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Anadromous and Catadromous Fish Restoration Programmes:
A Time for Evaluation (Theme Session T)

A recipe for success: Anadromous fish restoration in the Susquehanna River, USA

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Abstract

Stocks of anadromous American shad (*Alosa sapidissima*) and river herring (*A. aestivalis* and *A. pseudoharengus*) are being restored to the Susquehanna River in Maryland and Pennsylvania, USA. Fishery re-introduction and project evaluation activities have been undertaken over a three-decade period by several state, federal, and utility company partners. The shad population returning to the lowermost dam on the Susquehanna grew from only a few hundred to over 60,000 fish in the past 11-years. Most of this population growth resulted from stockings of 5-20 million marked larval shad each year, and trap and transport of thousands of pre-spawned adults to suitable spawning waters above blockages. Survival of out-migrating juvenile shad through hydroelectric turbines has been evaluated and, where necessary, innovative measures were developed to direct fish away from turbine intakes. Costly fish elevator systems are currently being constructed at a series of large dams which, by 2000, will reopen over 700 km of historic spawning habitat to anadromous fishes for the first time since 1910.

Introduction

The Susquehanna River basin is one of the largest on the east coast of the United States draining over 71,000 km^2 from southern New York to Maryland where it supplies most of the freshwater to the Chesapeake Bay. Extensive and valuable commercial and subsistence fisheries for anadromous American shad and river herring were lost in the 1830's due to construction of feeder dams for the Pennsylvania canal system. Spawning runs resumed in the late 1800's as the canal dams were removed, but the river was once again closed to fish migrations in 1910 with development of four large hydroelectric dams. The 29-m high Conowingo Dam eliminated all but the first 16 km of the river to spawning shad and herring.

The states of New York, Pennsylvania and Maryland joined with the United States Fish and Wildlife Service in 1969 to begin restoration of anadromous fishes to their historic range in the Susquehanna River. Habitat suitability studies indicated that at least 530 km of the main river and major tributaries could support shad reproduction. Engineering feasibility studies determined that fish passage facilities could be built and successfully operated at Susquehanna River dams. However, shad and herring populations in the upper Chesapeake Bay and lower Susquehanna River were extremely low and it was necessary to demonstrate that these stocks could be rebuilt prior to fish passage construction. An experimental fish trap was built at Conowingo Dam and upstream shad culture and stocking was initiated by the Pennsylvania Fish Commission. Funding for all aspects of this program was provided by the utility companies.

Stock Rebuilding

During the early 1970's, the number of American shad trapped at Conowingo Dam amounted to fewer than 300 fish per season. To supplement the returning population, over 200 million shad eggs were collected from distant rivers and placed in hatching boxes at several locations above dams. Beginning in 1976, the Pennsylvania Fish Commission began operating an intensive culture hatchery for shad on a major Susquehanna tributary and egg stocking was discontinued. Because of continued low abundance of shad in the Chesapeake Bay, Maryland Department of Natural Resources (DNR) closed all fisheries for this species in their waters in 1980.

By the mid-1980's, the adult shad count at Conowingo had improved to a few thousand fish each year which were transported upstream to spawn. These were supplemented by the stocking of an additional 3,000-6,000 adult shad netted and trucked from the Hudson River during 1985-1987. Shad and herring collected at Conowingo Dam are sorted and placed into 5,400 l insulated fiberglass circular tanks fitted with circulator pump and oxygen augmentation. These can safely handle 150 shad or 1,000 herring for 2-4 hr. trips with less than 2% mortality.

As culture techniques and egg collections improved, larval shad stocking increased from fewer than four million to more than 12 million per year by the late 1980's. Pennsylvania researchers developed mass-marking techniques for American shad using 4-hr. immersion in 200 ppm oxytetracycline hydrochloride (Hendricks et al., 1991). This chemical is incorporated into the calcium matrix of the shad otolith and displays itself as a fluorescent ring on the daily growth ring when viewed under ultraviolet light. Multiple immersions 3-4 days apart allow for numerous discrete tag combinations which are used to differentiate between strain (egg source), age, time, or place of stocking. Fingerling shad grown in ponds received additional marks using tetracycline laced diets. The marking regime appears to be 100% effective and the tag stays with the fish throughout its life.

In the past several years Maryland DNR has developed tank spawning techniques for American shad building on their prior success with striped bass (*Morone saxatalis*). Gravid fish taken from Conowingo Dam are implanted with a timed-release hormone and placed into 3.7 m circular tanks (two to one male : female ratio). Spawning occurs in the tanks over a several day period and eggs are automatically delivered to a collection box through a center drain air-lift system (Richardson and Minkkinen, 1996). Individual females can produce 50,000 to 100,000 fertile eggs, a considerable improvement over strip-spawning. As this technique is further refined it is expected to supply all shad eggs for the Susquehanna River restoration program.

Through the 1990's, the returning populations of shad and herring increased dramatically. Shad counts at Conowingo improved from 15,000 to over 60,000 fish and herring numbers grew from 10,000 to over 100,000. Each spring the Maryland DNR conducts tag and recapture population assessment for American shad in the upper Chesapeake Bay and lower Susquehanna River. Up to 1,000 fish are tagged and released from pound nets and by angling in the Conowingo tailrace and most recaptures are taken in the fish lifts. Based on this assessment, the estimated population size grew from 8,000 fish in 1984 to 339,000 in 1995.

Fish Passage Development

In response to the increase in abundance of shad returning to Conowingo Dam, owners of that project reached agreement with state and federal resource agencies in 1988 to design and build a large fish passage facility (lift) at the east end of the powerhouse. This $12 million single hopper structure was completed in 1991 and has a capacity to handle 750,000 shad and 5,000,000 herring. As designed, a second fish hopper can be added in the future to double that capacity. Fish passage development at Conowingo Dam triggered a similar requirement in a separate agreement among resource agencies and the operators of three upstream hydroelectric projects.

