
1977	11	1.04	-	165	-	-
1978	-	2.13	-	54	-	-
1979	-	0.66	-	50	-	-
1980	-	3.53	114	139	-	-
1981	-	2.05	1,165	328	-	-
1982	-	5.06	2,565	2,039	800	
1983	-	4.15	4,310	413	64	-
1984	-	12.03	3,777	167	0	-
1985	-	6.34	2,834	1,546	967	-
1986	-	9.97	4,965	5,195	4,172	-
1987	-	5.26	6,051	7,667	7,202	-
1988	-	6.53	-	5,146	4,736	-
1989	-	13.53	-	8,218	6,469	-
1990	-	5.71	-	15,719	15,075	-
1991	-	7.27	-	27,227	24,662	-
1992	-	3.06	-	25,721	15,674	-
1993	-	6.62	-	13,546	11,717	-
1994	-	6.56	-	32,330	28,681	-
1995	-	10	-	61,650	56,370	-
1996	-	7.47	-	37,512	33,825	-
1997	-	8.04	-	103,945	10,528	90,971
1998	-	11.76	-	46,481	4,593	39,904
1999	-	13.50	-	79,370	5,508	69,712
2000	-	9.79	-	163,330	1,351	153,546
2001	-	6.53	-	204,514	0	193,574
2002	-	2.59	-	117,348	0	108,001
2003	-	12.74	-	134,937	0	125,135
2004	-	5.64	-	112,786	0	109,360
2005	-	5.21	-	72,822	0	68,926
2006	-	4.95	-	60,335	0	56,899
2007	-	1.38	-	27,765	0	25,464
2008	-	2.49	-	22,541	0	19,914
2009	-	3.07	-	35,806	0	29,272
Totals	222.30	207.43	25,781	1,427,349	232,394	1,090,678

Table 2. Stocking of American shad larvae in the Susquehanna River basin.

Map ID	River/Stream	Site	Life Stage	Years	Amount
1	Conodoguinet Creek	Near Hogestown	Eggs	70, 73-74, 77	21,304,000
2	Juniata River	Muskrat Springs	Eggs	70-71, 73-76	89,529,880
3	Beaver Creek	Tributary to Pequea Creek	Eggs	70, 73-74	1,100,000
4	Pequea Creek	Pequea Creek	Eggs	70, 73-76	13,100,000
5	Susquehanna River	Fishing Creek	Eggs	77	1,360,000
6	Susquehanna River	Montgomery Ferry	Eggs	70, 73, 77-78, 89	10,207,060
7	Susquehanna River	Muddy Creek	Eggs	77	640,000
8	Susquehanna River	Sunbury	Eggs	71	6,456,560
9	Yellow Breeches Creek	Yellow Breeches Creek	Eggs	74-76	70,660,000
10	Tioughnioga River	Factory Brook, near Cortland	Eggs	75	400,000
11	Susquehanna River	Below Conowingo Dam	Fry	86-90, 92	22,790,385
12	Conestoga River	Conestoga Pines Park	Fry	96-98	737,100
13	Conestoga River	Conestoga River (Mouth)	Fry	95	190,000
14	Conestoga River	Route 322	Fry	96, 99-04, 06-08	1,548,720
15	Conodoguinet Creek	Conodoguinet Cr. (Mouth)	Fry	95	230,000
16	Conodoguinet Creek	North Middleton Park	Fry	96-04, 06-08	2,069,680
17	Juniata River	Arch Rock	Fry	97-98, 00	881,705
18	Juniata River	Huntingdon	Fry	97, 03-06	4,005,827
19	Juniata River	Lewistown	Fry	97	424,000
20	Juniata River	Mexico	Fry	97-02, 04-05	3,895,810
21	Juniata River	Mifflin	Fry	97-01, 04-05	4,729,015
22	Juniata River	Miller's Canoe Rental	Fry	97-01, 04	4,128,719
23	Juniata River	Millerstown (Greenwood)	Fry	95-05	15,483,413
24	Juniata River	Millerstown (Rt. 17 Bridge)	Fry	97-08	11,386,159
2	Juniata River	Muskrat Springs	Fry	97-00, 02	3,458,042
25	Juniata River	Standing Stone Creek	Fry	98	42,900
26	Juniata River	Thompsontown	Fry	76-83, 85-95, 97-00, 02, 04-06	82,180,841
27	Juniata River	Treaster's Exxon	Fry	97-99	2,015,000
28	Juniata River	Tuscarora Creek, Pleasant View	Fry	03	248,890
29	Juniata River	Warrior Ridge Dam	Fry	03	932,442
30	Muddy Creek	Muddy Creek	Fry	95	93,000
31	Susquehanna River	Clark's Ferry	Fry	04	50,000
32	Susquehanna River	Clem son Island	Fry	01, 05-08	1,059,378
33	Susquehanna River	Liverpool	Fry	00-01, 03, 05	3,696,567
34	Susquehanna River	Mahantango	Fry	00, 03	924,256
35	Susquehanna River	Millersburg	Fry	01	637,580
6	Susquehanna River	Montgomery Ferry	Fry	95-98, 00-01, 03-04	9,152,498
36	Susquehanna River	Nesbit Park	Fry	96-97	1,881,500
37	Susquehanna River	Test Track Park	Fry	98-99, 07-08	2,783,175
38	Susquehanna River	Tunkhannock	Fry	00-04, 06	3,226,124
39	Swatara Creek	Boathouse Road Park	Fry	98-04, 06-08	1,265,302
40	West Banch Susquehanna River	Bald Eagle Creek	Fry	01, 06-08	632,353
41	West Banch Susquehanna River	Muncy	Fry	97-04	3,240,538
42	West Banch Susquehanna River	Susquehanna State Park	Fry	05-08	2,125,965
43	West Conewago Creek	Upstream of Detter's Mill Dam	Fry	96, 98-01, 03-04, 06-08	2,131,357
44	Chemung River	Dunn Field	Fry	02-04, 06	674,267
45	Chemung River	Route 8 Bridge, Wellsburg	Fry	03-04, 06	455,884
46	Susquehanna River	Appalachin Boat launch	Fry	02-04, 06	756,813
47	Susquehanna River	Rock Bottom Dam	Fry	02-04, 06	616,882
11	Susquehanna River	Below Conowingo Dam	Fingerling	85, 90, 92	218,300
48	Susquehanna River	Havre deGrace	Fingerling	91	111,500
18	Juniata River	Huntingdon	Fingerling	05	1,250
25	Juniata River	Standing Stone Creek	Fingerling	98	2,200
26	Juniata River	Thompsontown	Fingerling	76-83, 85-94	1,194,777
29	Juniata River	Warrior Ridge Dam	Fingerling	01	6,500
49	Susquehanna River	Conowingo Reservoir	Fingerling	85	30,150
39	Swatara Creek	Boathouse Road Park	Fingerling	97	25,000
50	Susquehanna River	Columbia	Transfers from Conowingo	98, 00	1,081
51	Susquehanna River	Conestoga	Transfers from Conowingo	00	495
52	Susquehanna River	Middletown	Transfers from Conowingo	82-83, 85-99	230,924
7	Susquehanna River	Muddy Creek	Transfers from Conowingo	00	59
38	Susquehanna River	Tunkhannock	Out-of-Basin Transfers	80-87	26,262
53	Susquehanna River	Owego	Out-of-Basin Transfers	82	1,005

Table 3. ***Annual catch of river herring and hickory shad at the Conowingo West Fish Lift, 1972-1989***

Year	Bluebacks	Alewives	Hickory shad
1972	58,198	10,345	429
1973	330,341	144,727	739
1974	340,084	16,675	219
1975	69,916	4,311	20
1976	35,519	235	0
1977	24,395	188	1
1978	13,098	5	0
1979	2,282	9	0
1980	502	9	1
1981	618	129	1
1982	25,249	3,433	15
1983	517	50	5
1984	311	26	6
1985	6,763	379	9
1986	6,327	2,822	45
1987	5,861	357	35
1988	14,570	674	64
1989	3,598	1902	28

Table 4. Conowingo Dam river herring and hickory shad catch and upstream stocking, 1990-2009.

Year	East Lift			West Lift			No. Transported Above Dams		
	Blueback	Alewife	Hickory shad	Blueback	Alewife	Hickory shad	Blueback	Alewife	Hickory shad
1990	0	0	0	9,658	425	77	1,027	7	0
1991	13,149	323	0	15,616	2,649	120	2,605	1,396	0
1992	7,347	314	0	27,533	3,344	376	12,435	233	0
1993	4,574	0	0	4,052	572	0	1,130	203	0
1994	248	5	0	2,603	70	1	286	58	0
1995	4,004	170	0	93,859	5,405	36	17,935	3,120	0
1996	261	3	0	871	1	0	410	0	0
1997	242,815	63	0	133,257	11	118	27,783	1	0
1998	700	6	0	5,511	31	6	4,755	0	0
1999	130,625	14	0	8,546	1,795	32	2,204	0	0
2000	15,000	2	0	14,326	9,189	1	4,783	2,026	0
2001	284,921	7,458	0	16,320	7,824	36	5,049	1,820	0
2002	2037	74	6	428	141	0	0	0	0
2003	530	21	0	183	16	1	0	0	0
2004	101	89	0	1	0	0	0	0	0
2005	0	0	0	4	0	0	0	0	0
2006	0	0	4	6	2	0	0	0	0
2007	460	429	0	153	7	0	0	0	0
2008	1	1	0	7	2	0	0	0	0
2009	71	160	0	165	20	4	0	0	0

Note: All fish counted at the East Lift since 1997 were passed directly into Conowingo Pond.

Table 5. American eels (thousands) transported into Pennsylvania waters of the Susquehanna River from Maryland, 1936-1980.

County	Water	1936	1941	1942	1946	1957	1958	1959	1960	1961	1962	1963	1964	1965	1968	1978	1979	1980	2008	2009
Bedford	Dunning Ck.												500							
Bedford	Juniata R. Raystown Br.												167	100	100					
Centre	Black Moshannon Lake	15	12	2																
Centre	Bald Eagle Ck.	15	12		8							90	69	83						
Clinton	Kettle Ck.											90								
Clinton	Bald Eagle Ck.										375	90	554	83						
Columbia	Fishing Ck.								500											
Cumberland	Susquehanna R.																300			
Cumberland	Conodoguinet Ck.								175	25	156	50	83	100						
Cumberland	Yellow Breeches Ck.								5											
Huntingdon	Aughwick Ck.						35	97	524	50	156	50	83	100						
Huntingdon	Raystown Dam																			
Huntingdon	Juniata R., Raystown Br.						48	110	353	50		50	167	100						
Huntingdon	Juniata R.									75	156									
Juniata	Cocolamus Ck.									75	156	50								
Juniata	Tuscarora Ck.					3	39	97	496	50	156	50	83	100						
Lancaster	Susquehanna R.															1,000				
Lancaster	Conowingo Cr.																			17
Lancaster	Conestoga R.																		17	
Lycoming	Susquehanna W. Br.																			
Lycoming	Pine Ck.										375									
McKean	Allegheny R.											90								
McKean	Marvin Ck.											90								
McKean	Potato Ck.											90								
Mifflin	Kishacoquillis Ck.													100						
Mifflin	Jacks Ck.									75		50		100						
Montour	Chillisquaque Ck.							72	196	0	375	90	69	83						
Montour	Mahoning Ck.						30	70	228	200	375	90	69	83						
Montour	Susquehanna R., N. Br.					6		35		300										
Montour	Susquehanna R.						70	35												
Northumberland	Susquehanna R., N. Br.						40	42		300					50					
Perry	Susquehann R.															20	183	108		
Perry	Juniata R.															15	300	108		
Perry	Buffalo Ck.						39	97	335	50	156	50								
Perry	Shermans Ck.					2	39	97	367	50	156	50	83	100	100					
Snyder	Middle Ck. Lake													83						
Snyder	Middle Ck.						50	49	413	200		90								
Snyder	Mussers Dam						40	98		300										
Snyder	Penns Cr.k						90	135	413	400		90		83						
Tioga	Pine Cr.																			1
	Total	**30**	**24**	**2**	**8**	**11**	**520**	**1,035**	**4,005**	**2,200**	**2,594**	**1,300**	**1,928**	**1,300**	**250**	**1,035**	**783**	**216**	**17**	**18**
																			Grand total	**17,276**

Table 6. American shad passage counts at Susquehanna River dams, 1997-2009.

