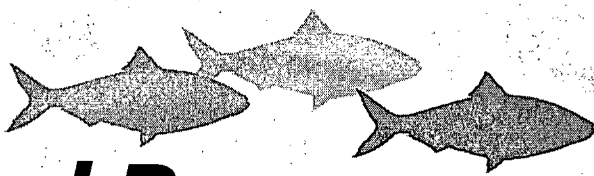
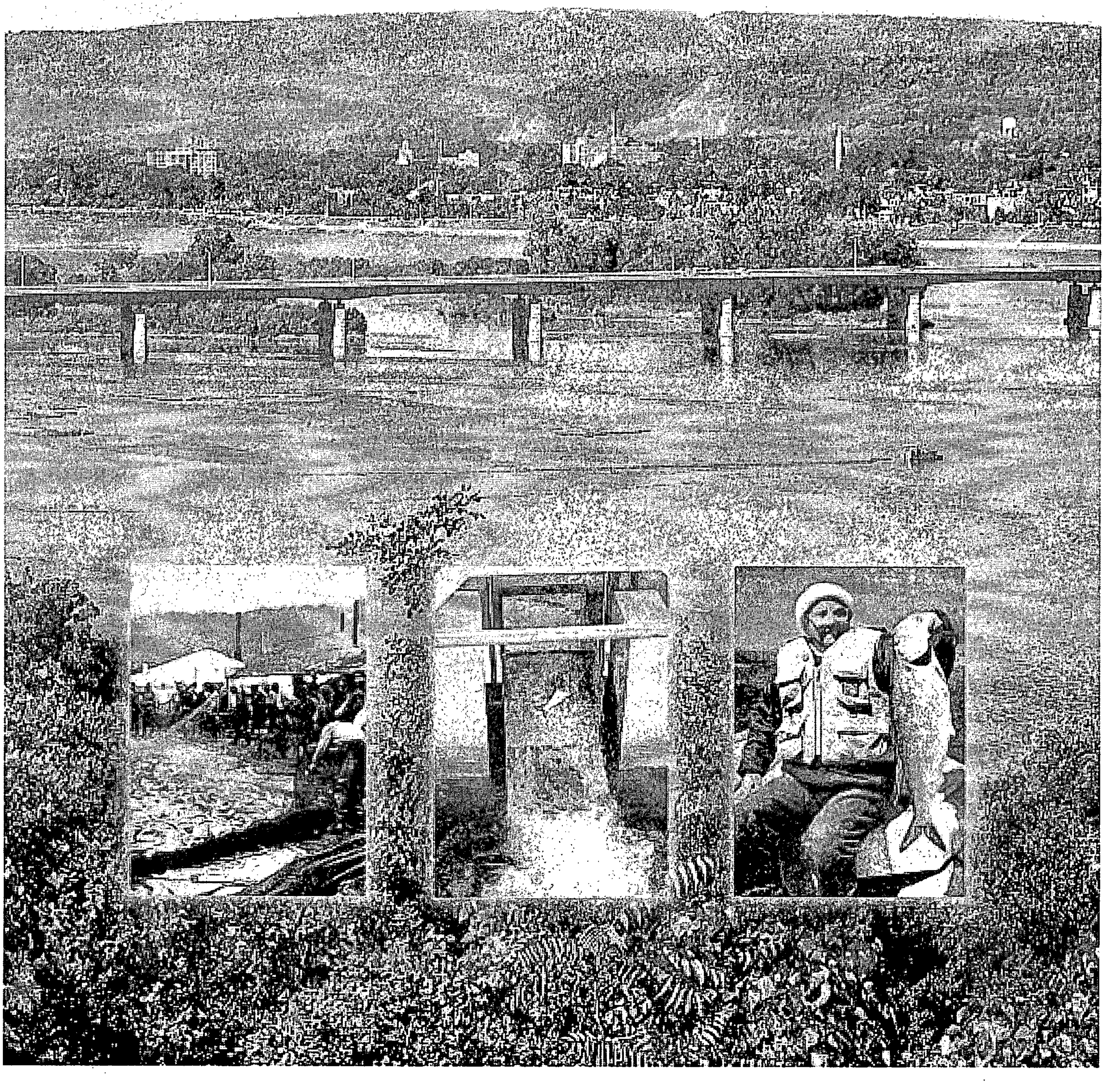
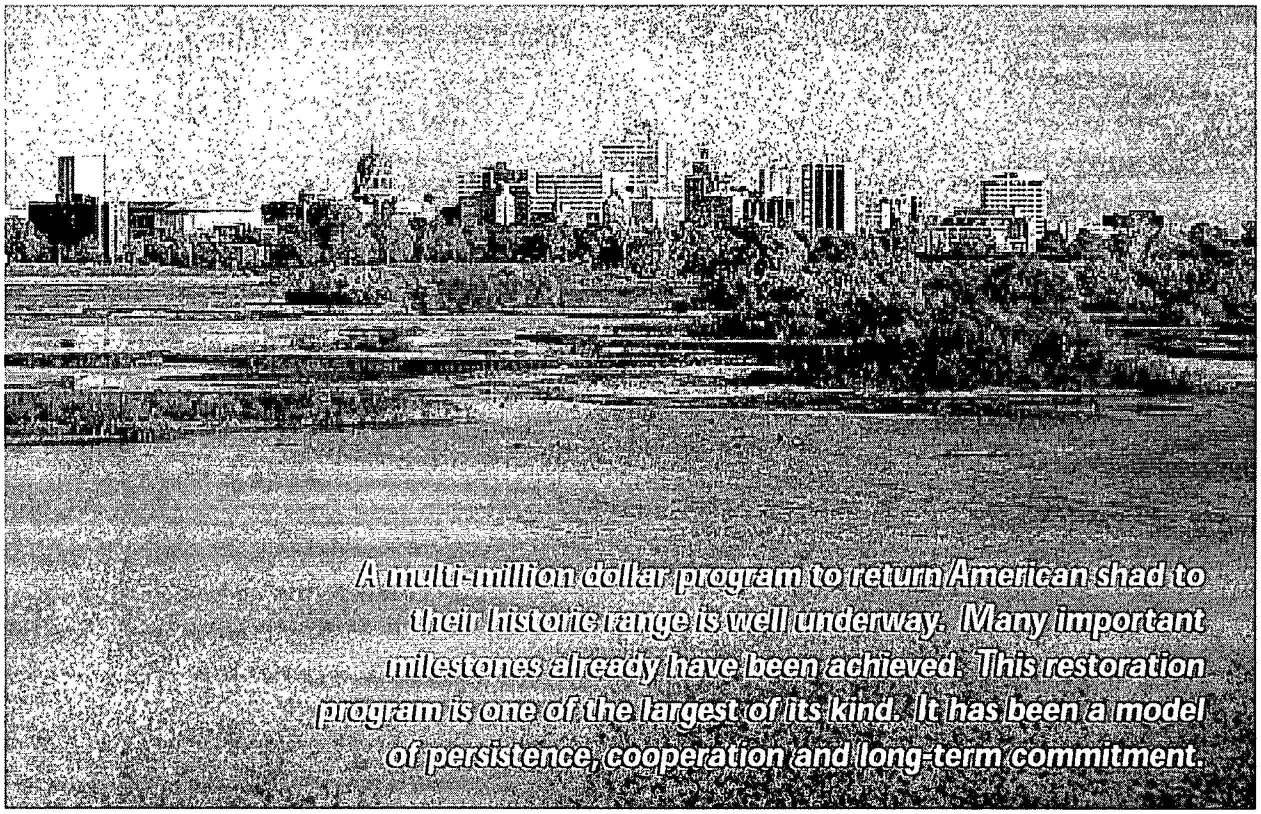
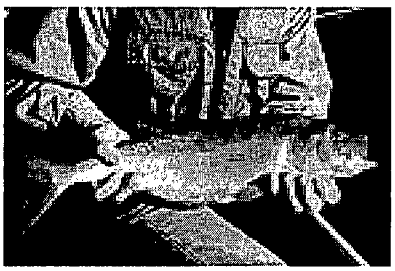
# Migratory Fish Restoration and Passage on the Susquehanna River









*American Shad*

Few Pennsylvanians are aware that the American shad once ruled the waters of the Susquehanna River and its tributaries. Their sheer abundance made for bountiful harvests each spring during their spawning runs. They were one of the region's most valued commodities for commerce and daily living through the 1830s. Tragically, the shad's natural migratory cycle was broken by human activities, primarily the construction of dams. A multi-million dollar program to return American shad to their historic range is well underway. Many important milestones already have been achieved. This restoration program is one of the largest of its kind. It has been a model of persistence, cooperation and long-term commitment. Restoration program participants are:

- U.S. Fish & Wildlife Service.
- U.S. Environmental Protection Agency, Chesapeake Bay Program.
- National Marine Fisheries Service.
- Susquehanna River Basin Commission.
- Pennsylvania Fish & Boat Commission.
- Maryland Department of Natural Resources.
- New York Department of Environmental Conservation.
- PECO Energy (owner of Conowingo Dam).
- Pennsylvania Power and Light Company (owner of Holtwood Dam).
- Safe Harbor Water Power Corporation.
- York Haven Power Company.

In this publication, we take you on a journey to learn the history of these fish, the reasons for their demise, and the noble efforts to restore migratory fish populations in the Susquehanna River watershed.