In 1993, owners of the Holtwood and Safe Harbor projects agreed to develop fish passage at their dams by spring 1997. As was the case at Conowingo, these facilities will be fish lifts. The 17-m high Holtwood Dam will have two elevators (spillway and tailrace) both releasing fish to a common exit channel. The Safe Harbor project is 23-m high and will have a single lift at the west end of the powerhouse. Passage capacity at these projects is estimated to be 2-3 million alosids. The fourth and final main river blockage is the low level York Haven Dam located 40 km above Safe Harbor. Project operators here have agreed to develop a natural passage through a 61-m wide gated opening by spring of 2000. Total costs for fish passage construction at Holtwood, Safe Harbor, and York Haven is estimated to be $40 million.

Program Evaluation

Each year during July through November juvenile shad are collected from several locations in the lower river to determine stock origin (hatchery versus wild), distribution and abundance, growth rates, and migration timing. Weekly seine surveys are conducted near Columbia, PA at river kilometer (rkm) 64 and these are supplemented during autumn months with lift net sampling three times each week in the Holtwood forebay (rkm 40). The seine measures 122 m x 2 m with 1 cm mesh. The lift net measures 2.4 m x 2.4 m with 1 cm mesh. Typical shad collections range from a few to several hundred fish. Out-migrating juvenile shad are also passively sampled from cooling water strainers at Safe Harbor and Conowingo dams, and from intake water screen washes at the Peach Bottom Atomic Power Station in the Conowingo Pond (rkm 26). Maryland DNR samples for shad in the upper Chesapeake Bay during summer and fall months using seines and electrofishing gear.

Subsamples of juvenile shad from all collections are frozen for otolith analysis. These are extracted from the fish and mounted on slides. Otoliths are then ground on both sides to create a thin cross section and viewed under a microscope with ultraviolet light to display tetracycline marks. Over the years information gained from this analysis has been used to determine the best egg source for culture (i.e. enhanced relative survival), age and places for stocking, and the relative contributions from hatchery releases and natural production. As the numbers of adult shad stocked above dams has increased, so has the relative abundance of wild juveniles in summer-fall collections.

Considerable evaluation work has also been done with adult shad in the Susquehanna River. Analysis of otoliths from adult shad sacrificed at Conowingo Dam during 1991-1995 indicated that 70-85% of the return stock was hatchery origin. This hatchery to wild ratio is expected to reverse

within the next several years as hatchery inputs are relatively constant while the number of adult spawners continues to increase. In numerous studies adult shad have been fitted with radio transmitters to determine migration rates and pathways through impoundments; to assess migratory behavior following handling and transport stress; to locate spawning congregations; to evaluate downstream passage success through turbines; and to identify best locations for planned fish passage entrances.

Downstream Passage

Stocking of spawning adults and cultured shad larvae into suitable waters above dams are techniques used to re-establish a population imprinted to return to the Susquehanna River. However, to be successful, these progeny must be able to safely migrate to the sea to complete their maturation. In studies conducted at Safe Harbor, Holtwood, and Conowingo projects miniature radio tags were used on juvenile shad in conjunction with balloon tags (Heisey et al., 1992) to evaluate acute and delayed mortality following turbine passage. Juvenile mortality measured at the two large dams through Kaplan and fixed blade mixed flow turbines (Conowingo and Safe Harbor) was less than 5% (RMC, 1994; RMC, 1991). Holtwood project has high speed Francis-type runners and juvenile shad mortality there was considerably higher at about 15% (RMC, 1992). Other than maintaining peak efficiency flows through select turbines during early evening hours of the 6-8 week migration season, no special downstream passage provisions are required at Safe Harbor and Conowingo. Because turbine passage problems exist at Holtwood Dam the fish lift system currently under construction there has been designed to also accommodate downstream migrants attracted to the exit channel outside the forebay skimmer wall and dropped to the tailrace via a chute.

The York Haven project also uses small high-speed Francis turbines. Although passage mortality was not assessed there, project operators have tested and committed to using behavioral modifying devices (underwater strobe lights) to repel juvenile shad away from the turbine intake area and to attract them to an adjacent controlled spillway opening. Studies suggest that 90% or more of out-migrant shad that reach the York Haven headrace during peak migration periods can be effectively passed using this system (Stone & Webster, 1994). York Haven is currently evaluating automation of this system using hydroacoustics, strobe light operators, and gate controls.

Future Outlook

In the spring of 1997 the Conowingo East fish lift and new passage facilities at Holtwood and Safe Harbor dams will be operated daily to pass all shad and herring that reach them. Sufficient spawning habitat is available above Safe Harbor to accommodate the expected runs until the gated opening at York Haven is completed in spring 2000. Recognizing that some operational adjustments will likely be needed at these new devices to maximize their performance, state and federal resource agencies intend to continue to operate the Conowingo West lift for data collection and for trap and transfer of limited numbers of spawners above York Haven Dam. Downstream passage of spent adult and juvenile shad will continue to be assessed and improved.

The hatchery programs in Pennsylvania and Maryland with production targets of about 10 million shad larvae per year will continue, probably until about 2005. It is likely that tank spawning will replace strip-spawning within the next two years and a large scale (6-8 tanks) system is being planned for development at Conowingo Dam.

Most of the economic benefits associated with this program relate to sport fishing for shad. Fishing regulations in Maryland and Pennsylvania are expected to relax as the Susquehanna River and upper Chesapeake Bay shad population continues to grow. The goal for this restoration program is to develop self-sustaining annual runs of about two million American shad and 20 million river herring.

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