Year	Conowingo (rm 10.0)	Holtwood (rm 24.6)	Safe Harbor (rm 32.2)	York Haven (rm 56.1)	Holtwood %	Safe Harbor %	York Haven %	Combined %
1997	90,971	28,063	20,828	-	31%	74%	-	-
1998	39,904	8,235	6,054	-	21%	74%	-	-
1999	69,712	34,702	34,150	-	50%	98%	-	-
2000	153,546	29,421	21,079	4,687	19%	72%	22%	3%
2001	193,574	109,976	89,816	16,200	57%	82%	18%	8%
2002	108,001	17,522	11,705	1,555	16%	67%	13%	1%
2003	125,135	25,254	16,646	2,536	20%	66%	15%	2%
2004	109,360	3,428	2,109	219	3%	62%	10%	0%
2005	68,926	34,189	25,425	1,772	50%	74%	7%	3%
2006	56,899	35,968	24,929	1,913	63%	69%	8%	3%
2007	25,464	10,338	7,215	192	41%	70%	3%	1%
2008	19,914	2,795	1,252	21	14%	45%	2%	0%
2009	29,272	10,896	7,994	402	37%	73%	5%	0%
Total	1,061,406	339,891	261,208	29,095	32%	71%	10%	2%

Note: Although the Conowingo East lift began operating in 1991, fish were sorted and transported upstream by truck until 1997.

Table 7. American Shad population trend based on tag and recapture (MDNR) and stock origin (hatchery vs. wild) of adults based on otolith analysis from fish collected at Conowingo Dam.

Year	Total catch	Wild (%)	Hatchery (%)	Upper Bay Estimate	Tailrace Estimate
1984	167	-	-	8,074	3,516
1985	1,546	-	-	14,283	7,876
1986	5,195	-	-	22,902	18,134
1987	7,667	-	-	27,354	21,823
1988	5,146	-	-	42,683	28,714
1989	8,218	19	81	75,820	43,650
1990	15,719	27	73	123,830	59,420
1991	27,227	27	73	139,862	84,122
1992	25,721	23	77	105,255	86,416
1993	13,546	17	83	47,563	32,529
1994	32,330	10	90	129,482	94,770
1995	61,650	15	85	333,891	210,546
1996	37,513	45	55	203,216	112,217
1997	103,945	60	40	708,628	423,324
1998	46,481	71	29	487,810	314,904
1999	79,370	47	53	684,316	583,198
2000	163,331	54	46	1,357,400	961,542
2001	204,514	35	65	693,033	560,912
2002	117,348	34	66	-	578,319
2003	134,937	26	74	-	487,073
2004	112,786	28	72	-	1,005,797
2005	72,822	35	65	-	322,920
2006	60,335	50	50		131,326
2007	27,765	52	48		139,283
2008	22,541	57	43		149,676
2009	35,806	62	38		188,113

Table 8. PFBC Area Fisheries Managers ratings on the suitability of stream sections in the Susquehanna River Basin for restoration of migratory fish.

Stream section	Suitability	Comments
A. Major River Segments		
Susquehanna mainstem		
Mouth to Sunbury	highly suitable	
North Branch		
Sunbury to Hunlock Cr.	highly suitable	
Hunlock Cr. to Lackawanna R.	moderately suitable	AMD; inadequate sewage treatment
Lackawanna R. to NY line	highly suitable	
Chemung River		
NY line to Mouth	moderately suitable	
West Branch		
Confluence to Loyalsock Cr.	highly suitable	
Loyalsock Cr. to Bald Eagle Cr.	moderately suitable	acid mine drainage
Bald Eagle Cr. upstream	unsuitable	acid mine drainage
Juniata River	highly suitable	
B. Rated Tributaries		
Muddy Cr.	highly suitable	
Otter Cr.	highly suitable	
Pequea Cr.	moderately suitable	Farm runoff, siltation
Conestoga River	highly suitable	
Chickies Cr.	moderately suitable	Farm runoff, siltation
Codorus Cr.	unsuitable	industrial waste, urban run-off
Conewago Cr. (East)	unsuitable	Farm runoff, siltation
Conewago Cr. (West)	highly suitable	
Swatara Cr.	highly suitable	
Yellow Breeches Cr.	highly suitable	
Conodoguinet Cr.	moderately suitable	inadequate sewage treatment, farm run-off
Sherman's Cr.	highly suitable	
C. Unrated Tributaries		
Juniata to Sunbury tribs	not rated	
West Branch tribs	not rated	
Sunbury to NY line tribs	not rated	
NY to Binghamton tribs	highly suitable	
Chemung River and Tribs	highly suitable	

Note: Classifications were based upon Area Fisheries Manager's subjective knowledge of water quality and fish and invertebrate diversity.

Table 9. Recreational creel survey data from the Susquehanna River below Conowingo Dam, 2001-2009.

Year	Number of Interviews	Total Fishing Hours	Total Catch of American Shad	Mean Number of American shad caught per hour
2001	90	202.9	991	4.88
2002	52	85.3	291	3.41
2003	65	148.2	818	5.52
2004	97	193.3	233	1.21
2005	29	128.8	63	0.49
2006	78	227.3	305	1.34
2007	30	107.5	128	1.19
2008	16	32.5	24	0.74
2009	40	85.0	120	1.41

Table 10. Summary of the spring American shad logbook data, 1999-2009.

Year	Number of Returned Logbooks	Total Reported Angler Hours	Total Number of American Shad Caught	Mean Number of American Shad Caught Per Hour
1999	7	160.5	463	2.88
2000	10	404.0	3,137	7.76
2001	8	272.5	1,647	6.04
2002	8	331.5	1,799	5.43
2003	9	530.0	1,222	2.31
2004	18	750.0	1,035	1.38
2005	18	567.0	533	0.94
2006	19	227.3	305	1.34
2007	10	285.5	853	2.99
2008	16	568.0	1,269	2.23
2009	10	378.0	967	2.60

Table 11. Data from American shad tagged in the tailrace and recaptured at Conowingo Dam (lifts combined) 1984-2009.

Number Tagged	Number Tagged	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1984	96	7	2																								
1985	151		32	1																							
1986	256			76	6	1																					
1987	319				100	0																					
1988	221					37	0																				
1989	253						46	0	1																		
1990	286							52	5																		
1991	377								120	5	1																
1992	342									101	7			1													
1993	245										98	2	3														
1994	429											143	10	1													
1995	556												147	16													
1996	398													129	3												
1997	554														129	17											
1998	279															31	0	0	0								
1999	759																103	5	2	0							
2000	687																	116	20	4							
2001	902																		297	0	0	1	0				
2002	788																			132	8	0	1	1			
2003	734																				189	7	4	1			
2004	385																					36	27	0			
2005	405																						78	1	0	0	
2006	368																							94	1	0	
2007	449																								97	18	
2008	160																									10	3
2009	668																										104

Table 12. List of species caught at Conowingo Dam since 1972.

Alewife	Muskellunge
American Eel	Northern Hogsucker
American Shad	Northern Pike
Atlantic Menhaden	Palomino Trout
Atlantic Needlefish	Pumpkinseed
Banded Darter	Quillback
Bigmouth Buffalo	Rainbow Smelt
Black Crappie	Rainbow Trout
Blacknose Dace	Redbreast Sunfish
Blueback Herring	Redfin Pickerel
Bluegill	River Chub
Bluntnose Minnow	Rock Bass
Brook Trout	Rosyface Shiner
Brown Bullhead	Salmo Sp.
Brown Trout	Sea Lamprey
Carp	Shield Darter
Carps & Minnows	Shiners
Chain Pickerel	Shorthead Redhorse
Channel Catfish	Smallmouth Bass
Comely Shiner	Splake
Common Shiner	Spotfin Shiner
Creek Chub	Spottail Shiner
Creek Chubsucker	Striped Bass
Flathead Catfish	Striped Bass x White Bass
Gizzard Shad	Striped Bss x Wht Perch
Golden Shiner	Striped Mullet
Goldfish	Sunfish Hybrids
Green Sunfish	Swallowtail Shiner
Greenside Darter	Tadpole Madtom
Herrings	Tessellated Darter
Hickory Shad	Tiger Muskie
Lake Herring	Walleye
Lampreys	White Catfish
Largemouth Bass	White Crappie
Log Perch	White Perch
Longnose Dace	White Sucker
Margined Madtom	Yellow Bullhead
Mummichog	

Table 13. Summary of 2008 Maryland striped bass commercial and recreational removals-at-age (harvest) in numbers of fish.

	Catch at age (numbers of fish)										
Fishery:	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13+**	**Total**
Comm. Atl Gill net, Trawl	0	249	3,358	1,649	4,650	2,225	650	316	320	316	273	**14,004**
Comm. CB Gill net	4,615	34,396	141,737	28,221	28,655	12,168	2,744	3,812	1,377	1,611	412	**259,749**
Comm. CB Hook and Line	2,144	87,492	43,318	12,663	2,151	1,224	1,122	218	46	40	62	**150,480**
Comm. CB Pound Net	546	85,323	44,063	29,734	4,857	2,667	2,173	571	135	222	129	**170,422**
Rec. Wave 2 CB	0	0	34	120	1,558	2,370	3,181	3,275	3,573	5,673	3,605	**23,389**
Rec. Wave 3 CB	0	12,297	41,438	7,186	10,468	9,600	8,578	8,167	7,955	11,794	6,447	**123,927**
Rec. Waves 4-6 CB	209	20,372	131,806	25,110	39,072	28,386	15,257	13,892	12,746	20,743	14,090	**321,681**
Rec Atlantic	0	0	0	0	0	0	0	0	0	0	0	**0**
Harvest Total	**7,514**	**240,129**	**405,754**	**104,683**	**91,412**	**58,640**	**33,705**	**30,250**	**26,152**	**40,397**	**25,017**	**1,063,652**

Appendixes

Appendix 1. Life History of Migratory Fishes

On the Atlantic Coast of the United States, the genus *Alosa* within the clupeid (herring) family is represented by four species: American and hickory shad and alewife herring and blueback herring. These species are all anadromous, i.e., they reproduce in freshwater reaches of most tributaries along the coast and spend several years maturing at sea. The following accounts were adapted largely from Chesapeake Executive Council (1989) and Greene et al. (2009).

American shad (*Alosa sapidissima*)

Fecundity: 113,000 to 659,000; higher in southern range, lower in north.
Spawning season: mid-April through mid-June in the upper Bay and Susquehanna River.
Spawning area: Tidal freshwater, upstream to areas far upstream from the head of tide.
Salinity: 0 to 2.0 parts per thousand (ppt).
Flow: 0.5 to 3.0 feet/second required for spawning.
Temperature: 55 to 72F for spawning (peak at 60 to 65F).
Outmigration (juveniles): October to December, primarily during evening hours; correlated to decrease in temperature and increase in flow.
Maturation: Majority of males mature at 4 years of age, females at 5 years.
Repeat spawning: Common in northern range, non-existent in south; approximately 10 to 20 percent expected in the upper Chesapeake Bay/Susquehanna River.

Hickory shad (*Alosa mediocris*)

Fecundity: 43,000 to 350,000.
Spawning season: April through May in the Chesapeake Bay.
Spawning area: Tidal and lowland freshwater, near the fall line.
Spawning activity: Primarily evenings.
Salinity: Similar to American shad.
Flow: Similar to American shad.
Temperature: 59 to 66F for spawning.
Outmigration (juveniles): Early summer.
Maturation: Majority mature at age two for males and three for females.
Repeat spawning: 10 to 80 percent.