SPORT FISH RESTORATION

Your purchase of fishing equipment and motor boat fuels supports Sport Fish Restoration and boating access facilities

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*wraparound cover photo-Art Michaels; inset cover photos (from left)-courtesy of U.S. Fish & Wildlife Service, Ted Walke, Art Michaels; this page top photo-Art Michaels; small photo-Vic Attardo*

# A Lost Legacy: American Shad in the Susquehanna River

*Susquehanna Flats, MD, around 1900*

*photo-courtesy of U.S. Fish & Wildlife Service*

Long before the first Europeans settled the interior of Pennsylvania, great numbers of fish migrated hundreds of miles from the ocean each spring to complete their life cycle in the Susquehanna River. Shad, river herring and eels were important sources of food for Native Americans for centuries. Their fishing skills, using brush nets and rock-crib traps, were passed on to early settlers on the frontier. The first formal shad fishing companies were established by Connecticut Yankees laying claim to the northern tier of Pennsylvania in the 1750s. These settlers to the Wyoming Valley brought netmaking skills and introduced seines for harvesting the plentiful shad.

It seems that during the several decades following the American Revolution, the annual harvest of shad from the upper Susquehanna was limited only by the availability of salt needed for preservation. Although shad fishing occurred during only a few spring months, the species comprised the most valuable "crop" from this region of colonial Pennsylvania, and no family was without its share.

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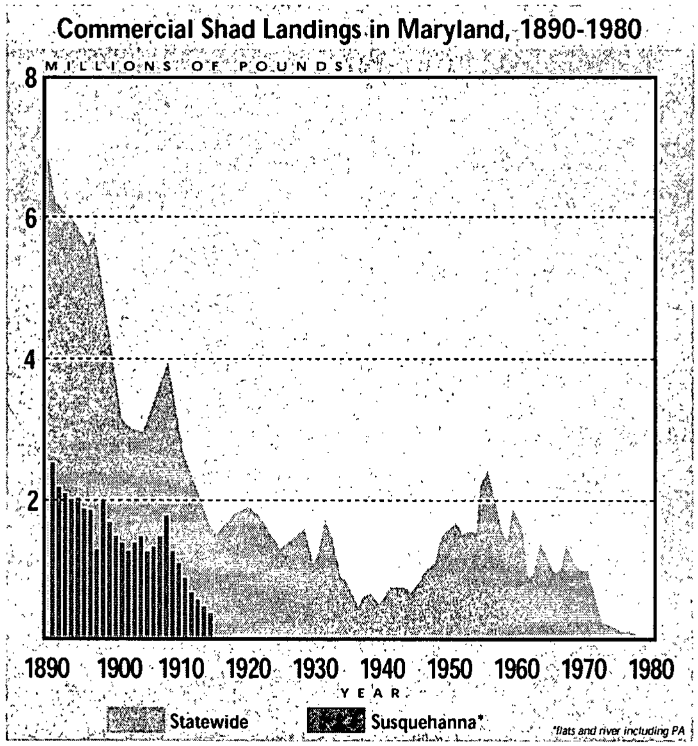
## Long journey home

Shad are reported to have reached the Susquehanna headwaters near Cooperstown, NY, before the development of dams at Binghamton. This 640-mile journey from the sea was the longest recorded for the species on the Atlantic Coast. The historic record suggests that shad reached the foothills of the Alleghenies near Hollidaysburg, on the




*Annual Pennsylvania shad landings in the Susquehanna River during 1890 to 1909 averaged 252,000 pounds each year, equivalent to 63,000 fish. In 1896, the shad catch in the river, both in Pennsylvania and Maryland, was 140,000 fish. The total Maryland shad catch that year was about 1.4 million fish, constituting the most important fishery of the Chesapeake Bay.*

Juniata River, and at least to Lock Haven on the West Branch. The closely related river herring (alewife and blueback herring) also were plentiful throughout the river basin but were not considered as valuable as the shad. Shad sold for between 3 cents and 20 cents apiece in the early 1800s. A bushel of salt typically traded for 100 shad.

Leasing and transfer of fishing rights on many river islands are well-documented in the public record. There were many dozens of such fisheries in the lower river below Harrisburg and in the North Branch from Northumberland to Towanda. Even though early 19th century harvest records are largely anecdotal, typical catches numbered in the hundreds each day and night, and many thousands of shad were annually reported for each fishery.

*Susquehanna Flats, MD, around 1900*

*photo-courtesy of U.S. Fish & Wildlife Service*

There is little doubt that shad numbers were great. The North Branch fisheries alone accounted for several hundred thousand fish each year. The initial demise of shad and herring runs in the Susquehanna River was related to the construction of dams that blocked migrations. Hundreds of mill dams were erected in tributaries, and although passageways for fish were required as early as 1800, few were developed. Shad fisheries on the mainstem Susquehanna up to the New York state line flourished until 1830. Over the course of the next five years, feeder dams for the new Pennsylvania canal system were erected at Nanticoke, Shamokin, Clarks Ferry, Duncan's Island and Columbia. The Juniata River was dammed a few miles above Newport.

## Dams, pollution, overfishing

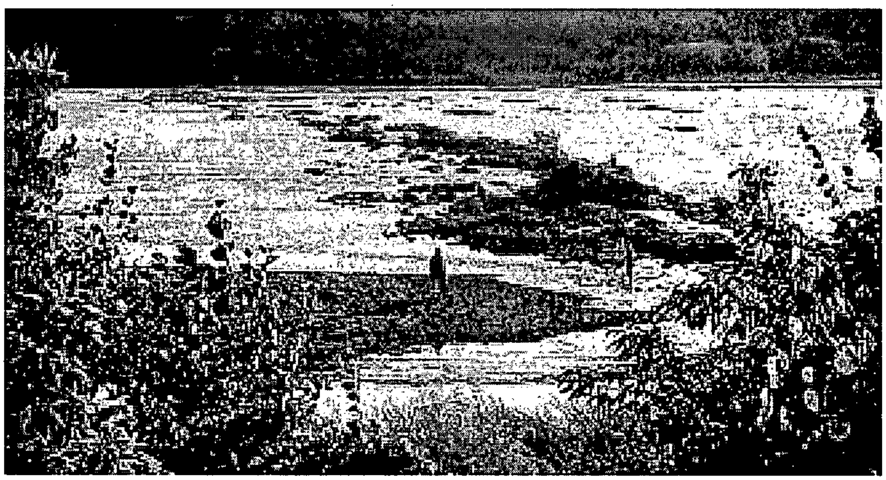
Hundreds of miles of spawning habitat and all river fisheries above Columbia were lost. Throughout the remainder of the 19th century, sizable shad fisheries developed in the river below Columbia Dam and at the head of the Chesapeake Bay. In 1866, immediately following the Civil War, the Pennsylvania legislature passed a law directing persons or companies that owned dams on the Susquehanna River and certain tributaries to "make, maintain and keep up a sluice, weir, or other device for the free passage of fish and spawn, up and down the streams..." This same Act created the office of a commissioner, appointed by the governor, to oversee and enforce the fish passage provisions. This appointment was the forerunner of the present-day Pennsylvania Fish & Boat Commission.

Early attempts at fish passage failed. The first Pennsylvania Fish Commissioner, James Worrall, blamed the further demise of shad runs on illegal fish traps and weirs that destroyed millions of juvenile fish trying to make their way to the sea, and on uncontrolled harvest of shad near the river's mouth by Maryland fishermen using huge nets.

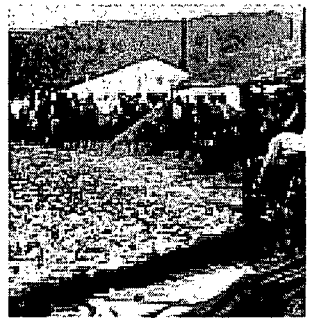
Excessive harvest of spawners and inadvertent killing of great numbers of juvenile fish were not the only factors driving the shad population down. Throughout the 19th century, the water quality of the Susquehanna River was greatly diminished. The culprits were coal mining operations in the North and West branches, and siltation and erosion resulting from extensive timbering operations, especially in the West Branch. Industrial and agricultural development in the lower basin and sewage discharge from growing riverside cities added to this pollution problem.

Railroads replaced the canal system, and by the late 1800s shad runs resumed once the dams at Columbia and farther upstream were abandoned and breached. Annual Pennsylvania shad landings in the Susquehanna River during 1890 to 1909 averaged 252,000 pounds each year, equivalent to 63,000 fish. In 1896, the shad catch in the river, both in Pennsylvania and Maryland, was 140,000 fish. The total Maryland shad catch that year was about 1.4 million fish, constituting the most important fishery of the Chesapeake Bay.

Between 1904 and 1932, four hydroelectric dams were built on the lower Susquehanna River. The Holtwood Dam was completed in 1910. Located only 25 miles above the river mouth, many of the best historic fishing islands were inundated. Fish passage design was primitive, and although fishways were included in this construction, they failed to pass shad. By 1915, the Susquehanna River shad catch fell to 33,000 pounds. By 1921, there were no shad to be harvested. When the 95-foot-high Conowingo Dam was built at river mile 10 in 1928, state and federal fishery authorities conceded that development of effective fish passageways at high dams was not practical. The Susquehanna River shad resource was lost.



