Hudson River American Shad
An Ecosystem-Based Plan for Recovery
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Hudson River Estuary

HUDSON RIVER AMERICAN SHAD
AN ECOSYSTEM-BASED PLAN FOR RECOVERY

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To meet the goals of the
Hudson River Estuary Action Plan

Results of a recent Atlantic States Marine Fisheries Commission analysis of coast-wide shad stocks indicated that Hudson River American shad are in serious trouble (ASMFC 2007a). Commercial landings of shad from the Hudson River Estuary are at their lowest level since 1880. Moreover, the spawning stock is experiencing excessive and unacceptably high mortality, and that mortality has seriously reduced the abundance of adults and the production of young in the estuary. Restoration of this signature species will require a broad-based ecosystem initiative that includes management actions in the estuary and in the Atlantic Ocean and focused ecological studies to understand American shad's role within the estuary. The following summarizes current causes of decline and outlines a detailed program of response.

Causes of Decline

American shad of the Hudson River Estuary are anadromous. They spawn in spring in the river, but spend most of their lives in the nearshore Atlantic Ocean from Virginia to Maine. The Hudson estuary extends 245 km from NY City to the Federal Dam at Troy. American shad spawn in freshwater from Kingston (km 145) through Troy. Juveniles use the upper 150 km of the estuary as a nursery area and emigrate from the river in fall. They return to the Hudson 3-7 years later for spawning.

American shad are caught by recreational and commercial fishermen while in the Hudson and by various commercial fisheries while in the ocean. It is not known if shad are taken by recreational fishing while in ocean waters, or if they are taken in combination with, or mistaken for, hickory shad. Commercial ocean fisheries that targeted American shad (directed fisheries) were closed in all Atlantic coastal states in 2005. Incidental take of shad in other ocean commercial fisheries (called bycatch) continues and can be legally sold in some states including New York.

The principal known cause of the decline in Hudson River American shad was overharvest by directed ocean commercial fisheries and in-river commercial and recreational fisheries (ASMFC 2007a). Directed ocean harvest of American shad has ended, but losses to in-river harvest continue. Losses of young and adult shad to ocean commercial bycatch (unintended catches) may have been a factor in the decline, but the magnitude of such losses is essentially unknown. Young American shad in the river are also lost to various cooling water intakes.

Habitat loss and alteration most likely affected historical abundance of American shad in the Hudson River Estuary. Substantial destruction of potential shad spawning and nursery habitat occurred from the late 1800s through the mid 1900s from dredge and fill in the upper third of estuary during development and maintenance of the navigation channel from New York City to Albany/Troy (Miller and Ladd 2004). This habitat alteration was probably a factor in shad decline in the late 1800s and early 1900s. However, major habitat alteration has not occurred over the last 50 years and it is unlikely that it has been a factor in the most recent stock decline. Such habitat loss however, may influence the rate of stock recovery.

Interactions among biota within the estuary may influence shad abundance, but supportive data are lacking. It has been suggested that changes in predator abundance in the river may have affected survival of young shad. Largemouth bass, smallmouth bass, white catfish, and channel catfish occur throughout the freshwater shad nursery area when early shad life stages are present. Bluefish, striped bass, and weakfish are present in the lower estuary in fall as young shad emigrate from the river. Diets of these potential predators in the river have been poorly studied and the effects of these predators on shad survival remain speculative. Competition with other biota may also influence young shad survival. The recent introduction and explosive growth of zebra mussels in the Hudson substantially reduced phytoplankton, along with subsequent zooplankton production (Caraco 1997). Since young shad feed on zooplankton, it is possible that feeding by mussels reduced food available to young shad. Following the arrival of zebra mussels, the diet of blueback herring shifted from open water zooplankton and benthic drift to biota found in shallow water vegetation beds (personal communication, Dr. D. Strayer, CIES, Millbrook, NY). Presumably, this shift occurred because open water prey became less available. It is not known if a similar diet shift has occurred in American shad. However, Strayer et al. (2004) did find that growth of young of year American shad decreased after zebra mussels established themselves in the river. A decrease in growth has the potential to affect survival of age zero shad during their first winter.