Blueback herring (*Alosa aestivalis*)

Fecundity: 43,000 to 400,000.
Spawning season: April through mid-May in the Chesapeake Bay.
Spawning area: Swift flowing, relatively deep freshwater from the head of tide upstream.
Spawning activity: Primarily evenings.
Salinity: 0 to 6.0 ppt, mostly below 1.0 ppt.
Temperature: 57 to 80F for spawning.

Outmigration (juveniles): Autumn.
Maturation: Majority at four years of age for both sexes.

Alewife (*Alosa pseudoharengus*)

Fecundity: 100,000 to 467,000.
Spawning season: Late March through April in the Chesapeake Bay.
Spawning area: Sluggish tidal and lowland freshwater near the fall line, less than one foot deep.
Spawning activity: Primarily evenings.
Salinity: 0 to 6.0 ppt, mostly below 1.0 ppt.
Temperature: 50 to 70F for spawning.
Outmigration (juveniles): Autumn.
Maturation: Majority at four years of age for both sexes.

Gizzard shad (*Dorosoma cepedianum*)

Fecundity: Up to 500,000.
Spawning season: April through July in freshwater areas.
Spawning area: Shallow water less than 1.5 meters deep.
Salinity: Freshwater.
Flow: Moderate.
Temperature: Range from 50F to 73F but normally greater than 59F
Maturation: Males at age one, females at age two.
Repeat spawning: Yes.

Gizzard shad are a very adaptive resident species of the Chesapeake Bay and its tributaries but are less desirable in the eyes of anglers because of their poor palatability. Sexual maturity occurs when fish are one to two years old. Gizzard shad prefer to spawn over rocky or sandy substrate, and spawning occurs during April through May in the Upper Chesapeake Bay area at temperatures of 21°C. Young-of-year fish prefer shallow water, over-winter in deeper bay waters, and feed on detritus. Adults are more benthic feeders. Winter mortality occurs at temperatures below 3°C.

Gizzard shad are an important prey species in the Chesapeake Bay and tributaries, as is also the case in many inland lakes and reservoirs where they have been introduced as a forage species or via bait bucket releases. Gizzard shad influence fish communities and nutrient cycling, particularly in hypereutrophic lakes where they often dominate total fish biomass (Heidinger 1983). Gizzard shad adults forage at the sediment-water interface on detritus, algae, and zooplankton. Subsequent excretion of nutrients into the water column can cause further eutrophication of a system such as the Chesapeake Bay.

Atlantic sturgeon (*Acipenser oxyrinchus)*

Fecundity: 400,000 to 4 million.
Spawning season: April and May in the mid-Atlantic. Post-spawn males may remain in river until fall while females move out of the river after spawning.

Spawning area: Freshwater rivers and possibly tidal-freshwater regions of large estuaries, above the salt front, and over solid substrates of cobble/gravel.
Salinity: 0 to 28.6 ppt.
Flow: Optimal flow between 0.65 to 2.5 feet per second; Unsuitable if $\leq$ 0.19 feet per second or $\geq$ 3.5 feet per second.
Temperature: Spawning occurs between 55 and 74F. Mature males migrate upriver before females when water temperatures reach 42 to 43F; Females reach spawning areas at water temperatures of 54 to 55F.
Outmigration: Juveniles may remain in fresh water for several years before migrating to sea (between second and sixth fall). Downstream migration triggered by 68F water temperature and peaks between 54 to 64F.
Maturation: Varies considerably over latitudinal gradient and between sexes (i.e. greater maturation time with increasing latitude, and females mature slower than males). In South Carolina waters females mature between 7 and 19 years, while males mature in 5 to 13 years; versus 15 to 30 years for females and 8 and 20 years for males in the Hudson River, New York.
Repeat spawning: Atlantic sturgeon do not spawn every year; however, some fish participate in annual spawning migrations. Spawning periodicity for females can vary from two to five years, where males may spawn at one to five year intervals.

Note: Account summarized from Jenkins and Burkhead (1993), Rhode et al. (1994), and Smith (1985).

Atlantic sturgeon (Acipenser oxyrinchus) is native to the lower Susquehanna River and Chesapeake Bay. This species is listed as endangered by the Commonwealth of Pennsylvania. Maryland does not list it as endangered or threatened but did close the fishery in 1996.

Atlantic sturgeon spawn in rivers and mature in the ocean where they can reach maximum lengths of greater than nine feet. Spawning usually occurs in flowing fresh water between the salt line and the fall line (United States Fish and Wildlife Service 1998). Such conditions exist in the lower portion of the Susquehanna River from the mouth of Deer Creek downstream to the river's mouth. This area is well downstream of Conowingo Dam that is unlikely to create an impediment to upstream movement for this species.

Shortnose sturgeon (*Acipenser brevirostrum*)

Fecundity: 27,000 to 208,000.
Spawning season: Likely March/April in the upper Chesapeake Bay and Susquehanna River.
Spawning area: Typically in swift flows (40 to 60 cm/s) over gravel/rubble substrate in large estuarine rivers, upriver of tidal influence.
Salinity: 0 to 30ppt.
Flow: Spawning may occur during or after peak spring flows (40 to 60 cm/s).
Temperature: Spring spawning temperatures range from 48to 54F.
Outmigration: Juvenile may remain in freshwater until 45cm FL (2 to 8 years of age) prior to migrating to saline waters in during the fall of the year.
Maturation: In the mid-Atlantic, maturation occurs around three to five years for males and six to seven years for females (40 to 50cm FL). First spawning may occur one to two years after

maturation for males (44 to 55cm FL), while females may be 7 to 10 years of age at first spawning (50 to 70cm FL).
Repeat spawning: Generally, females spawn every three years, although males may spawn every year.

Note: Account summarized from Dadswell et al (1984) and Jenkins and Burkhead (1993).

Shortnose sturgeon (*Acipenser brevirostrum*) is native to the Susquehanna River and Chesapeake Bay. This species is listed as endangered under the Federal Endangered Species Act of 1973, and is currently listed as state endangered by Pennsylvania and Maryland. Shortnose sturgeon spend the majority of their lives within the river system or estuary of their birth. They reach a maximum length of approximately four feet. Spawning takes place in the flowing water areas of rivers while foraging and overwintering occurs in the estuaries, slow, lower river pools or, in this case, the Chesapeake Bay. The NMFS recognizes 19 distinct population segments associated with 25 river systems. The Chesapeake Bay Population Segment includes the Chesapeake Bay and Potomac River. The Susquehanna River is not recognized as a distinct population segment (USFWS 1998). Shortnose sturgeon were documented in the Susquehanna River in the 1980s and near the mouth of the river in 1997 (National Marine Fisheries Service 1998). Currently, there is no shortnose sturgeon restoration effort underway in the Susquehanna River or Chesapeake Bay.

Striped bass (*Morone saxatilis*)

Fecundity: 15,000 – 4,000,000
Spawning season: Chesapeake populations tend to spawn from April into early June with males typically ascend rives before females.
Spawning area: Lower reaches of tidal and non-tidal rivers. Primary spawning areas for the upper Chesapeake Bay are the Susquehanna Flats and the mouth of the Susquehanna River.
Salinity (spawning): Less than 10ppt, usually less than 1ppt.
Flow: Variable. Some authors note spawning area suitability increases with greater river discharge, while others found sustained minimum flows were necessary for suitable spawning.
Temperature: Spawning occurs from 50.7 to 75.0F, peaking between 64.0 and 68.0F.
Outmigration: Males and females both remain in natal waters, lower portions of those waters, or the Chesapeake Bay proper for at least 2 years. Coastal migrants out-migrate from Chesapeake Bay in early spring; most are age 3 to 4; nearly 90% are females.
Maturation: Males at age 2, females at age 4 or 5.

Note: Account summarized from Jenkins and Burkhead (1993) and Green et al. (2009).

Repeat spawning: Striped bass appear to be iteroparous, but may not spawn annually.
Although the east coast migratory population of striped bass is composed of three major stocks, the Hudson, Chesapeake and Roanoke, the Chesapeake Bay serves as the prominent spawning area on the entire east coast. The Chesapeake stock is composed of pre-migratory fish, primarily ages 10 and younger, while coastal migratory fish range in age from age 2 to more than age 30. Mature striped bass move into tidal freshwater in early spring to spawn and after spawning, migratory fish return to the ocean. Spawning is triggered by an increase in water temperature and

generally occurs in April, May and early June in Chesapeake Bay tributaries.

Striped bass have become the most important recreational species in the Chesapeake Bay. Anglers target striped bass in the Susquehanna Flats during the early spring catch and release season, and incidental catches of striped bass occur in the lower Susquehanna River during the spring. As the water warms, more striped bass move into the river, coinciding with the opening of the inriver season on 1 June. Recreational anglers also target striped bass below Conowingo Dam from June through October and observations indicate success is highly influenced by generation schedule and time of day (B. Sadzinski, MDNR; personal communication).

The turbine discharge at Conowingo Dam provides a unique feeding opportunity for striped bass as forage species traveling downstream must pass through the turbines (except during spill) and into the tailrace. A proportion of these fish are injured but all are likely disorientated, subsequently increasing their susceptibility to predation by striped bass as well as other predatory species. The quick changes in water levels associated with generation changes may also make prey species more susceptible to predators.

Since striped bass generally spawn in tidal freshwater areas, the primary spawning area for the upper Chesapeake Bay is the Susquehanna Flats and the mouth of the Susquehanna River. Striped bass likely proceed up into the lower river after spawning in search of forage (including gizzard shad, white perch, American shad, hickory shad and river herring) and likely stay in upriver locations until water temperature and photoperiod cues in early fall bring them to the deeper water of the Bay.

American eel (*Anguilla rostrata*)

Longevity: 30 years or more.
Fecundity: Up to 20 million eggs per female.
Spawning season: Probably winter and spring.
Spawning area: Sargasso Sea, probably above the thermocline at depths of less than 350m.
Salinity (spawning): 35 ppt.
Temperature: 72 to 77F.
Leptocephali: Occur in ocean waters.
Glass eels: Occur in offshore and coastal waters.
Elvers: Occur in inshore waters; smaller individuals (< 6”) in shallow water, larger individuals in deeper water.
Salinity: 0 to 35 ppt.
Juveniles/Adults: Occur in fresh, estuarine and marine waters.
Salinity: 0 to 35 ppt.
Upstream migration: Occurs at night, March through October; may continue until they reach sexual maturity; can crawl up the face of low head dams or undertake “overland migrations” during their upstream movements as long as moisture is present.
Outmigration: Fall, primarily at night.

On the Atlantic Coast of the United States, the genus Anguilla within the family Anguillidae (eels) is represented by one species, *Anguilla rostrata*. The European eel, *Anguilla anguilla* is found in the eastern Atlantic Ocean. These species are catadromous, i.e., they mature in freshwater, reproduce in saltwater and are semelparous (die after spawning). The above account was adapted largely from CBP (1991).

Appendix 2. American shad population targets for selected areas in the Susquehanna River Basin, based on a target of 2 million.