*Recreational shad fishing on the Susquehanna will result in some $30 million annually in economic benefit.*



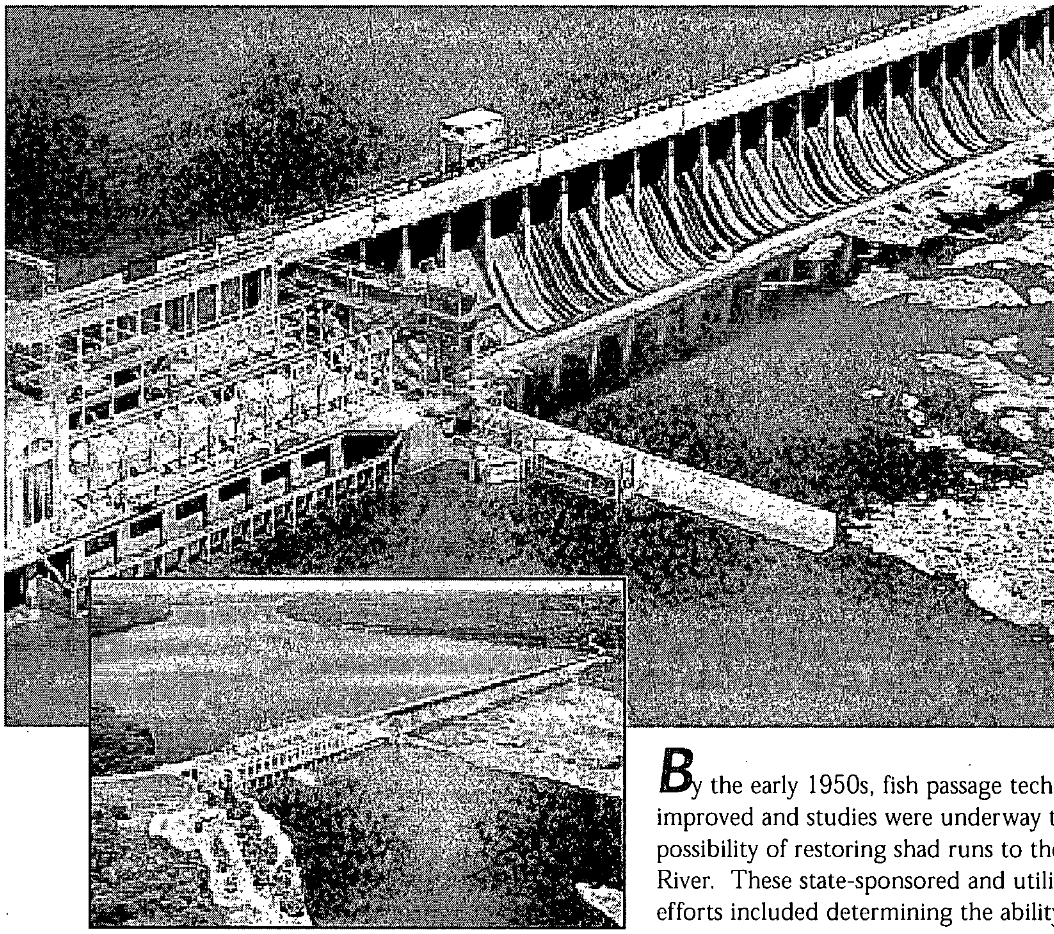
## *Why Restore This Legacy?*

Restoring migratory fish to the Susquehanna is the right thing to do! In fact, it means more than just restoring an ecosystem or the natural balance of the fishery. Migratory fish are part of Pennsylvania's natural, cultural and economic heritage. Restoration efforts since the late 1800s have been driven by this fact. Restoration efforts are simply aimed at reversing the effects of earlier human activity and regaining our natural, cultural and economic legacy.

Natural resources in Pennsylvania have always been and continue to be an important component of Pennsylvania's economy. Recreational fishing obviously depends on our natural resources. The Pennsylvania Fish & Boat Commission estimates that recreational shad fishing on the Susquehanna will result in some $30 million annually in economic benefit. That's nearly 10 times the economic benefit of shad fishing on the Delaware River. Of course, an open season for shad won't happen until the Commission decides the population can support fishing. Clearly this is another example where restoring ecosystems results in both ecological and economic benefits.

*top photo-courtesy of U.S. Fish & Wildlife Service; bottom photo-Art Michaels*

# 40 Years of Shad Restoration



Conowingo Dam spans the Susquehanna River about 6 miles below the Pennsylvania-Maryland border and 10 miles above the mouth of the Susquehanna River at the head of the Chesapeake Bay.

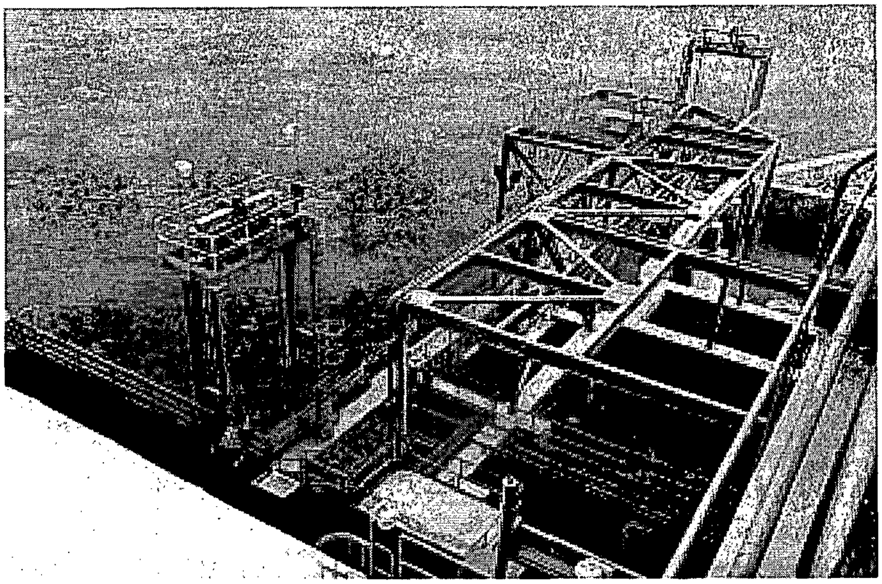
photos-PECO Energy

By the early 1950s, fish passage technology had improved and studies were underway to assess the possibility of restoring shad runs to the Susquehanna River. These state-sponsored and utility-sponsored efforts included determining the ability of shad to move upstream and reproduce, engineering and biological feasibility for fish passage at dams, and evaluating the suitability of the river to support migratory fishes. Results of the fish passage engineering and habitat suitability studies were favorable. However, questions remained on the abundance of shad reaching the Conowingo Dam and their willingness to continue migrating.

In 1969, representatives of the U. S. Fish & Wildlife Service, the Pennsylvania Fish Commission (now the PA Fish & Boat Commission), the New York Department of Environmental Conservation, and the Maryland Department of Natural Resources joined to form the Susquehanna Shad Advisory Committee. The committee worked closely with the utility companies that owned the dams. In 1970, these parties reached an agreement to stock the river with shad eggs and to build a fish-trapping facility at Conowingo Dam.

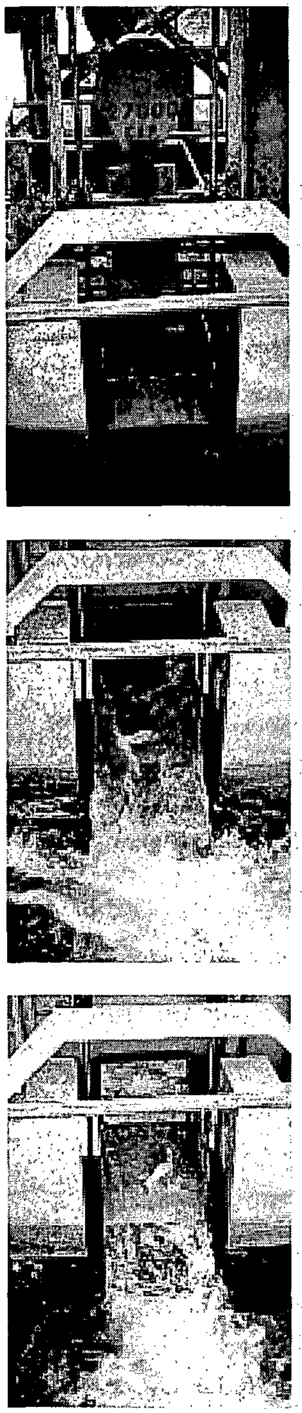
## Anadromous fish restoration committee

Philadelphia Electric Company (now PECO Energy) constructed a fish elevator at the west side of Conowingo Dam, and over a five-year period, 200 million shad eggs were placed in hatching boxes in the river. In 1976, egg stocking was replaced with culture and release of shad fry. Using utility funds, the Pennsylvania Fish Commission developed the first modern American shad hatchery in the world, the Van Dyke Research Station at Thompsontown, Juniata County, PA, on the Juniata River. Also that year, the Shad Advisory Committee was renamed "Susquehanna River Anadromous Fish Restoration Committee" (SRAFRC).



*The new fish lift at Safe Harbor Dam began operation in 1997. This fish lift, like Conowingo Dam's east lift, passes migrating fish directly into the pool above the dam.*

*Water from above the dam attracts fish into the fish lift. A gate closes and crowds the fish over a bucket, which lifts the fish, in water, and releases them into the exit channel at reservoir level above the dam.*



*top photo-Safe Harbor Water Power Corporation; sequence photos-Ted Walke*

The shad population declined sharply in the upper Chesapeake Bay after 1971. Overfishing, poor river conditions and the flooding effects related to Tropical Storm Agnes, which passed through the basin in June of 1972, were among the contributing factors. From 1972 through 1980, only 945 shad were collected at the Conowingo lift. During this period, the hatchery stocked seven million shad fry and fingerlings in the Juniata River. All shad fisheries in Maryland waters of the Chesapeake Bay were closed in 1980 in response to the continued decline.

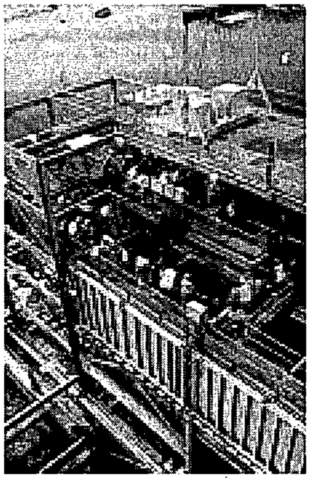
In 1979, SRAFRC adopted a "Strategic Plan for Restoration of Migratory Fishes to the Susquehanna River." The goals of that plan were to reopen the river to natural migrations and to restore annual spawning populations of two million shad and 10 million herring within 25 years of fish passage development. The Susquehanna River Basin Commission included all components of the strategic plan in its Comprehensive Plan for the management of the basin.