Boundaries	Water Surface area (hectares)	Percent	Am. Shad target
Susq. R., Marietta to York Haven	1,461	5.4%	107,118
Susq. R., York Haven to Sunbury	10,407	38.2%	763,123
Susq. R., Sunbury to NY line	6,664	24.4%	488,680
Susq. R. NY line to Binghamton	1,142	4.2%	83,757
Susq. R., Binghamtom to mouth of Unadilla Cr.	1,147	4.2%	84,137
Fabri-Dam to Lock Haven	2,978	10.9%	218,415
Conestoga River to mouth of Cocalico Cr.	308	1.1%	22,598
Conewago Creek (York Co.) to mouth of Bermudian Cr.	165	0.6%	12,100
Swatara Creek to mouth of Little Swatara Cr.	229	0.8%	16,829
Conodoguinet Creek to mouth of Big Spring Cr.	325	1.2%	23,823
Sherman's Creek to mouth of McCabe Run	80	0.3%	5,893
Juniata River to Raystown Dam and Warrior Ridge Dam	2,018	7.4%	147,952
Penn's Creek to mouth of Laurel Run	245	0.9%	17,977
Chemung/Tioga River PA state line upstream to PA state line	104	0.4%	7,597
	27,274	100.0%	2,000,000

Appendix 3. Commonly used acronyms

ACFCMA	Atlantic Coastal Fisheries Cooperative Management Act
ASMFC	Atlantic States Marine Fisheries Commission
CBP	Chesapeake Bay Program
EEZ	Exclusive Economic Zone (3 to 200 miles offshore)
GPU	General Public Utilities
FERC	Federal Energy Regulatory Commission
FPTAC	Fish Passage Technical Advisory Committee
MDNR	Maryland Department of Natural Resources
NGO	Non-Governmental Organization
NMFS	National Marine Fisheries Service
NYSDEC	New York State Department of Environmental Conservation
OTC	oxytetracycline antibiotic
PA DCNR	Pennsylvania Department of Conservation and Natural Resources
PA DEP	Pennsylvania Department of Environmental Protection
PECO	Philadelphia Electric Company (now Exelon Energy Corp.)
PFBC	Pennsylvania Fish and Boat Commission
PP&L	Pennsylvania Power & Light Company (now PPL Utilities)
SECO	Susquehanna Electric Company
SHWPC	Safe Harbor Water Power Corporation
SRAFRC	Susquehanna River Anadromous Fish Restoration Cooperative
SRBC	Susquehanna River Basin Commission
SRTC	Susquehanna River Technical Committee
SSAC	Susquehanna Shad Advisory Committee (1969 to 1975)
SSAC	Shikellamy Shad Advisory Committee (1999 to present)
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
YHPC	York Haven Power Company

Appendix 4. Glossary

* Definitions taken from: *NOAA Fisheries Glossary*, NOAA Technical Memorandum NMFS-F/SPO-69, October 2005, Revised Edition June 2006.

** Definitions taken from: Stock Assessment Report No. 07-01 (Supplement) of the Atlantic States Marine Fisheries Commission, *American Shad Stock Assessment Report For Peer Review,* August 2007, List of Terms.

All other definitions were developed by the ASMFC Plan Development Team.

***Alosa*:** The name of the genus (first part of the scientific name) that includes American shad, hickory shad, alewife, and blueback herring. The scientific names for these species are Alosa *sapidissima, Alosa mediocris*, *Alosa pseudoharengus,* and *Alosa aestivalis,* respectively.

Anadromous*: Fishes that migrate as juveniles from freshwater to saltwater and then return as adults to spawn in freshwater; i.e. American shad.

Bycatch*: Fish other than the primary target species that are caught incidental to the harvest of the primary species. Bycatch may be retained or discarded. Discards may occur for regulatory or economic reasons.

Catadromous: Fishes that migrate as juveniles from saltwater to freshwater and then return as adults to spawn in saltwater; i.e. American eels.

Catch Per Unit (of) Effort (CPUE)*: The quantity of fish caught (in number or in weight) with one standard unit of fishing effort; e.g. number of fish taken per 1,000 hooks per day or weight of fish, in tons, taken per hour of trawling. CPUE is often considered an index of fish biomass (or abundance). Sometimes referred to as catch rate. CPUE may be used as a measure of economic efficiency of fishing as well as an index of fish abundance. Also called: catch per effort, fishing success, availability.

Diadromous: Term describing migratory fishes that are either anadromous or catadromous (see above).

Directed Fishery*: Fishing that is directed at a certain species or group of species. Applicable to both sport and commercial fishing.

Discard*: To release or return fish to the sea, dead or alive, whether or not such fish are brought fully on board a fishing vessel.

Elvers: Immature American eels that arrive in inshore waters and normally ascend streams and rivers.

Eutrophic: Fertile, productive. (Refers to a water body or aquatic system)

Eutrophication: The process of becoming eutrophic.

Fish Lift (Fish Elevator): Devices that catch fish and lift them up over dams.

Fish Passage:** The movement of fish above or below a river obstruction, usually by fish lifts or fishways.

Fishery*: 1. Activity leading to harvesting of fish. May involve capture of wild fish or raising of fish through aquaculture;
2. A unit determined by an authority or other entity that is engaged in raising or harvesting fish. Typically, the unit is defined in terms of some or all of the following: people involved, species or type of fish, area of water or seabed, method of fishing, class of boats, and purpose of the activities;
3. The combination of fish and fishers in a region, the latter fishing for similar or the same species with similar or the same gear types.

Fishway: Artificial channels that allow fish to swim around and/or over dams).

Geometric Mean: A measure of the central tendency of a data set, using logarithmic transformations, that minimizes the effects of extreme values.

Harvest*: The total number or weight of fish caught and kept from an area over a period of time. Note that landings, catch, and harvest are different.

Hypereutrophic: Very eutrophic (see "eutrophic" above).

Iteroparous: A term used to describe fish that spawn more than once.

Landings*: 1. The number or poundage of fish unloaded by commercial fishermen or brought to shore by recreational fishermen for personal use. Normally reported at the locations at which fish are brought to shore;
2. The part of the catch that is selected and kept during the sorting procedures on board vessels and successively offloaded at dockside.

Larvae: Fish developmental stage well differentiated from the later young-of-year and juvenile stages and intervening between the time of hatching and time of transformation or loss of larval character (i.e., fish resembles a young or juvenile individual by absence of a yolk sac, and presence of continuous fin folds and pigmented young-of-year character).

Leptocephalus: The long thin small-headed transparent pelagic first larva of various eels.

Otoliths: Ear stones within the inner ear of fish.

Population: The number of individuals of a particular species that live within a defined area. (See *Stock*)

Post-spawn Fish: Adult fish that have completed spawning.

Potadromous: Species of fish which undertake breeding or dispersal migrations wholly within freshwater.

Predation*: Relationship between two species of animals in which one (the predator) actively hunts and lives off the meat and other body parts of the other (the prey).

Pre-spawn Fish: Adult fish that have not yet spawned.

Recruitment (R)*: 1. The amount of fish added to the exploitable stock each year due to growth and/or migration into the fishing area. e.g., the number of fish that grow to become vulnerable to the fishing gear in one year would be the recruitment to the fishable population that year;
2. This term is also used in referring to the number of fish from a year class reaching a certain age. For example, all fish reaching their second year would be age 2 recruits.

River herring: Blueback herring and alewife.

Run*: Seasonal migration undertaken by fish, usually as part of their life history; e.g., spawning run of salmon, upstream migration of shad. Fishers may refer to increased catches as a "run" of fish, a usage often independent of their migratory behavior.

Silver Eels: Sexually mature American eels that are moving down streams and rivers on their way to spawn in the Sargasso Sea.

Spent Adult Fish: Adult fish that have completed spawning.

Stock*: A part of a fish population usually with a particular migration pattern, specific spawning grounds, and subject to a distinct fishery. A fish stock may be treated as a total or a spawning stock. Total stock refers to both juveniles and adults, either in numbers or by weight, while spawning stock refers to the numbers or weight of individuals that are old enough to reproduce.

Comment: In theory, a unit stock is composed of all the individual fish in an area that are part of the same reproductive process. It is self-contained, with no emigration or immigration of individuals from or to the stock. On practical grounds, however, a fraction of the unit stock is considered a "stock" for management purposes (or a management unit); as long as the results of the assessments and management remain close enough to what they would be on the unit stock.

Stock Assessment*: The process of collecting and analyzing biological and statistical information to determine the changes in the abundance of fishery stocks in response to fishing, and, to the extent possible, to predict future trends of stock abundance. Stock assessments are based on resource surveys; knowledge of the habitat requirements, life history, and behavior of the species; the use of environmental indices to determine impacts on stocks; and catch statistics. Stock assessments are used as a basis to assess and specify the present and probable future condition of a fishery.

Stock Status:** The relative level of fish abundance.

Stocking*: Generally, refers to the practice of putting artificially reared young fish into a sea, lake, or river.

Subadult: Juvenile American shad and river herring that migrate from their birth river to become part of the coastal migratory mixed stock population until they become mature.

Trap and Transport: The practice of catching adult American shad before they have spawned, and then transporting them upstream of the four hydroelectric dams on the Susquehanna River.

Young-of-year, or Age-0 (Zero)*: The age 0 group are the fish in their first year of life. A fish born in April of a given year remains in the age 0 group until April of the following year.

Appendix 5. Responses to public comments.

Exelon Comment Letter

1. The Plan Need Not Have Numeric Goals for Fish Populations

"The draft Plan states that numeric goals of 2 million American shad and 5 million river herring spawning upstream of York Haven dam have been established, but that numeric goals for American eel and other migratory species have not been determined. (pp. 6, 34, 35) However, it also states that this target will be revisited (p. 34).

Exelon agrees that the numeric targets for American shad and river herring, if retained at all, should be revisited. These targets are based on the assumption of 48 spawning shad per acre and were established decades ago. To Exelon's knowledge, this level of density has never been shown to exist, even in rivers which do not have fish passage issues, and notwithstanding that some restoration programs have been ongoing for decades."

Shad production per unit water surface area has been assessed by other resource agencies. The State of Maine Fishery Resource Agencies conducted an assessment of production for their "Draft Fishery Management Plan for the Presumpscot River Drainage" as follows:
"Maine currently has no rivers with extensive runs of American shad or blueback herring and historical information on the size of populations produced by specific Maine rivers generally is lacking, because runs were greatly reduced or extirpated by dam construction beginning in the 1700s. Therefore, potential population sizes must be estimated from information on restored runs in other rivers. In the past, MDMR has used 111 shad/acre (=2.3 shad/100 yd^2), based on shad restoration in the Connecticut River during the early 1980s. MDMR's earlier estimates of shad production for the Presumpscot River (e.g. MDMR reply comments to FERC dated January 24, 2001) were based on 111 shad/acre of habitat. To determine whether this number remained valid, MDMR obtained counts of shad passed at the Holyoke Dam (1st) and Turners Falls Dam (2nd) on the Connecticut River for the years 1983-2000, and a GIS estimate of surface area for this river reach. The average shad production for the reach between the two dams for the 20 year-period was 98.9 shad/acre. Production estimates based on both values have been included in Table 1 for comparison, but MDMR recommends using production based on 98.9 shad/acre. Use of 98.9 shad/acre for estimating production is further supported by historical information on commercial landings in Maine. A significant fishery for American shad existed in the freshwater tidal section of the Kennebec River and its tributaries after access to inland waters was obstructed by impassable dams at the head-of-tide. From 1896-1906 the average annual landings of American shad in the Kennebec River were 802,514 pounds. This represents 267,500 adult shad, assuming an average weight of three pounds per fish, and a commercial yield of 0.6778 shad/100 yd^2 . If the exploitation rate ranged from 25-50%, then the total run from Merrymeeting Bay to Augusta (including tributaries) may have ranged from 535,000-1,070,000 shad. This represents a production of to 68-131shad/acre (equivalent to 1.4-2.7 adult shad/100 yd^2)."
Use of Maine's estimate of shad production potential would double the Susquehanna River American shad goal to 4 million fish. The SRAFRC chose to use the more conservative goal previously established by R. St. Pierre and may consider revising the goal upward to be

consistent with the Maine goal once the two million American shad goal is reached on the Susquehanna River if the other portion of the goal to " Restore self-sustaining, robust, and productive stocks of migratory fish capable of producing sustainable fisheries, to the Susquehanna River Basin throughout their historic ranges in Maryland, Pennsylvania, and New York." is not met.

"Moreover, the Susquehanna River Basin numerical targets have never been approached, even when, prior to the termination of trap and truck operations, populations were increasing dramatically. In addition, the draft Plan also correctly identifies many factors that may be contributing to the decline, including factors over which the SRAFRC agencies have little or no control. Exelon suggests that a more realistic approach to goal setting is to state the goal generally, similarly to the first sentence of the statement in the draft. Progress toward the goal can be assessed by evaluating population estimates in concert with the incremental elimination or reduction of identified limiting factors."

The SRAFRC disagrees with Exelon Corporation regarding goal setting. A good goal needs a measurable outcome and includes a method to periodically assess progress towards that outcome. Setbacks detected as a result of the monitoring are no reason to abandon the goal. Setbacks do indicate a need to reassess the approach being employed to reach the goal, which is what the SRAFRC is doing. The product of that reassessment is this draft Plan. Exelon states that progress be measured by evaluating population estimates. SRAFRC asks what those population estimates would be evaluated against if there were no numeric goals. As Exelon has stated, the SRAFRC acknowledges that there are other factors that may inhibit attainment of its goal, and the plan has identified many tasks to address those factors.

2. Tasks Related to Passage of American Eel Are Not Supported

"The draft Plan contains very little discussion of American eels. There is a historical discussion focused on the abundance of eels and their commercial value through the 1920s (p. 9-11), a paragraph discussing the dramatic drop in eel populations along the entire Atlantic coast in recent years, the problem of over-harvest, and the problem of insufficient data to support species management decisions.

Notwithstanding the absence of any evidence linking the existing Susquehanna River hydroelectric dams to the eel population decline (they were in place many decades before the decline, which is also occurring coast-wide and in non-dammed rivers), identification of over-harvest as a problem, and the admitted paucity of evidence to support management decisions, the draft Plan includes tasks to trap and transport eels from lower river sites to upstream sites (C8) and require downstream passage for silver eels with subject to very high performance standards (A5). The draft Plan includes no task intended to address over-harvest, not even advocacy for harvest restrictions, although the draft Plan recognizes that Maryland permits unlimited fishing for eels larger than six inches and allows any individual to take up to 25 eels per day smaller than six inches. Similarly, Pennsylvania allows year-round harvest subject only to a limit of 50 per creel, which is essentially no limit at all. (pp. 16-17)

Exelon suggests that the final Plan should remove any tasks related to upstream or downstream passage of eels, at least with respect to hydroelectric projects, until there is credible evidence establishing that passing eels upstream will not be detrimental to the overall eel population due to the lack of existing technology for the downstream passage of adult eels at hydroelectric projects. Moreover, in its review of recent eel literature, DOI determined that the American eel life cycle is not freshwater dependent.' Recent studies referenced by DOI also suggest that brackish (or estuarine) waters produce eels that grow faster, mature earlier, and emigrate as silver eels sooner than eels in fresh water. 2 In fact, some eels spend their entire life cycle in brackish or marine waters without ever entering fresh water."

Contrary to Exelon's statement in comment 2, there is very clear evidence that American eel stocks in the Susquehanna River watershed above the four hydroelectric dams declined dramatically after access was cut off by these projects. This drainage-wide decline occurred decades before the more recent coast-wide decline cited by Exelon. As cited in the discussion on page 15 of the Management Plan, New York State Conservation Department fisheries biologists stated that eels completely disappeared from the North Branch Susquehanna River by 1953. A subsequent increase in eel numbers in the New York portion of the Basin during the 1960's and 1970's was certainly a direct result of Pennsylvania's trap-and-transport efforts which are highlighted in Table 5. The nearly complete absence of American eels from the New York portion of the basin in the past 25+ years (Dittman, D.E., et.al. 2009) is further evidence that trap-and-transport which ended in 1980, was the key to supporting an eel population upstream of the four hydroelectric projects.
As efforts to enhance eel populations continue, SRAFRC member states will need to address the issue of harvest within their respective jurisdictions. This is addressed in the plan under Task C9. However, it is clear that immediate action both locally and coast-wide is needed. American eels serve a valuable ecological function in river environments as predators, prey and as key players in the life cycle of several species of freshwater mussels. If only for these reasons, restoration of eels throughout the Susquehanna River drainage is important, but a robust eel population also has the potential to support a significant, economically valuable commercial fishery. Clearly both upstream and downstream eel passage at hydroelectric dams must be addressed in order for restoration to be successful. Some hydroelectric facilities have had success at reducing downstream eel mortality by implementing operational changes. Whether this or some other engineering fix is the solution for the Susquehanna River system, the challenge of finding the solution(s) will not be met by doing nothing.

3. The Fish Passage Performance Standards Are Unsupported

"Exelon is also concerned that the performance standards for fish passage lack a scientific basis. Task Al calls for each of the four lower river hydroelectric dams to pass upstream "at least 85 percent of the adult American shad reaching project tailwaters, or at least 75 percent of the adult American shad passed at the next downstream facility." The draft Plan provides no explanation of how these numbers were derived and no evidence to suggest they are attainable.

The same deficiency exists with respect to the downstream passage standards of 80 percent for outmigrating adult (Task A2) and 95 percent for out-migrating juvenile (Task A3) Alosines (shad and river herring). The unsupported 85 percent survival rate for downstream passage of silver eels at hydroelectric dams (Task A5) seems to be particularly unreasonable on its face. It is difficult to credit the assumption that a higher downstream passage standard is achievable for outmigrating adult eels, which are far longer and therefore more likely to be harmed in turbine passage, than outmigrating adult alosines.

The final Plan should explain, with reference to existing literature and study results, how these standards were developed and why it is reasonable to conclude they may be achievable. If the existing evidence does not support these numeric standards they should be revised based on achievable standards experienced at other Atlantic coast rivers. The final Plan should also recognize that passage standards should not be static, but, like the population targets, needs to be periodically revisited in light of new information developed in studies undertaken in connection with other hydroelectric and non-hydroelectric dams in the Atlantic coast region, including those conducted in connection with relicensing of Susquehanna River hydroelectric projects."

The performance standards used in the FMP are based upon fish passage data from the Susquehanna River. An average of 71 % of the American shad that have passed Holtwood Dam, have also passed Safe Harbor Dam. This has been accomplished with no additional operational or structural modifications to the original fishway at Safe Harbor. SRAFRC partners established 75% as a performance standard for Holtwood Dam, assuming that minor operational modifications at Safe Harbor could achieve an additional 4%. Owners of Holtwood Dam expressed concern about the potential for "drop off", i.e. fish might not migrate from one dam to the next for a variety of reasons. To accommodate this, we established a two-tier performance standard. If any fishway does not pass 75% of the fish passed by the next downstream fishway, compliance can be demonstrated by passing 85% of the fish that reach project tailwaters.
Our performance standards for downstream passage survival for American shad (80% for adults, 95% for juveniles) were also derived from data collected on the Susquehanna River. Normandeau (1998) demonstrated 24-48 hour turbine passage survival of 86.2% for adult American shad at Safe Harbor Dam. For juvenile shad, Heisey et al. (1992) demonstrated 48 hour Kaplan and mixed flow turbine passage survival of 98 to 100%, respectively, at Safe Harbor Dam. Similar studies at Conowingo Dam demonstrated 48-hour survival of 92.9% for juvenile shad passed though Kaplan turbines (RMC Environmental Services 1993). Thus, we know those standards are achievable. To be consistent, these standards were also applied to the other Susquehanna River Dams.
For silver eel downstream turbine survival there are no data available for the Susquehanna River. With a passage survival standard of 80% the four-dam cumulative survival would be only 41%. With an 85% standard, four-dam cumulative survival would be 52%. Given the current declining stock of American eels, SRAFRC partners felt that a more conservative standard was appropriate.

4. The Plan Should Be Redirected Toward Practical Measures That Can Be Taken in the Short Term to Avoid Collapse of the Susquehanna River American Shad Fishery

"Even if the draft fish passage performance standards are ultimately shown to be feasible, there is ample reason to think that far too much reliance has been placed on volitional fish passage at hydroelectric dams. The draft report identifies several likely causes of the recent decline in American shad stocks other than fish passage limitations. These include decreased hatchery production, conditions in the environment, commercial fisheries bycatch or other causes of ocean mortality, poor water quality, habitat degradation, and predation (pp. 5, 24, 28-29). Moreover, the decline in migratory fish stocks is occurring along the entire Atlantic coastline, and the Atlantic States Marine Fisheries Commission observed that "ocean harvest may well prove to be the most important factor driving the decline" (p. 29, citing ASMFC 2007).

Although it states that "successful restoration of diadromous fish in the Susquehanna River is dependent on resolving all of these issues" (p. 24), the draft Plan places very heavy reliance for restoration on improvements to upstream and downstream volitional fish passage at hydroelectric dams and very little reliance on addressing the other limiting factors. This is particularly troubling in light of the fact that American shad numbers increased dramatically between the early 1970s and the early 1990s, when a combination of trap and truck and hatchery production was employed, but have suffered an equally dramatic decline since volitional passage was installed at all four lower river dams and trap and truck was discontinued."

As Exelon has stated the SRAFRC has acknowledged other issues that may impact attainment of the goal stated in the Plan. However, in order to "restore self-sustaining, robust, and productive stocks of migratory fish capable of producing sustainable fisheries, to the Susquehanna River Basin throughout their historic ranges in Maryland, Pennsylvania, and New York" these migratory fish will have to have safe, timely and effective access to and from spawning and rearing habitat in the upper Susquehanna River basin. Without question the major and primary impediments to that access exist in the form of the hydroelectric developments in the lower 55 miles of the Susquehanna River. It is key to the success of the restoration of migratory fish stocks to the Susquehanna River that the issue of blocked or impeded access to and from critical habitat be addressed as soon as possible. With respect to the FERC licensed hydroelectric projects on the lower Susquehanna River the best time to address the impacts of hydroelectric project operations on public resources such as migratory fish is during FERC licensing actions under the Federal Power Act. As Exelon is well aware, relicensing actions are currently ongoing at 3 of the 5 FERC hydroelectric projects on the lower river. Therefore, there is an immediate and urgent need to address the fish passage impacts the hydroelectric projects impose upon migratory fish. Hence the high priority given to this issue by the SRAFRC Plan.

"Even if improvements can be made to upstream and downstream passage efficiency, there is very little in the draft Plan to address the other likely causes of the current decline. For instance, the commercial American shad ocean fishery was closed in 2005, but "a significant increase in recruitment... has not occurred" (p.29) and the mid-water ocean trawl fishery, the source of the bycatch problem, "has increased significantly since the late 1990s." (Id.) The draft Plan provides only for the agencies to "[a]dvocate for minimization of bycatch and discard mortalities" (Task E3) and maintain existing closures or restrictions on commercial and recreational American shad fisheries in the Susquehanna River Basin and Chesapeake Bay. (Task C9) There is no reason to think that tinkering with existing bycatch restrictions and continuing existing closures and restrictions that have been in place during the decline of recent years will have a significant beneficial effect."

The SRAFRC member agencies have taken an active role in addressing the issue of ocean fishery impacts on migratory fish restoration efforts through participation in Atlantic States Marine Fishery Commission management boards, technical committees, plan development teams, and fishery management councils. In addition, the SRAFRC has reviewed and commented on fishery management plans that could have impacts on Susquehanna River migratory fish stocks during their oceanic life phase. Through the Plan the SRAFRC and its member agencies have committed to work with other fishery regulatory agencies to address the potential impacts the ocean and coastal fisheries may be having on migratory fish.

"The draft Plan's response to habitat degradation is limited to generally stated tasks of seeking funds for and coordinating removal of non-hydroelectric project dams (Task B 1), assessing the impacts of hydroelectric projects on spawning and spawning habitat in the context of relicensing (Task B2), advocating avoidance or mitigation measures for dams or other developments that could affect migration, spawning, rearing, or habitat (Task B3), and advocating for the maintenance and improvement of water quality standards (Task B4). All of these tasks should be undertaken, but they are unlikely alone or in combination to bring measureable improvement except, possibly, in the very long term."