Long-term operating licenses for all four Susquehanna River hydroelectric projects were renewed by the Federal Energy Regulatory Commission in 1980. Questions related to shad restoration and fish passage requirements at the dams were addressed at a formal hearing held in Washington, D.C. All parties were urged to negotiate a settlement that would meet their common purpose of designing and implementing a cost-effective program to rebuild shad stocks returning to the river.

## Shad population rebuilding

Such an agreement was reached with owners of the three upstream dams in December 1984. Pennsylvania Power & Light Company, Safe Harbor Water Power Corporation and York Haven Power Company provided $3.7 million over the 10-year period 1985-1994 to fund trap and transfer of adult shad, expand hatchery operations and conduct other studies related to shad restoration. All parties agreed to resolve outstanding issues related to the design and construction of fish passage facilities at Holtwood, Safe Harbor and York Haven projects once Philadelphia Electric Company initiated construction of permanent passage facilities at Conowingo Dam.

With this secure funding agreement in place, hatchery production increased substantially, averaging over 10 million shad fry each year. Also, the catch of returning adult shad at Conowingo improved from a few hundred fish each year in the early 1980s to many thousands of shad by the end of the decade.



In response to this improvement and other costly measures imposed by the federal regulators, Philadelphia Electric Company reached a separate agreement with resource agencies to construct a permanent fish passage facility at the east side of the Conowingo powerhouse. This facility is capable of handling 1.5 million shad and 10 million herring. The east lift began operating in April 1991. This commitment at Conowingo encouraged upstream dam owners to begin fish passage design at their facilities, based on the 1984 agreement.

## Reopening the river

In 1993, owners of the three upstream hydroelectric projects reached a final settlement with state and federal fishery resource agencies to construct permanent fish passage facilities at Holtwood and Safe Harbor dams by spring 1997, and at York Haven by spring 2000. All three met their obligations with state-of-the-art facilities. Over 450 miles of the Susquehanna mainstem, the West Branch, and the Juniata River are once again available for use by migratory fishes.

During 1985-1998, over 350,000 adult shad were passed above Conowingo or transported and released to spawn above all dams. The Van Dyke Hatchery stocked over 150 million juvenile shad in the same period. The annual return of shad to Conowingo Dam increased steadily from fewer than 2,000 to over 100,000 fish. The shad restoration program on the Susquehanna River has been a model of persistence, cooperation and long-term commitment among resource agencies and private utility companies who share a common goal of restoring migratory fish runs. This effort is the largest of its type ever undertaken for American shad, and the anglers from the three basin states will soon reap the benefits as this long-lost resource returns to the river.

## *Shad Restoration Milestones*

**1904-1932.** Four large hydroelectric dams are built across the mainstem Susquehanna River between Conowingo, MD, and Middletown, PA.

**1947-1952.** Pennsylvania Legislature requests the U. S. Congress to support studies for restoring shad to the Susquehanna River. Atlantic Coast investigations begin.

**1954-1960.** Continued federal-, state- and utility-sponsored studies indicate that shad can survive and migrate through Susquehanna impoundments.

**1961-1962.** Pennsylvania Fish Commission completes study indicating that fish passage is feasible at Susquehanna River dams.

**1963-1968.** Utility-sponsored studies show that most Susquehanna and Juniata River habitat is suitable for shad reproduction and survival.

**1970-1980.** Conowingo west fish lift is built and operated; shad egg stocking is replaced with hatchery culture of fry at Van Dyke; return population of shad at Conowingo is fewer than 300 fish per year.

**1981-1982.** Long-term operating licenses are reissued to Susquehanna hydroprojects; the Federal Energy Regulatory Commission holds hearings on shad restoration and instream flow needs.

**1984.** Settlement agreement for shad stock rebuilding ($3.7 million) is reached.

**1985-1994.** Van Dyke develops tetracycline marking and stocks over 100 million shad fry; over 125,000 adult shad are stocked above Conowingo Dam; annual shad returns to the river grow from 1,500 to 60,000.

**1988-1991.** Separate settlement is reached with Philadelphia Electric Company; first permanent fish passage facility (east lift), costing $12 million, is completed at Conowingo Dam.

**1993-1997.** Settlement on fish passage is reached with all upstream utility companies; fish elevators are completed and placed into operation at Holtwood and Safe Harbor dams at a cost of about $38 million; shad return at Conowingo exceeds 100,000 fish in 1997.

**1999-2000.** York Haven Water Power Company completes a 500,000-shad fish ladder at Three Mile Island east channel dam at a cost of about $9 million; the Susquehanna River and its largest tributaries up to Binghamton, NY, totaling 435 miles, are reopened to natural runs of shad and herring for the first time in almost 100 years.

*top photo-Safe Harbor Water Power Corporation; bottom photo-Alliance for the Chesapeake Bay*

# Restoration Approach

Restoration of shad to their historic abundance in the Susquehanna River requires a four-part approach:

**Regulating the harvest of adult fish.** State and federal agencies have regulations in place to restrict harvest of American shad in the river, bay and ocean, paving the way for successful restoration.

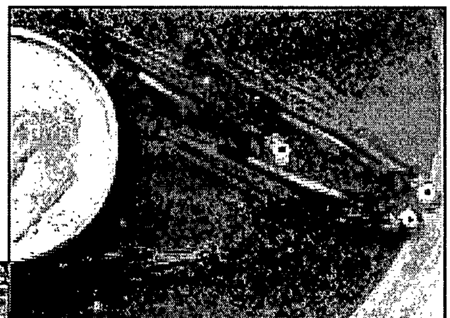
**Improving degraded habitat.** Baywide water quality initiatives are addressing habitat restoration (see "The Chesapeake Connection" on page 16). Removal of dams restores stream habitat for migrating fish.

**Constructing fish passage facilities.** Construction of fish passage facilities at the four lower river dams is now complete. Cooperating government agencies and private concerns are addressing fish passage issues at other dams in the basin.

**Restocking above blockages.** Restocking above blockages has included both migrating adults and hatchery-produced fry. Before fish passage facilities were built, migrating adults could not reach spawning areas above dams on their own.

## Trap and transport

The trap and transport program began at Conowingo Dam, where PECO Energy built two fish lifts to trap migrating fish. The west lift, built in 1972, collects fish for transport by truck to upstream spawning areas. The newer east lift was also used for trap and transport during 1991 through 1996, but its current role is to pass fish directly into Conowingo Reservoir. These lifts use flowing water to attract migrating fish into collection chambers where they can be crowded and lifted in large steel buckets. When operating for the trap and transport program, the lifts dump thousands of fish into large tanks. Biologists then sort the fish by type, removing shad and river herring to holding tanks. These fish are later transported by truck to upstream spawning areas at Middletown and Columbia. The other fishes are released back into the Conowingo tailrace. Most shad and herring reaching Conowingo Dam are now passed directly into the reservoir above. Because the river is now open to migration, trap and transport of shad from the west lift will soon be phased out.



*Shad fry*

*Fish & Boat Commission personnel release 21-day-old inch-long shad fry into the Juniata River at Millerstown, Perry County. The Commission raises 10 million to 20 million shad fry annually for stocking. Raising shad and stocking them above blockages is currently a major part of restoration. Restoration success will ultimately be shown when the hatchery effort can be safely discontinued.*

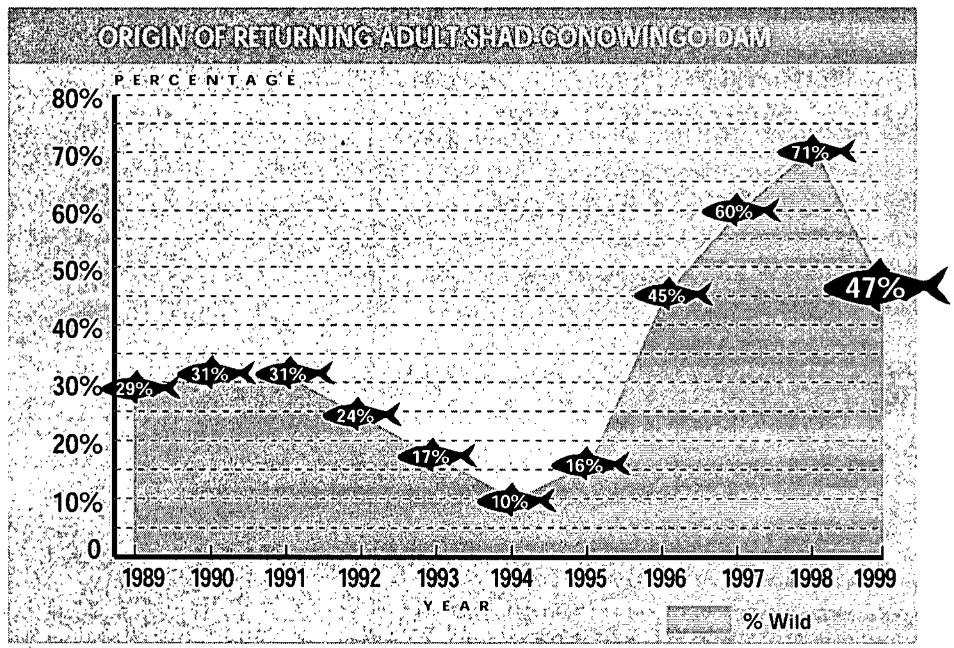
*shad fry photo-Russ Gettig; bottom photo-Mike Hendricks*

## Hatchery culture

The second component of the restocking effort, hatchery culture, has resulted in the rearing and stocking of millions of shad fry into the Susquehanna River. Adult American shad are collected during their spawning runs in other East Coast rivers, primarily the Delaware and Hudson. These adults are stripped of their eggs, which are then fertilized. The fertilized eggs are delivered to the Pennsylvania Fish & Boat Commission's Van Dyke Research Station. Eggs are also obtained from Susquehanna River shad, collected at Conowingo Dam. These fish are injected with hormones, stocked in hatchery tanks, and allowed to spawn naturally. After seven days of incubation, the tiny, fragile fry emerge from the eggs. Three-day-old fry are fed a combination of live brine shrimp and finely ground dry diet. After seven to 21 days of culture, the fry are carefully scooped from the tanks and released into the river. At this stage, they are less than two-thirds of an inch long, and must avoid predation from minnows and other small fish. The rest of the life cycle of these hatchery-reared shad is the same as naturally spawned shad as described on page 10.

## Evaluation

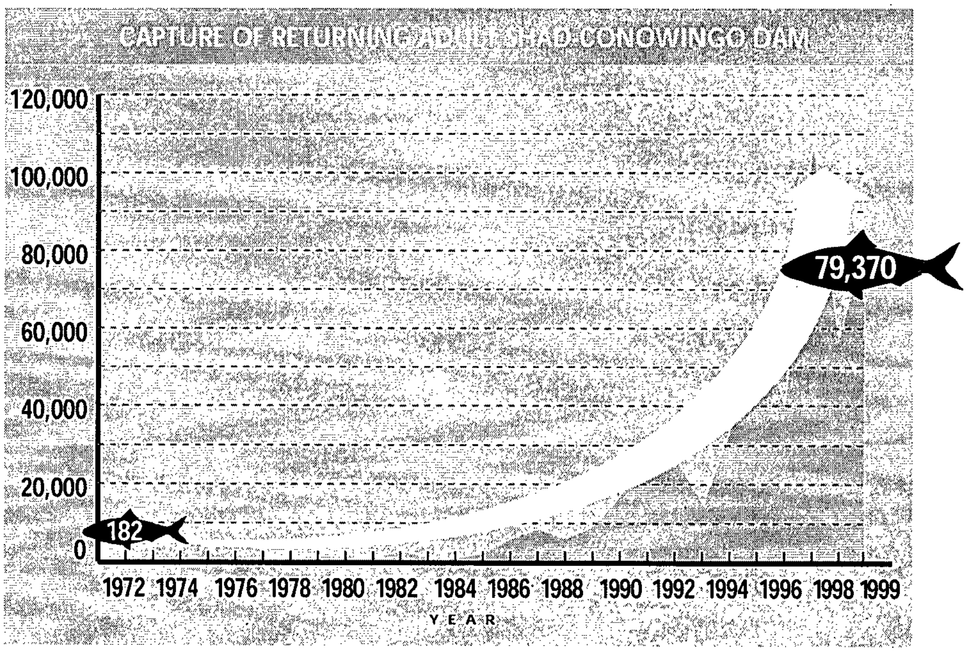
Monitoring the success of the natural reproduction and hatchery stocking begins in July as soon as juvenile shad are large enough to be collected with nets. Large 400-foot seines and electrofishing gear are used in the free-flowing sections of the river to collect specimens for otolith analysis and to monitor growth and abundance (see the sidebar "Tetracycline Marking" on the next page). Summer seine collections are




*Initially, hatchery fish contributed up to 90 percent of the spawners returning to the Susquehanna. But in recent years, unmarked naturally reproducing fish have dominated the run. This information shows that the hatchery program has been a key ingredient to the recovery of the Susquehanna River shad stocks.*

augmented by fall collections at the Holtwood hydroelectric dam using lift nets to capture juveniles as they move downstream toward the ocean. Evaluation of otoliths from collected sub-samples of juvenile shad demonstrates the success of the hatchery and the adult trap and transfer programs.

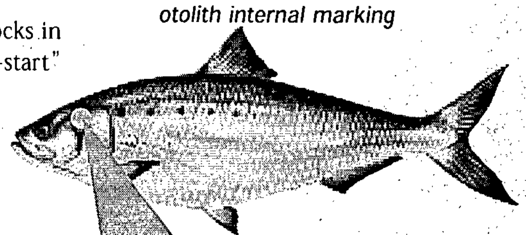
The catch of adult shad in the lifts at Conowingo increased markedly in recent years from an average of only 300 fish per year from 1972 to 1984 to more than 100,000 in 1997. Otoliths are evaluated from representative samples of these adult collections each year. Initially, hatchery-marked fish contributed up to 90 percent of the spawners returning to the Susquehanna. But in recent years, unmarked naturally reproducing fish have dominated the run.




*The trend of increasing numbers of returning adult shad at Conowingo Dam suggests that the shad population is increasing. Nevertheless, true restoration ultimately depends on the ability of returning adult shad to migrate upstream successfully so that they can spawn above dams, as a naturally reproducing, self-sustaining population.*

The hatchery program has been a key ingredient to the recovery of shad stocks in the Susquehanna River. But culture and stocking are tools used only to "jump-start" the rebuilding process. True restoration ultimately depends on the ability of returning adult shad to migrate upstream successfully so that they can spawn above dams, as a naturally reproducing, self-sustaining population. Success will ultimately be shown when the hatchery effort can be safely discontinued.

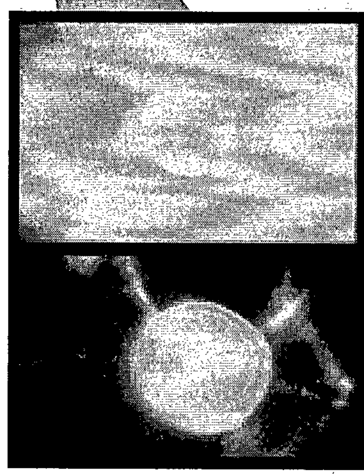
*otolith internal marking*



## Tetracycline Marking

Developing methods to evaluate the stocking program has been a key to showing that the restoration of shad will succeed. Because both naturally spawned and hatchery juvenile shad coexist in the upper river, a method for distinguishing the hatchery-reared fish had to be developed. Traditional tagging methods such as dart tags, jaw tags and fin clips would not work because shad fry are so tiny when released.

Researchers modified a method developed by West Coast scientists to mark Pacific salmon. This method allows for mass-marking of large numbers of American shad fry. The mark is applied by adding tetracycline to the rearing tank, effectively immersing the fry in an antibiotic bath. The tetracycline is taken up by the fish and incorporated into growing bone tissue, specifically into the otoliths (earstones). The otoliths are disk-shaped bones found in the inner ear that serve in balance and hearing. Otoliths grow by laying down new calcium-bearing rings each day. The tetracycline present can be detected by examining a thin slice of otolith under a microscope. Using ultraviolet light, biologists look for the fluorescent-yellow glow that is produced by the antibiotic.



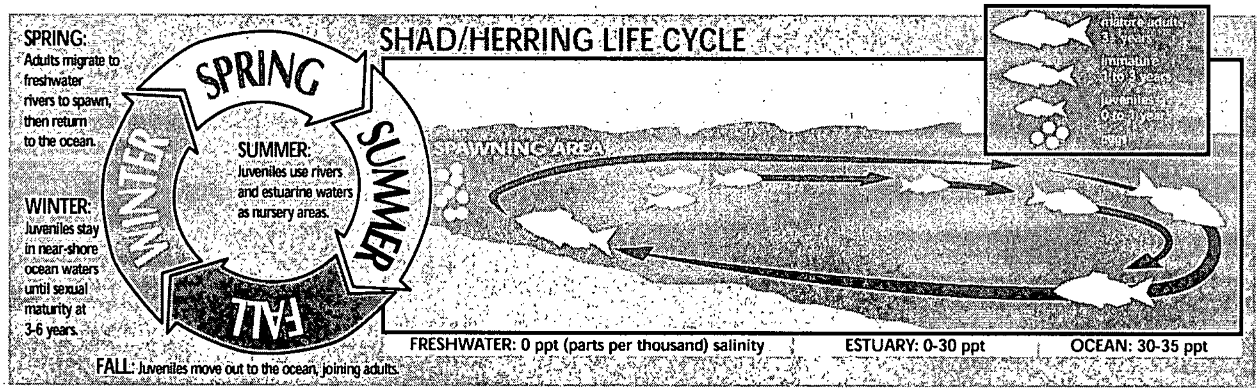
*Tetracycline-marked shad-fry earstones (otoliths) illuminated with ultraviolet light under a microscope.*

The same fish can be marked many times at intervals of several days. Varying the number of marks and the intervals produces distinct Morse code-like mark combinations. These "codes" allow many types of evaluations, including juvenile survival from different egg sources, stocking sites and times, and size or age of fish at release.

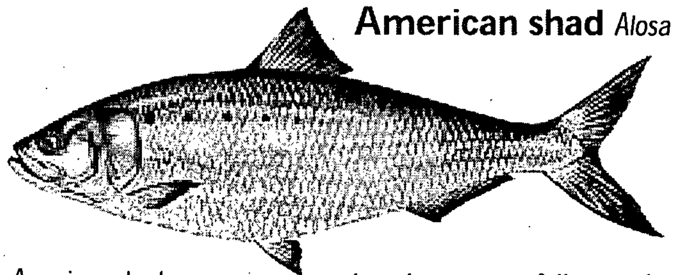
The shad tetracycline marking program on the Susquehanna River is the largest of its kind in the world. More than 135 million marked shad fry were stocked between 1985 and 1998.