The Plan includes both short and long-term tasks that will lead to achieving the goal of the Plan. Exelon notes that restoring quality habitat is only part of the picture. The Plan also addresses adequate access to restored habitat through fish passage, and prudent management of all fisheries that may impact sustainability of migratory fish stocks.

"The draft Plan also includes no tasks intended to address continued population growth in the basin and land use practices as sources of habitat degradation, except perhaps the very generally framed task of expanding public education and information initiatives. (Task E4)"

Many of the impacts from land use practices will also be addressed in the tasks related to habitat restoration.

"In particular, Task B2, assessing the impact of hydroelectric projects on spawning and spawning habitat in the relicense proceedings, while appropriate, needs to be viewed in context. A study cited in the draft Plan found that over 300 miles of the mainstem Susquehanna, Juniata, and lower West Branch rivers are suitable for Shad spawning and rearing. (p. 14). In contrast, the pools of the four hydroelectric projects occupy only 36 river miles. (p. 12) Moreover, the draft Plan appears to assume (p. 12) that all of the existing pool habitat behind the hydroelectric dams would be suitable for spawning in the absence of the dams. No evidence is provided to support this supposition."

Fish sampling in the lower free flowing river and the upper Chesapeake Bay near the mouth of the Susquehanna River indicates successful American shad spawning occurs in these areas. Prior to hydroelectric dam construction the lower 36 miles of the river were likely similar to the remaining free flowing reach and provided spawning and rearing habitat. Currently the best and most abundant spawning and rearing habitat for American shad is in the upper Susquehanna River basin upstream of the lower river hydroelectric projects, hence the Plan's focus on restoring safe, timely and effective access to this habitat, and protecting and enhancing the habitat quality in the upper reach.

"The draft Plan's response to decreased hatchery production is to establish tasks to: (1) continue supplementing wild production with hatchery produced American shad larvae (C3); and (2) develop a reliable source of Susquehanna River Basin American shad eggs (C5). However, a plan to fully implement these tasks has not been developed."

Task C4 of the plan is to" Develop a reliable source of Susquehanna River American shad eggs to replace out-of-basin sources and to enhance genetic integrity of the program." This task will be more fully developed pending results of FERC re-licensing proceedings.

"The draft Plan concludes that predation on juvenile American shad by striped bass could be a significant factor in the declining stocks and that hatchery-reared juvenile shad are less susceptible to striped bass predation than wild shad. (p. 29) However, one of the tasks in the draft Plan is to investigate the potential for restoring striped bass to historic levels upstream of Conowingo Dam (C11). Moreover, there is very little in the plan dealing with active fisheries management to address the effects of predation as well as inter and intra species competition."

Issues of interaction with other managed fisheries are addressed in Task E2 of the plan.. During the assessment of the potential for restoring striped bass upstream of Conowingo Dam the impacts of such an action on migratory fish restoration will be investigated by SRAFRC.

"In sum, the draft Plan is placing nearly all of the eggs in the volitional fish passage basket. Because the draft Plan offers so little to address other factors that are likely contributing to the severe decline in American shad stocks, it is reasonable to suppose that additional modifications to volitional fish passage measures at the four lower river hydroelectric projects, however effective, may contribute little to accomplishment of the goal of a robust and productive migratory fishery on the Susquehanna River. Exelon is not suggesting that none of these other tasks should be pursued and is aware that the agencies have limited ability to address some of the other likely sources of distress to this fishery, but suggests that the Plan's inherent limitations in this regard are not a valid reason to pursue fish passage tasks that are also unlikely to contribute significantly to the overall goal. Rather, Exelon believes the situation warrants a reorientation of the Plan to give priority to practical, implementable measures that are likely to lead to success before American shad stocks diminish to catastrophically low levels."

This comment was addressed above in response to a similar Exelon comment.

"The draft Plan should also consider in greater detail the potential to trap and transport American shad from Conowingo Dam to release points above York Haven dam as a means to reverse the tide of declining stocks. Trap and transport is embodied in Task C4; however, the task as drafted provides only that the SRAFRC agencies will "consider" this action and then only as an interim measure while efforts continue to improve volitional passage at York Haven and Holtwood Dams. Exelon believes that the general resource goal of reestablishing a robust and sustainable migratory fishery will be better served if Task C4 is identified as a higher priority task."

This comment was addressed above in response to a similar Exelon comment.

"The other action most likely to assist in reversing the American shad population collapse is increased supplemental hatchery production. Although the draft Plan includes this task, there is no suggestion that this has an elevated priority."

This comment was addressed above in response to a similar Exelon comment.

"Consistent with that modification, the "Objective A" fish passage tasks should also be reframed, first to provide for development and implementation of upstream and downstream passage plans and performance measures to the extent they are shown to be necessary to restore a robust and sustainable fishery after trap and transport has had a reasonable opportunity to take effect, and second to include in the task development of performance standards that are demonstrably achievable based on scientific studies and literature review."

This comment was addressed above in response to a similar Exelon comment.

"The final Plan would also benefit from inclusion of additional tasks intended to address factors other than fish passage. For instance, a task or tasks should be added to address the impacts of predation, beginning with a rigorous assessment by the agencies of the predation impacts of striped based and other species, such as smallmouth bass, walleye, and catfish, on American shad stocks. Such an assessment could lead to direct measures to suppress populations of these predators, at least until American shad populations have increased substantially. Similarly, the Plan would benefit from a task or tasks addressed to evaluation of the role that exploding populations of gizzard shad may have in alosid population decline as a competitor for resources."

This comment was addressed above in response to a similar Exelon comment.

"Exelon also believes the final Plan should include a more specific, proactive task to identify and bring into the restoration effort entities whose activities may be contributing to habitat degradation and other likely causes of declining migratory fish resources."

This comment was addressed above in response to a similar Exelon comment.

"In conclusion, Exelon is prepared to work with the SRAFRC agencies and other stakeholders to restore the migratory fish resources of the Susquehanna River Basin, but believes that the Plan should be reoriented toward accomplishment of tasks that are most likely to contribute to that end in a timeframe that best takes account of and addresses the severe, continuing depletion of American shad stocks."

The SRAFRC is happy to hear of Exelon's offer to help to restore migratory fish stocks to the Susquehanna River basin and looks forward to working with Exelon. The SRAFRC will continue to reevaluate priorities with respect to task implementation, as a periodic review process has been built into the plan. As is often the case, there are many needs, but limited resources to address all of the needs at once, hence a need to prioritize has been recognized by the SRAFRC.

<u>York Haven Comment Letter</u>

1. **The Management Plan should not be just a fisheries agency plan, but should reflect the involvement of all major stakeholders.**

"If we are going to be successful in convoking truly cooperative efforts at fisheries restoration and management, the development, adoption and implementation of this type of plan should involve not just the fisheries agencies, but must include all of the major river basin stakeholders. In some respects, this draft Plan suffers from having not convoked that dialogue with other stakeholders much earlier in the process. However, we believe that going forward it will be imperative that all major stakeholders be "at the table."

Unlike the previous SRAFRC anadromous fish management plan, this draft Plan went out for public review and comment before being finalized. The Plan was revised based on comments such as those provided by York Haven Power Company (YHPC). We note that the responsibility and authority to protect, conserve, and enhance the fishery and water resources of the public lies with the natural resource agencies. The primary fisheries agencies with responsibility to mange fisheries resources in the Susquehanna River basin formed into the Susquehanna River

Anadromous Fish Restoration Cooperative in a effort to best serve their collective interests of restoring migratory fish. All agencies mission is to serve the public including stakeholders with an interest the Susquehanna River. YHPC has been given the opportunity to have input into the process the same as all members of the public and the SRAFRC intends to continue the practice of seeking public involvement in its planning process.

2. The expansion of Management Plan to cover additional species has caused some loss of focus, and if additional species are to be added, much more detailed information is required to support management efforts addressing those species.

"The 2002 Plan was focused on Alosids (shad and river herring) only and had specific, well defined tasks. The proposed Management Plan adds a number of additional species, including eels, gizzard shad, and striped bass. The addition of new species has, we believe, caused the Plan to lose focus, and resulted in the Plan becoming more general in many respects.

If additional species are to be considered, the goals, objectives and tasks need to be developed with greater focus on the issues relating to the respective species. For example, if species such as striped bass are to be included, the Plan should include a discussion of historical abundance vs. current conditions in order to lay the foundation for considering management efforts. Further, in the statement of goals on page 34, it would seem appropriate to discuss the goals separately for (1) Alosids, (2) American eel, (3) sturgeon, and (4) striped bass, and then consider the interplay of these goals in the subsequent sections.

We find the inclusion of gizzard shad in the Plan confusing and questionable, since it is an invasive nuisance species. In the introductory sections, gizzard shad appears to be treated similar to the other key species, but then later is discussed as a species that may interfere with American shad passage. Notably, the Plan does not address how this nuisance species should be managed. As a species that has come to dominate the biomass of the entire lower river fishery in the last 12 to 15 years, the role of gizzard shad as a potential culprit in the recent Alosid population declines (as an ecological niche competitor and resource consumer) is a subject that the Plan should address with serious attention. We note that other diadromous fish restoration plans on major rivers (e.g. Columbia River) include actions intended to remove unwanted species (e.g. pike minnow). This Management Plan would benefit from establishing goals related to active management of gizzard shad populations."

The SRAFRC technical committee added information for all of the migratory fishes in the Susquehanna River as reflected by the decision to change the name of the plan from just "anadromous" to "migratory fish". The term "migratory fish" also encompasses the catadromous American eel. The plan also recognizes that alewife and blueback herring need additional management attention due to serious declines in their numbers. In the Susquehanna River, gizzard shad exhibit migratory behavior in that they use the fishways and travel from areas below Conowingo Dam upstream into other pools. We agree that gizzard shad are a nuisance. However, according to the Atlas of North American Fishes (Lee et. al., 1980) the native range of gizzard shad includes the Chesapeake Bay and lower Susquehanna River. We agree that they are having an impact on other migratory and resident species in the river. We disagree that the plan loses focus. Indeed, in the latest revised draft of the plan, the tasks related to American shad and American eel are more defined than ever and we have also made room to begin to consider the roles of the other migratory species that have historically received less *attention. This plan is expected to be a living plan that builds upon earlier versions and we expect that there will be additional growing attention directed toward the other species in addition to the traditional primary focus that has been placed on American shad.*

3. **The Management Plan must forthrightly recognize and address the causes of the current stock declines of American shad throughout the Atlantic region, and consider short-term, interim enhancement measures while we continue to work on longer-term restoration efforts.**

"A major missing element in the Management Plan is the lack of attention to the apparent causes of the dramatic declines in the Susquehanna River Alosid stocks (particularly American shad and river herring populations). While the Plan clearly focuses on enhancements to upstream and downstream passage and habitat access in the river basin, there is no indication of the projected benefits to the fish population in terms of reversing the current downward trends and making progress towards reaching the alosid population goals (2 million shad & 5 million river herring). Given current trends, it is highly questionable whether the tasks outlined in the Management Plan will make a difference in the current populations; and the Plan lacks any basis for concluding that such enhancements will have a meaningful effect on shad populations given the overall declines seen in the Atlantic region populations.

The Plan should focus on those tasks that have the greatest potential to make a difference in the shad populations as a whole; and tasks should be prioritized accordingly. All of these issues should be addressed with citations to the underlying scientific data supporting these conclusions. The underlying challenge is a difficult, and classic, one in multivariate science. In the Susquehanna River Basin, the fishery resource is affected by numerous conditions and factors, including conditions and factors that are well beyond the reach of the Susquehanna Basin, including conditions in the Atlantic and overfishing of shad in the ocean. This fact is noted on page 24 of the Plan, but then the Plan lacks elements addressing each of those key factors. We recognize that some of the individual factors are more easily dealt with than others, but unfortunately, the relative ease of dealing with a particular factor does not mean that addressing that factor will solve the larger biological issue. If the Management Plan does not address the major contributors and causes of the obvious shad population decline across the entire Atlantic region, all of the Plan's objectives and tasks will be for naught. Currently, the Plan lacks the showing of cause−effect which would give the objective reader the confidence to concur with the Plan's almost complete reliance on improving upstream/downstream passage as the method for assuring future success of the restoration.