*photos-PA Fish & Boat Commission*

# Six Fishes Connecting the Susquehanna River with the Sea



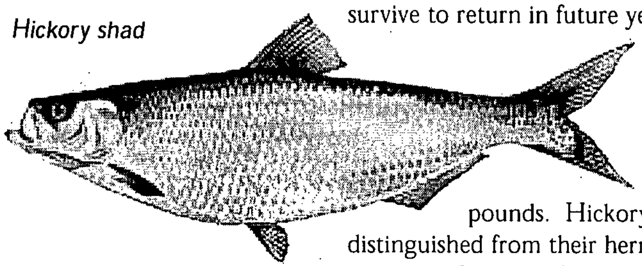

## American shad *Alosa sapidissima*



American shad

Annual migrations of fish into the Susquehanna River include four species of the herring family, in addition to the striped bass and the American eel. The American shad is the largest herring in North America, and from the angler's perspective, the most important. The shad range includes the Atlantic Coast from northern Florida to southern Canada, and they also have been successfully introduced to the U.S. West Coast. Shad are relatively deep-bodied with a forked tail. They have a dusky spot behind the gill cover sometimes followed by several smaller spots on their silvery sides. They commonly reach a size of 18 to 24 inches and 4 to 6 pounds. Like all anadromous fish, American shad spend most of their lives at sea and enter freshwater only to spawn. In mid-Atlantic states, spawning occurs in springtime, usually coinciding with the bloom of the dogwood. Once water temperatures warm to about 60 degrees, spawning occurs at night in relatively shallow but moving water. Unlike salmon and bass, which build nests to protect their eggs, the female shad releases 100,000 to 300,000 eggs directly into the water column. After fertilization, eggs slowly sink while drifting with the current until hatching takes place in 4 to 6 days. Shad fry grow rapidly feeding on plankton and aquatic insects. The young shad live in their river nurseries for about six months, growing to about 4 to 6 inches. In the fall, cooler water temperatures trigger schools of juveniles to swim downriver to the ocean. Once in the open ocean, young shad join shad schools from other rivers and begin their seasonal migrations up and down the East Coast, from the mid-Atlantic in winter to Canada's Bay of Fundy in summer. Shad live in the ocean until they mature in three to five years when they return to their rivers of birth to repeat the spawning cycle. Most shad die after spawning, but some may survive to return in future years.

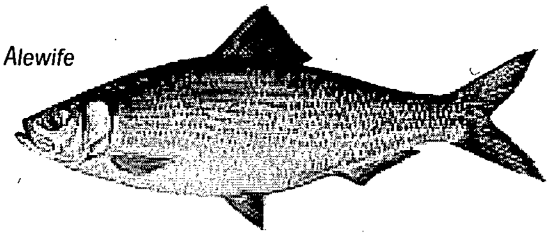
Hickory shad



## Hickory shad *Alosa mediocris*

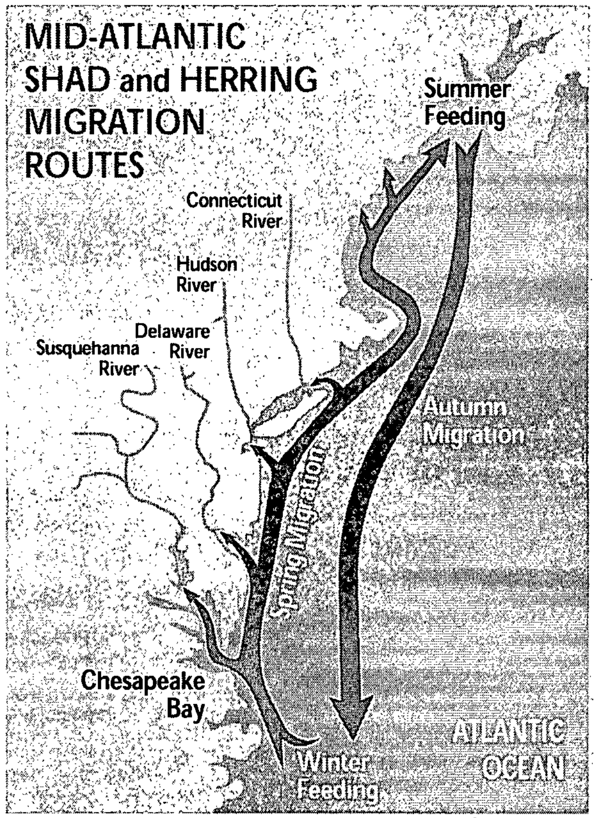
The relatively scarce hickory shad is intermediate in size between the American shad and the river herrings. It commonly measures 12 to 15 inches and weighs 1 to 2 pounds. Hickory shad range from the Carolinas to Long Island. They are distinguished from their herring and shad cousins by a protruding lower jaw and the presence of teeth, reflecting their preference to feed on fish instead of plankton.

*illustrations-Chesapeake Bay Foundation*



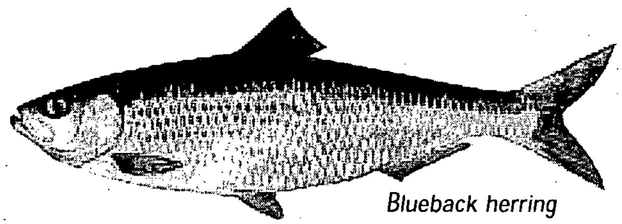

## Alewife *Alosa pseudoharengus*

One of the two river herrings, the anadromous alewife is a schooling species that spends most of its life at sea from North Carolina to Canada, returning to freshwater rivers and coastal ponds after three to five years to spawn. This species also occurs in the Great Lakes, and landlocked forms are commonly stocked as forage for game fish. Anadromous alewives are similar in appearance to the shad but are distinguished by the relatively large size of their eyes. They grow to about 10 to 12 inches, and although their life cycle is similar to that of the American shad, they prefer to spawn in smaller tributaries and slack water.



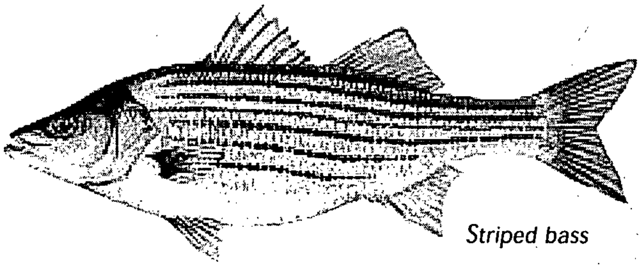

## Blueback herring *Alosa aestivalis*

Blueback herring closely resemble the alewife in size and appearance. Because they are anadromous, they have a similar life cycle but may travel farther upstream into tributaries to spawn in swift waters. Their coastal distribution and spawning seasons coincide with those of American shad.


*Blueback herring*

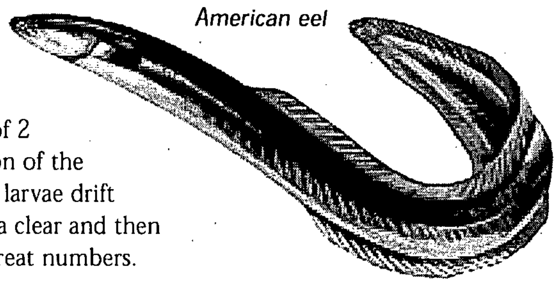
## Striped bass *Morone saxatilis*

The striped bass is an important native Atlantic Coast sport and commercial species. Stripers, also known as rockfish in the Chesapeake Bay, may live for 30 years and reach great sizes with fish over 4 feet long and 50 pounds not uncommon. Stripers are shaped like other basses and are distinguished by the six or seven dark stripes that run the length of their bodies. Spawning occurs in springtime near the salt line of tidal tributaries, and significant numbers of smaller striped bass may ascend the Susquehanna River to feed during the summer. Following several years of tight restrictions on harvest and catch, striped bass populations have recovered from low levels recorded in the late 1970s.


*Striped bass*

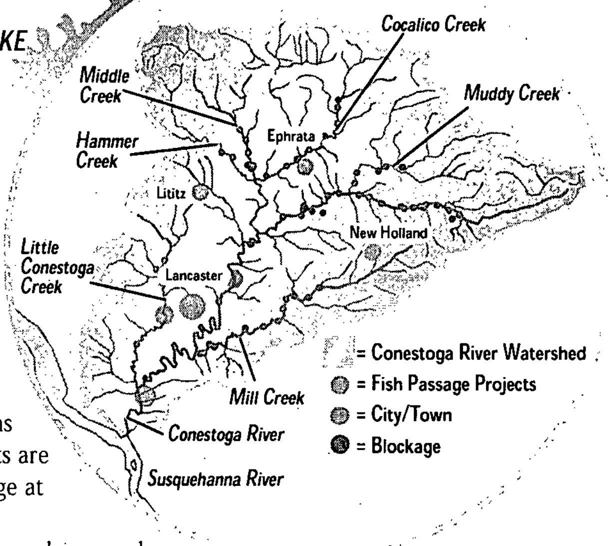
## American eel *Anguilla rostrata*

American eels are catadromous. Just the opposite of shad, herring and striped bass, catadromous fish spend most of their lives in freshwater and migrate to the ocean to spawn. The American eel is common in most rivers draining into the Atlantic Ocean. Once they mature in 10 to 15 years at a size of 2 to 3 feet, adult eels migrate downstream and return to a portion of the North Atlantic called the Sargasso Sea, where they spawn. Eel larvae drift with ocean currents for up to a year when they transform into a clear and then pigmented "elver" stage. Then they enter coastal streams in great numbers.


*American eel*

# Reopening Susquehanna Tributaries

*Barriers to fish migration can be found on nearly every stream in the Susquehanna River Basin. Restoration efforts are now focusing on providing fish passage at many of these tributary blockages.*


Migratory fish now have access to hundreds of miles of water in the Susquehanna River Basin, thanks to construction of fish-passage facilities at the large hydroelectric dams. However, migratory fish are blocked from more miles of additional fish-spawning habitat on Susquehanna tributaries. Migration up these tributaries is blocked by dams and other barriers. Restoration efforts are now focusing on providing fish passage at many of these tributary blockages.

Barriers to fish migration can be found on nearly every stream in the Susquehanna River Basin. Although shad and herring are strong swimmers, they cannot jump over obstructions. Unlike Pacific or Atlantic salmon, migrating shad can be blocked by a structure only one foot high. Some of these blockages occur naturally. They include debris dams that form around trees when they fall into the water, and waterfalls.

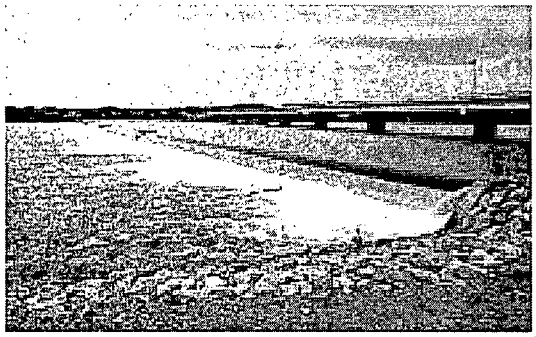
## Small dams

The most common human-made barriers are small to mid-sized water supply dams. These dams range in height from a few feet to 20 feet. These dams were built to supply water for mills, industrial needs, municipal water systems and recreational purposes. In addition, road crossings may form barriers to migration. This occurs where a road crosses a small tributary. Here the stream culvert may act as a blockage.

top photo-Michael J. Philippe; bottom photo-U.S. Fish & Wildlife Service

Debris may also collect at highway bridges, causing a blockage. Gaging station weirs, which measure water flow on some tributaries, may also act as blockages.

The first step in the effort to re-open tributaries was to identify barriers to migration. The potential spawning habitat upstream of these barriers was also considered. With Chesapeake Bay Program funding, the Pennsylvania Fish & Boat Commission identified barriers to fish migration on Susquehanna River tributaries. The Pennsylvania State University Cooperative Fish and Wildlife Unit conducted an inventory for the Fish & Boat Commission. Penn State's efforts focused on those tributaries downstream of the confluence of the Juniata and Susquehanna rivers. They identified hundreds of barriers, most of them privately owned. On tributaries not surveyed by Penn State, the Pennsylvania Department of Environmental Protection (DEP), Division of Dam Safety, provided information on the location of permitted dams. These two sources were used to establish a list for future fish passage projects. Those barriers with great potential of upstream spawning habitat and closeness to the Bay are at the top of the list.



*Fabridam, Susquehanna River, Sunbury, PA*

## Solution for fish passage

When a blockage is identified, the Pennsylvania Fish & Boat Commission works with the owner to determine the best and most cost-effective solution to provide fish passage. The Chesapeake Bay Program provides some funds for selected fish passage projects. The Program provides funding with non-federal dollars on a 1:1 matching basis.

Some sites are required by current laws or regulations to provide passage. Owners wishing to make structural modifications to a dam are required to provide fish passage as part of the permitting process. Federal law requires owners of hydroelectric dams to provide fish passage once migratory fish are present at the base of the dam. Pennsylvania state law also requires owners of dams and other obstructions to provide fish passage once migratory fish are present.

The goal of fish passage is to provide an easy, relatively effortless way for migrating fish to swim past the barrier and reach upstream habitat. The simplest and best method is to remove all or part of the obstruction. For a low-head dam, this may involve creating an opening or notch (breaching), or removing the dam entirely. Removing a dam is often the better option because it restores the natural free-flowing condition of the stream. Other obstructions such as culverts and weirs can be redesigned to provide the necessary gradient and flow for fish passage.

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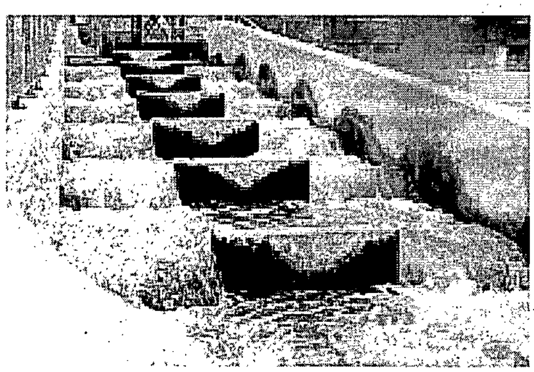
## Fishways

Another more expensive solution is to construct a fishway. The most common fishways constructed on these barriers are called ladders. Migrating fish swim up the ladders at their own pace to reach upstream spawning habitat. This is similar to people using steps or a ladder to climb a hill. Ladders consist of a series of baffles, or weirs, that interrupt the flow of water. This creates a series of ascending pools. The fish swim from pool to pool. They move up a ladder just as they would swim through natural rapids.



Each fishway design is unique to that stream. Design is based on the type and size of the blockage, the number of fish that will pass, and the fluctuations in stream flow. Although fishways provide passage over obstructions, their use is limited and not a fix-all solution. Fishways are rarely 100 percent effective at passing all the migrating fish that encounter a blockage. As a result, proposals for new dams must consider the need for fish passage and the effect the dam will have on stream ecology.

*The most common fishways constructed on barriers are called ladders. Migrating fish swim up the ladders at their own pace to reach upstream spawning habitat.*

# Dam Removal: Restoring Fish Passage and Stream Habitat

Pennsylvania has hundreds of dams that were built long ago. These dams provided water to power mills and feed canals. They generated electricity that fed a growing country. Many of these dams no longer serve the purpose for which they were constructed. Many are in disrepair, or have been abandoned. Even though they have outlived their usefulness, these dams leave behind a less than beneficial legacy. They continue to degrade the streams and rivers on which they are built. In addition, many are hazardous to public safety. The backwash and undertow created as water flows over them is dangerous to those using the water for recreation.

The Pennsylvania Department of Environmental Protection (DEP) and the Pennsylvania Fish & Boat Commission are working to reverse the negative effects of some dams. Through breaching and removal of non-beneficial dams, hundreds of miles of stream habitat have been restored. Between 1995 and 1999, more than 25 dams have been removed statewide. Pennsylvania has removed more dams blocking fish migration than any other state. The Fish & Boat Commission has identified dozens more for removal during the next few years.

The DEP is facilitating the removal process. The DEP Division of Dam Safety modified its dam removal permit procedures to make it easier and less expensive for dam owners to remove unwanted and often unsafe dams.

## Benefits of removal

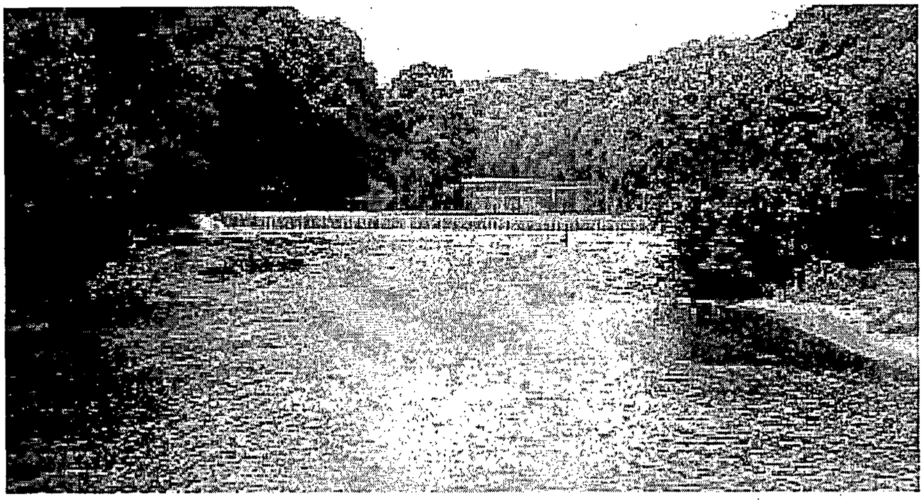
Removing a dam helps to protect the health and safety of those using the river. In addition, it protects downstream property. It also helps re-establish streams to their free-flowing conditions. Most removals have occurred in the Susquehanna River Basin. Here, the Pennsylvania Fish & Boat Commission is using federal funding for migratory fish passage and stream habitat restoration.

The Commission is looking for owners of dams to participate in the removal project in the Susquehanna drainage. The benefits of removing run-of-the-river low-head dams include:

- **Eliminating barriers to fish migration.**
- **Eliminating public safety hazards and threats to private property.**
- **Reducing liability concerns for dam owners.**
- **Restoring the structure and function of the aquatic ecosystem.**
- **Improving habitat for stream plants and animals.**
- **Reducing the need to provide for portage of canoes and other watercraft.**
- **Eliminating the need to construct, operate and maintain expensive fish ladders to restore valuable fish populations.**

Dam removal projects are receiving increased recognition and support among environmental agencies and organizations across the nation. Gaining public support for these projects can be quite challenging, though. Shoreline homeowners and neighbors have grown to enjoy their waterfront property and see dam removal as a loss. Anglers and hunters often object over concerns of loss of a place to hunt and fish. Often it becomes a matter of having a scenic view versus restoring an ecosystem. However, many people now recognize the value of free-flowing rivers. They learn that the system in its natural state offers as many or more opportunities than when dammed.

For information regarding dam removals in Pennsylvania, contact: Pennsylvania Fish & Boat Commission, Division of Research, at (814) 355-4837; or Pennsylvania Department of Environmental Protection, Division of Dam Safety, at (717) 787-8568.