From a prioritization perspective, we find there to be a lack of attention to perhaps the most important population determinant – ***the proportion of juveniles returning to the river as spawning adults.*** All of the juvenile production one can get from the river is meaningless unless it results in an increase in the number of shad surviving in the ocean and returning as spawning adults to the river. The population crash over the last five years raises the obvious question as to whether there has been a change in marine survival, and if so, what are the causes. The Plan touches on commercial and recreational fishery regulation and potential striped bass predation changes, but the Plan fails to contain any tasks directed towards the objective and focused evaluation of changes in marine survival, or in predation conditions, or the relative importance of these variables to restoration of the American shad populations. Embarking on massive river basin enhancements without understanding the relative potential of those actions to result in population growth is imprudent.

We believe a critical and fundamental question remains unanswered in the Plan – does the Plan treat the underlying causes of shad population declines? Lacking a focus on this question raises the very real specter that the "patient" will continue to deteriorate because the real causes of the problem are not identified and therefore going unaddressed.

In this regard, we believe that more focused attention should be given to what near−term efforts might be undertaken to address the precipitous decline in shad populations, and the associated declines in returning adults. Some of the Objective C tasks, such as trap−and−transport programs and improved hatchery augmentation techniques, merit serious and focused near−term attention. Unless there is some expeditious turn−around in the migratory fish spawning stocks and populations returning to the base of Conowingo Dam, all of the other objectives and tasks in the Plan for improving upstream passage will be of no merit or effect."

SRAFRC authors agree that ocean harvest, by-catch, and discard of American shad and herring may be a major issue impacting current and future success of the restoration effort and have addressed this issue in the plan. In fact, Objective E, Task E3 specifically calls out the need to advocate for reductions in bycatch and discard mortalities. Along those lines SRAFRC recently sent a letter to the Mid-Atlantic Fishery Management Council, related to Ammendment14, which requested a substantial increase in the at-sea observer monitoring program for those ocean fisheries that are likely having the greatest fishery impact on restoring shad and herring stocks. Among other things, the letter also specifically requested that all alosine bycatch should be individually identified to species and quantified as part of the increased observer coverage. This type of comprehensive data will be necessary to justify future requests by SRAFRC and other resource agencies to modify or close, as needed, those fisheries which are impacting shad and herring populations coast-wide.

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4. **In discussing hydroelectric project operations, the Plan should recognize that York Haven does not operate in the same manner as some other projects.**

"Page 13 of the Management Plan contains some sweeping statements regarding hydroelectric projects in general that are simply not true with respect to the York Haven Project. The Plan states:
Hydroelectric projects tend to generate power when it is most needed, during the daytime peak use period, and refrain from generation at night when water storage in the impoundment is replenished with incoming river flows. This results in unnatural flow conditions that can vary from flood to drought flow conditions within minutes during any given day.

Whatever may be the operating modalities of other hydro projects on the Susquehanna River, the above description most definitely does not apply to York Haven. The York Haven Project operates as a run−of-river facility, turning on and off turbine units as water flows into Lake Frederic increase or decrease, as evidenced by relatively minor fluctuations of Lake Frederic water levels. The areas below the York Haven Project are not subject to "flood" and "drought" induced by hydro operations – the flows passing below the York Haven dam are dependent on the natural river flows into the project from the upstream watershed."

The plan has been modified to address YHPC's specified mode of operation, which is different from the other hydroelectric projects on the lower Susquehanna River.

5. Statements as to York Haven Project's shad passage efficiency are misleading and fail to recognize the important issue of drop-off between Safe Harbor and York Haven.

"The Plan at page 29 contains a statement suggesting that the shad passage efficiency for York Haven has averaged 11% over the period from 1997 through 2008. We believe that statement is misleading for several reasons.

First, the Plan's "calculation" of fish passage efficiency represents nothing more than a comparison of the number of shad counted as passing through the Safe Harbor fish passage facility (some 24 miles downstream of York Haven) to the number counted as passing through the York Haven fish passage facility. The only appropriate measure for the efficiency of fish passage is to compare the populations of shad arriving at the base of a dam to those that arrive above the project through the passage facilities. If shad do not arrive in the near vicinity of the project seeking to pass upstream, that does not signify a passage efficiency issue. A significant portion of the intervening area of the Susquehanna River between Safe Harbor and York Haven includes approximately 15 miles of free flowing riverine areas and tributaries that are of a type suitable for shad spawning, and in any event, some "drop−off" of migrating adults would be expected over that distance. The suitability of this area for spawning is recognized in the 2002 Plan.1 For this reason, YHPC has undertaken (with concurrence of the natural resource agencies) a focused and multi−phased radio−tagging study to start to evaluate the pattern of shad moving upstream from Safe Harbor.

Second, reviewing the data over the past 12 years, we have noted a density−dependent pattern to the number of fish passing through the YHPC facilities. In general, the greater the number of shad that pass through Safe Harbor, the higher the percentage of those shad that pass through York Haven. This data indicate that "passage efficiency" as calculated by SRAFRC at low population densities (such as evidenced during the recent declines in overall shad populations) are much lower than if population densities were more robust."

The text on page 29 has been changed to reflect the above comments:

"<u>Fish passage efficacy</u>
Fish passage at Susquehanna River hydro-electric dams is shown in Table 6 and Figure 7. American shad passage efficiencies for Holtwood, Safe Harbor, and York Haven have averaged 32%, 71%, and 10%, respectively, over the period from 1997 through 2009. These efficiencies were calculated by dividing passage at the dam in question by passage at the next downstream dam. This calculation does not account for drop-off between dams. A better method of calculating passage efficiency would be to compare the number of shad passed to the number of shad present in the tailrace, however, the number of shad in tailrace waters is unknown. Despite this, SRAFRC partners believe that shad passage efficiency is poor at Holtwood and York Haven dams, and is substantially limiting access to upstream spawning and nursery habitat for migratory fish. Studies are ongoing in 2010 (and perhaps 2011) at both Conowingo and York Haven Dams to better estimate fish passage efficiency."

6. The upstream American shad passage objectives and related implementation timeframes proposed in Task A1 are not technically supported or likely achievable.

"Task A1 proposes a "fish passage" objective for all four lower river hydroelectric projects of passing at least 85% of adult American shad reaching the project tailwaters, or at least 75% of the adult American shad that passed at the next downstream facility. The Plan lacks any technical basis for setting either of these objectives, and absent any cited basis, these values appear to be entirely arbitrary.

First, the concept that every hydroelectric project can achieve 85% passage efficiency as to fish arriving at the tailwaters is unsupported. We are unaware of any project that has achieved a long−term passage efficiency for American shad approaching 85%, and no literature is cited by the Plan suggesting that such an objective is either feasible or necessary. Even the Safe Harbor lift, one of the most efficient shad fishways on the East Coast, has exceeded this value only once (1999), and has averaged only 71% over the long term (see Table 6 of draft Management Plan).

At the same time, as noted above, the drop-off of shad moving upstream for whatever reasons must be considered in setting any objectives. The embedded assumption in the Task A1 "objectives" that only a 10% drop-off occurs is simply not supported by any data. It is entirely premature to set such "objectives" until SRAFRC has a much better understanding of shad migrating patterns, such as the type of information sought in the YHPC study that is now underway."

The performance standards used in the FMP are based upon fish passage data from the Susquehanna River. An average of 71 % of the American shad that have passed Holtwood Dam, have also passed Safe Harbor Dam. This has been accomplished with no operational or structural modifications of the original fishway at Safe Harbor. SRAFRC partners established 75% as a performance standard for Holtwood Dam, assuming that minor operational modifications at Safe Harbor could achieve an additional 4%. Owners of Holtwood Dam expressed concern about the potential for "drop off", i.e. fish might not migrate from one dam to the next for a variety of reasons. To accommodate this, we established a two-tier performance standard. If any fishway does not pass 75% of the fish passed by the next downstream fishway, compliance can be demonstrated by passing 85% of the fish that reach project tailwaters.

Our performance standards for downstream passage survival for American shad (80% for adults, 95% for juveniles) were also derived from data collected on the Susquehanna River. Normandeau (1998) demonstrated 24-48 hour turbine passage survival of 86.2% for adult American shad at Safe Harbor Dam. For juvenile shad, Heisey et al. (1992) demonstrated 48 hour Kaplan and mixed flow turbine passage survival of 98 to 100%, respectively, at Safe Harbor Dam. Similar studies at Conowingo Dam demonstrated 48 hour survival of 92.9% for juvenile shad passed though Kaplan turbines (RMC Environmental Services 1993). Thus, we know those standards are achievable. To be consistent, these standards were also applied to the other Susquehanna River Dams.

For silver eel downstream turbine survival there are no data available for the Susquehanna River. With a passage survival standard of 80% the four-dam cumulative survival would be only

41%. With an 85% standard, four-dam cumulative survival would be 52%. Given the current declining stock of American eels, SRAFRC partners felt that a more conservative standard was appropriate.

There is no embedded assumption in Task A1 that only a 10% drop- off occurs. If passage at Dam 1 is 100,000 shad and 50% of them "drop off", then only 50,000 would be present in the tailrace of Dam 2 for passage. In order to achieve compliance, the fishway at Dam 2 would have to pass a minimum of 42,500 (85% of the shad in the tailrace).

York Haven suggests that it is premature to set such objectives. SRAFRC partners are not willing to wait 30 years for the next FERC re-licensing cycle.

7. The objectives and implementation timeframe for downstream survival of Alosines proposed in Tasks A2 and A3 are not technically supported or likely achievable.

"Task A2 would seek to establish a target of assuring at least 80% survival at each dam for down-migrating adult Alosines. Task A3 would establish a target of 95% survival for down-migrating juvenile Alosines at each dam. Both tasks would purport to set 2014 as an implementation date.

Again, the Plan fails to provide any technical backup to the establishment of this target, as opposed to other passage rates. No literature citations or explanations are provided as to either the benefits of setting this objective, or its achievability. The question may be fairly posed as to whether this level of downstream survival for shad has been consistently achieved at any hydroelectric project, and if so, how.

It appears that SRAFRC does not currently have any accurate data concerning down-migrating survival rates. The key question is whether down-migration is a serious problem or not, and given the current lack of adequate shad populations on the up-migrating leg, it is extremely difficult to answer the question. Some of the studies now underway at the various projects will help to answer this question, but pending those evaluations, trying to set arbitrary rates to be achieved almost immediately is not reasonable or appropriate."

In its comment YHPC apparently acknowledges that operation of its hydroelectric project has an impact on the survival of down-migrating fish attempting passage. Otherwise, YHPC would not take issue with the establishment of survival targets for fish passing downstream through its projects. The SRAFRC and its member agencies are attempting to get estimates of what the current passage survival is at the York Haven and other FERC licensed hydroelectric projects through consultation and study as part of the FERC relicensing and license compliance process. It is an objective of the SRAFRC resource agencies to eliminate or minimize impacts to the restoration goal associated with operation of the hydroelectric projects. The ideal situation would be no mortality or delay associated with migration through the hydroelectric projects (i.e., 100% survival). Loss of down migrating adult fish results in lost future spawning opportunity, and loss of juveniles results in lost future adult recruitment opportunity. In any restoration effort it is imperative to maximize future spawning potential in order to grow the population. Eliminating or reducing mortality during passage at hydroelectric projects is an action to maximize future spawning potential. With present technology, the most effective method to *ensure the lowest mortality of migrating fish associated with downstream passage is total turbine shut down during the passage season, accompanied by facilities and measures to provide a safe alternative passage route through or around the dam.*

8. The Task A5 downstream silver eel passage objectives and associated implementation timeframe are not technically supported or likely achievable.