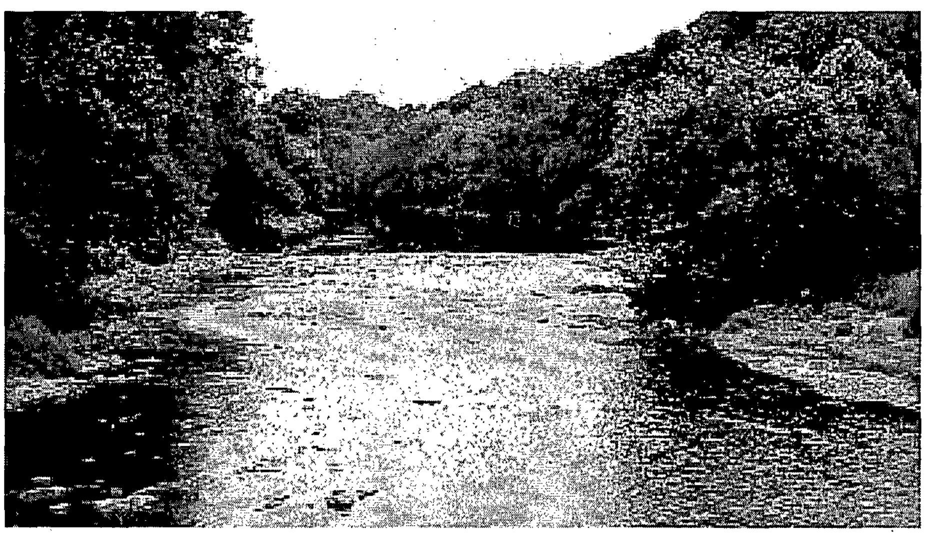
Rock Hill Dam, Conestoga River, Lancaster County, before removal. Dams slow moving water. The water slows so much that sediment and other things carried by the water drop out and settle on the bottom. Normally, these materials would be carried and deposited naturally throughout the river or stream. The damming causes sediments to cover areas once swept clean by the current. This results in loss of fish spawning habitat, and habitat for other aquatic organisms.

## Dams: Before and After

Dams slow moving water. The water slows so much that sediment and other things carried by the water drop out and settle on the bottom. Normally, these materials would be carried and deposited naturally throughout the river or stream. The damming causes sediments to cover areas once swept clean by the current. This results in loss of fish spawning habitat, and habitat for other aquatic organisms. This change and other effects influence the types of organisms that can live there. These new habitats favor fish that like slow-moving warm water and insects that like silt and sandy bottoms.

In addition, the stream channel or path it takes is changed. The dam may cause more erosion, which affects downstream habitats. A stream that had many twists and bends becomes straight after damming. These habitats are less diverse than those of free-flowing rivers and streams.

After the dam is removed, stream sections return almost to their pre-dam characteristics. Even though many changes occur virtually overnight, others take years to see. Water flow immediately increases and sweeps deposited sediments and excessive nutrients downstream. This cleansing results in improved aquatic habitat for stream organisms. These organisms will reestablish themselves as habitats improve. The stream channel will also change as bends, twists, riffles and runs form naturally. The stream will now be guided by the surrounding landscape, not a dam. This will increase the diversity and abundance of aquatic insects and stream fishes.



Rock Hill Dam site, after removal. After a dam is removed, stream sections return almost to their pre-dam characteristics. Even though many changes occur virtually overnight, others take years to see. Water flow immediately increases and sweeps deposited sediments and excessive nutrients downstream. This cleansing results in improved aquatic habitat for stream organisms.

photos-R. Scott Carney

# The Chesapeake Connection

*Blackwater National Wildlife Refuge, Maryland. With other Bay tributaries, the condition of the Susquehanna River influences the condition of this typical Chesapeake Bay salt marsh, and all of the Chesapeake Bay.*

photo-Karen Kilfeather

Shad and other anadromous fish face unbelievable odds and incredible journeys in their migration from the ocean through the Chesapeake Bay and upstream to the rivers of their beginnings. Their life cycles, which take them such great distances, clearly define the connection of local waterways to the Chesapeake Bay.

Recognizing the importance of the upstream waters to the health of the Bay's anadromous fish population and fishing industry, partners in the Chesapeake Bay Program agreed to develop management plans for "commercial, recreational, and ecologically valuable species," which include the American shad. Specific action taken to replenish shad stocks includes:

- **Fishing restrictions.** Maryland has had a moratorium on taking shad in the Bay since 1980 and Virginia since 1994.
- **Fish passage.** More than 1,000 miles of dammed tributary habitat in the Bay has been reopened to migratory fish, including 500 miles in the Susquehanna River watershed.
- **Shad stocking.** Record numbers of young shad, or "fry," have been released in spawning grounds upstream of dams that had blocked the adult shad migration. Bay states, the U. S. Fish and Wildlife Service and Native American tribal governments reared and released over 250 million shad in Bay tributaries since 1986.

In support of upstream restoration efforts, the Atlantic States Marine Fisheries Commission, which manages migratory species along the coast, has agreed to phase out all ocean fisheries for American shad by 2004.

Even though fishery management plans are vital to the shad's comeback, we also need to improve the water quality and spawning and nursery habitat in the Bay's tributaries. Shad prefer clear, moving water free of excess nutrients and sediments and free of pollution from heavy metals, acid mine drainage and toxic chemicals.

Because these same pollutants threaten the Chesapeake Bay's living resources, the Chesapeake Bay Program has set goals for reducing the amounts of nitrogen and phosphorus, sediment and toxic chemicals that flow into the Bay. Some of the Bay Program's most notable efforts in Pennsylvania include controlling pollution from agriculture by promoting and cost-sharing practices like proper fertilizer application, streambank fencing and proper storage and handling of animal waste.

Pennsylvania also is promoting the conservation and restoration of forested buffer zones along streams. In some areas, forest buffers can be highly effective in trapping sediment and removing nutrients from surface runoff and shallow groundwater. The leaf canopy from mature forest buffers also moderates the temperature of streams and provides food for many species of aquatic organisms.

# What you can do

The Chesapeake Bay has begun to show signs of improvement. For a healthy bay ecosystem, there are some simple things we can all do to help. We can make Bay-friendly choices in our daily routines, we can modify our habits in ways that minimize environmental effects, and we can communicate with our elected officials on issues that affect our natural resources.

## At home, at work

✓ Reduce or eliminate the use of toxic products and replace them with safe, water-based alternatives.

✓ Properly dispose of toxic substances such as solvents, paints, automotive products, lawn chemicals and cleaners at your local household hazardous waste collection day.

## "Green" yard care

✓ Have your soil tested and fertilize it only if necessary.

✓ Choose native plants that attract wildlife and that do not need pesticides, fertilizers or frequent watering.

## "Green" gardening

✓ Use organic gardening techniques and the least toxic pest controls possible.

✓ Reduce or eliminate the use of chemical herbicides and insecticides, and consider using manual weeding methods and attracting natural predators.

## Development and the natural landscape

✓ Get involved in local land use planning and support protection of rural resource lands.

✓ When purchasing a home, try to avoid properties in rural locations outside a jurisdiction's growth area (in particular, large lots of one to 20 acres).

## Bay-friendly recreation

✓ Keep boat motors well-tuned to reduce emissions.

✓ Make sure your boat is equipped with a marine sanitation device to store human waste for proper disposal on shore.

✓ Obey speed zones and reduce boat speed in creeks and rivers to reduce the effect of wakes on nearby shorelines.

## An active voice

✓ Register to vote and call, write or e-mail local and state officials in support of efforts designed to protect and restore the watershed.

✓ Stay informed about environmental issues and legislation.

*The pamphlet "What You Can Do to Save the Bay" and the 32-page booklet "Your Boat and the Bay" contain more detailed information on how to make Bay-friendly choices. To get these publications, contact the Chesapeake Bay Foundation. Contact information appears on the back cover of this publication.*

*Streamside native plants and trees that attract wildlife and that do not need pesticides, fertilizers or frequent watering help ensure healthy streams and rivers.*

## *Back to the future*

Salt, maple sugar, cider, whiskey, leather, iron, grain and whetstones are just a few of the many commodities traded for American shad during the heyday of shad fishing on the Susquehanna River. For most of this century, Pennsylvanians have lived without the benefits of Susquehanna shad runs. As a result, shad and their heritage have been largely forgotten. Through persistence and a few key successes in recent years, the return of shad to the Susquehanna now seems inevitable. Development of fish passage and shad hatchery technologies, combined with the cooperative work of state and federal agencies, utilities and private citizens, promises to rebuild the runs. In the next decade or two, hundreds of thousands of anglers will enjoy shad fishing on the Susquehanna. The potential economic, recreational and ecological values of American shad and related species provide a compelling argument for their restoration in the Susquehanna's waters, bringing them back to their historical abundance.

*top photo-Art Michaels; bottom photo-Chesapeake Bay Foundation*

## *For more information, contact:*

U.S. Fish & Wildlife Service
1721 North Front Street
Harrisburg, PA 17102
(717) 238-6425
www.fws.gov

Susquehanna River
Basin Commission
1721 North Front Street
Harrisburg, PA 17102-2391
(717) 238-0423
www.srbc.net

Pennsylvania Fish & Boat Commission
P.O. Box 67000
Harrisburg, PA 17106-7000
(717) 657-4518
www.fish.state.pa.us

Alliance for the Chesapeake Bay
225 Pine Street
Harrisburg, PA 17101
(717) 236-8825
www.acb-online.org

Chesapeake Bay Foundation
The Old Water Works Building
614 North Front Street, Suite G
Harrisburg, PA 17101
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Information Service
1-800-662-CRIS (2747)