"Task A5 proposes a target of achieving at least 85% survival of downstream migrating silver eels, with a stated implementation date of 2014. For many of the same reasons discussed above, this objective and its associated implementation timeframe are not technically supported. No citations to either appropriate studies or literature are provided, and no evidence is provided that such a rate has been achieved anywhere at any hydroelectric project."

See comment No. 7 above. SRAFRC notes the near 100% downstream passage survival for American eels has been achieved at other FERC hydroelectric projects where turbine shutdown and facilities and measures to provide for alternate safe passage routes were required during the downstream migration season (Presumpscot River Hydroelectric Projects FERC Nos. 2942, 2931, 2941, 2936, and 2897).

9. Tasks A6 – A9 are vague, undefined, and hence problematic.

"Tasks A6 through A9 propose to develop targets for upstream passage of "migratory fish at all dams" and then provide for implementation of those passage targets. These tasks are all very vague, and provide little value to the Plan absent more specific information as to (1) what migratory fish species are being targeted; (2) what dams are to be addressed; (3) the sequence and schedule of actions; (4) the anticipated habitat and population gains sought; and (5) the overall value of such efforts versus the anticipated costs."

We concur that these and all of the tasks were in need of more details and better descriptions. We have revised the format to include timelines, anticipated costs, and priorities. Tasks A6 through A9 outline a plan to develop more specific goals at non-FERC dams. Also as rewritten, it can be seen that Tasks a-6 through A-9 are serial in nature. That is, after accomplishing Task A-6, work will progress to Task A-7 and so on. We appreciate YHPC's comments regarding the need to further refine the tasks.

10. Efforts for near-term enhancement of migratory fish spawning stock biomass and juvenile recruitment warrant priority attention.

"Tasks C1 through C8 address management techniques (hatchery operations and trap−and-transport operations) that appear to have higher potential to reverse the current downward trend in stocks and provide quicker short−term positive results, as demonstrated by the success of earlier similar restoration efforts on the Susquehanna River. Current conditions suggest that the overall effort would seriously benefit to sequencing of these short-term high-value/results-oriented management techniques prior to more long-term enhancement measures. We would suggest that SRAFRC cooperating agencies consider potential alternative sequencing and scheduling of these tasks that appear to have mutual benefits to the fishery and the hydroproject owners.

During the next two years (2011-2012), extensive in-water construction activities at the Holtwood Project have the potential to further inhibit cumulative upstream passage efficiency of Alosid spawning runs. This situation alone could significantly impact two desperately needed year classes of wild fish recruitment from the river above Conowingo Dam.

We believe that action is required in the near-term, long before any improvements resulting from FERC licensing actions could conceivably take place. Even under the best case schedule scenario of the FERC Integrated Licensing Process, enhancement measures may be too late to save some migratory species.

For this reason, YHPC believes the type of actions outlined in Task C4 may offer the single most effective short-term action to address declining American shad stocks in the Susquehanna River, and believe it should also be a top priority in the Plan. This is not an arbitrary opinion, it is a proven fact, as documented in the first half of the Plan describing the chronology of past restoration efforts on the Susquehanna River. YHPC believes this is the best stock augmentation alternative with the fastest return time on the effort (one life cycle, 3-5 years). This enhancement option also will produce wild Susquehanna River juvenile recruitment from historic Susquehanna River spawning and rearing habitat, unlike hatchery production from out-of-basin egg sources."

The SRAFRC included Task C4 for many of the reasons stated by YHPC. As a result of public and internal comments received on the draft Plan SRAFRC has prioritized tasks and Task C4 was ranked as a priority one task. The SRAFRC will be developing operational plans in the near future and will take YHPC's comments into consideration.

"Task C4 suggests that such efforts be undertaken with funding from the dam owners and resource agencies. To expand on this, we believe that ***all stakeholders*** in the basin have a stake in, and should be invited to participate in, such a cooperative effort. Beyond the lower basin dam owners, the cooperation of other major users of the river whose activities may also put stresses on the system should be brought to the table if these restoration efforts are to succeed."

The SRAFRC intends to engage all stakeholders in the restoration effort.

"If this is a truly cooperative effort, YHPC is certainly willing to contribute its fair share. While we are conducting the radio telemetry study of American shad upstream migration at the York Haven fishway in 2010, we have concerns about the value of additional telemetry studies (especially in 2011 and 2012) given the Holtwood construction. PFBC and USFWS have also shared this concern with us about the effect of Holtwood construction activities on shad studies at recent relicensing consultation meetings. This places some doubt on the value of pursuing telemetry studies in 2011 and 2012 to predict future fishway efficiency. YHPC believes that a reallocation of radio telemetry study funds to support trap and transport activities until the American shad population in the Susquehanna River rebounds to the 2000-to-2004 levels would not only help the American shad population recover, but would also avoid the possibility of collecting shad passage efficiency data under conditions that are non-representative of a more restored shad run.

YHPC would respectfully suggest that SRAFRC convoke as soon as possible a focused dialogue with all stakeholders on how to pursue and implement the Task C4 actions."

The SRAFRC will consider all opportunities to advance the goal of the migratory fish restoration Plan, and will engage all interested stakeholders in the development of operational plans and opportunities for participation in restoration actions.

11. Pending restoration of American shad populations, concerted efforts should be made to curtail commercial and recreational fishing of this species.

"Tasks C9 and C10 address management of both the commercial and recreational fisheries. At the current reduced stock levels throughout the Atlantic coastal area, mortality of any type should be avoided when possible. Just as the Atlantic States Marine Fisheries Commission must address the issue of commercial fishing, shad mortality caused by catch-and-release recreational angling needs to be assessed. Recreational catch-and-release fishing may be more stressful to shad than scientific angling for shad tagging, due to differences in handling techniques. If such recreational handling causes measurable mortality, then consideration should be given to suspending such recreational fishing until stocks recover."

The SRAFRC acknowledges the need for further investigation and directed research to delineate coastal mortality of American shad. The purpose of the Plan is to define the tasks that we can accomplish in the watershed while advocating protection of all diadromous fish in their critical habitats.

Within state waters, all directed American shad fisheries are closed. With the closing of the coastal fishery in 2005, no significant stock response has been noted, emphasizing the need to quantify bycatch and predation rates for American shad. In addition, research into associated catch and release mortality of American shad from anglers below Conowingo Dam has shown a negligible mortality of released fish (Lukacovic and Pieper 1996, and Lukacovic 1998).

SRAFRC and ASMFC are proactively participating in reducing American shad mortality in the EEZ thru the public comment process in the Mid-Atlantic and New England Fishery Management councils. Presently both are assessing and evaluating their managed species in light of anadromous fish mortality and may increase bycatch monitoring for anadromous species.

With these safeguards in place, safe upstream and downstream passage will likely drive the Susquehanna River population of American shad (Sadzinski et al. 2001). Mortality associated with downstream passage likely results in the mortality of many of the American shad lifted at Conowingo Dam. Reducing passage mortality will increase spawning stock the following year.

The Nature Conservancy Comment Letter

Objective A: Restore access to historic habitats for juvenile and adult migratory fish.

"Tasks AI-5 (collectively) establish numeric performance measures and targets for upstream and downstream passage efficiency and survival of adult American shad and American eels, and downstream passage of juvenile shad at the four lower river hydroelectric dams. We commend the SFAFRC for committing to develop numeric minimum passage efficiency targets and for incorporating them into the FERC licenses, 401 certification, and other relevant regulatory processes. This approach requires each dam operator to adjust, as needed, to improving ecological conditions and improved passage efficiency at other facilities. It is a useful means to coordinate management of multiple facilities with different owners and with licensing schedules that are not synchronized.

We recommend revising Task A6 to clarify whether the development of" ... realistic targets for upstream passage ... " refer to dams other than the four hydroelectric dams on the lower river (which already have specified minimum passage efficiency targets) or whether the specified minimum passage efficiencies in Tasks AI-A5 (75%, 80%, 95%, etc.) also need to be revised to be more realistic."

Thank you for supporting the Plan's numeric passage goals. We concur that watershed coordination between dam owners will be necessary to accomplish such goals. Task 6 (Develop realistic targets for upstream passage of migratory fish at all dams) has been clarified to define this task as pertaining to non-FERC relicensed dams.

Objective B: Maintain or improve existing migratory fish habitat quality.

"We recommend adding introductory text summarizing the objective. Objectives A & C include several sentences summarizing the goals of the tasks within before listing specific tasks (Objectives B and E could also benefit from introductory text).

Task B1 focuses on inventorying tributary blockages, setting priorities and reopening blocked habitats. The Nature Conservancy is very interested in helping SRAFRC accomplish this task. The Conservancy currently coordinates the Northeast Aquatic Habitat Connectivity Assessment Project (funded through a grant from Northeast Association of Fish and Wildlife Agencies). This project includes active participation from state fish and wildlife agency staff in the thirteen northeastern states. By March 2011, the project will have assembled existing dam data throughout the region and developed and applied evaluation criteria to identify priority barriers. As this project nears completion, we would like to review the results with SRAFRC, discuss how these results might contribute to this task, and determine next steps for refinement or verification.

Task B1 seems to be more appropriately listed under Objective A - which focuses on access to habitat, rather than habitat quality. It may be somewhat redundant with (and could possibly replace) other tasks within Objective A (for example, Task AI6)."

SRAFRC is also very interested in establishing working relationship with The Nature Conservancy. Results from the Northeast Aquatic Habitat Connectivity Assessment Project and its possible application to the Susquehanna River watershed is of particular interest and coordination for a meeting would be beneficial.

Objective C: Enhance migratory fish spawning stock biomass and maximize juvenile recruitment.

“Task C3 focuses on stocking to supplement wild production of American shad and includes benchmarks for discontinuing stocking efforts. The first benchmark is <25% hatchery contribution passing at Conowingo for three consecutive years. We suggest that SRAFRC consider complementing this percentage benchmark with a numeric goal. For example, the condition could read: The number of adult American shad passing upstream exceeds X and the hatchery contribution is less than 25% for three consecutive years. Otherwise it is possible that the <25% condition could be met, but there are still too few wild American shad to re-establish mainstem and tributary stocks.

We also suggest clarifying the relationship between the stocking goals, the annual run goals, and the passage efficiency goals.

Finally, we encourage SRAFRC to contribute to development of range- and/or coast-wide goals for individual species and clarify how management and restoration of migratory fish within the Susquehanna River contribute to these goals.”

The overall restoration benchmark for the Susquehanna River is 2 million American shad and 5 million river herring above York Haven Dam. In light of the adult hatchery American shad captured at Conowingo Dam, Task C3 has been re-written to emphasize a more encompassing approach to restoration stocking and would not cease until at least three triggers have been met.

Objective E: Ensure cooperation among all restoration partners while generating support for the restoration of migratory fish among the general public and potential funding sources.

“The Nature Conservancy would potentially be a willing collaborator on migratory fish restoration proposals, especially for projects related to fish passage improvements, research on passage effectiveness and new technologies, barrier removal, habitat availability, or for strategic planning, goal setting, and adaptive management. We may have technical capacity to contribute to specific projects, and in other cases we may be able to help secure funds for projects that are within our geographic and/or programmatic priorities.”

SRAFRC agrees that all watershed stakeholders with an interest in migratory fish restoration should work together and would encourage a meeting with The Nature Conservancy and other interested parties.

Bill Lellis comments

“One quick note on Table 5, page 79. I believe the last two columns (2008, 2009) should be 17 each, since the rest of the numbers are in thousands of eels. Also, we released around 1k eels into Pine Creek, Tioga County, PA in 2009.”

Table 5 has been corrected and the data for 2009 included.

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