Two hypotheses for causes of shad decline were discounted in the recent ASMFC (2007a) analyses. They were striped bass predation on mature shad and poor water quality. Crecco et al (2007) reported that adult striped bass preyed on small mature American shad in the Connecticut River. The authors speculated that the recent increase in striped bass abundance may have affected shad abundance in other Atlantic Coastal rivers. However, extensive analyses of Hudson River striped bass gut contents concluded that this was not an issue in the Hudson (ASMFC 2007a). Moreover, abundance data for adults from several East Coast Rivers suggested no relationship between striped bass abundance and shad abundance. Declines in water quality in shad spawning and nursery areas have been suggested as a cause of shad decline in some east coast estuaries. However, this is not so in the Hudson where water quality has improved over the last 30 years.

Recovery Goals

The Draft *2010-2014 Hudson River Estuary Action Agenda* of NYSDEC calls for the restoration of the Hudson River shad by 2050. This shad recovery plan defines short and long term objectives associated with this goal and describes activities needed to achieve the goal and objectives.

Several measures are available to define objectives and assess the status of the Hudson River American shad stock. These include:

- Annual index of relative abundance of age zero fish called the juvenile abundance index or JAI. This is obtained by annual NYSDEC sampling by beach seine in the upper two-thirds, freshwater portion of the Estuary.
- Spawning stock biomass, or SSB. This is a relative annual index of total weight of mature female shad in the river. It is calculated from egg abundance estimated by contractors to Hudson Valley electric generating companies and age structure and weight at age data collected by NYSDEC spawning stock sampling.
- Rates of total annual mortality (A) of mature females. This is defined as that fraction of females present at the start of the calendar year that die during the year. The rate is estimated from data obtained by NYSDEC spawning stock sampling.

We propose that recovery objectives consist of a matrix of these three indices. No single index is adequate because each index responds at a different rate to different influences on the stock. For example, the JAI usually responds first to changing early life survival while SSB responds most quickly to changing adult survival. A healthy sustainable fish stock needs good recruitment (relatively high JAI), adequate spawning stock size, and reasonable (low) adult mortality rates. The use of all three indices addresses all of these needs and is the most robust approach to setting benchmarks.

1. Long term objective:

Restore American shad abundance to levels that occurred in the 1940s. Quantitative targets will include relative abundance of age zero American shad and SSB indices estimated for 1940-1950 from population modeling and calibrated to relative abundance indices obtained by NYSDEC beach seine sampling and recent SSB estimates. Restoration assumes a total mortality rate on the adult stock at or below 52% as specified in the 2007 ASMFC stock assessment.

Progress toward the JAI benchmark will be measured by a five year running average which dampens the influence of wide inter-annual fluctuations in the measure. Progress toward SSB and total mortality benchmarks will be measured by three year running averages. These indices warrant a shorter multi-year mean because they do not vary as widely among years and both already encompass many year classes. Inter-annual variation is too high in all of these indices to allow use of a single year's value to measure restoration progress.

2. Short term objective:

Restore American shad abundance to levels observed in the late 1980s. The quantitative targets will be the mean age zero abundance index from NYSDEC beach seine monitoring from 1985 through 1989, the mean SSB for 1985 through 1989, and a total mortality rate (A) on the adult stock at or below 52%.

Progress toward these benchmarks will be measured in the same manner as progress toward long term objectives. Specific quantitative targets for long and short term objectives will be defined in a separate report and updated as needed.

Recovery Plan

Recovery of Hudson River American shad will require continued stock monitoring, actions that we can implement relatively quickly and at relatively low cost, and longer term actions that will take planning and substantial funding. The following summarizes proposed recovery activities. It includes suggestions made at a Hudson River American shad workshop hosted by the Hudson River Foundation (HRF) in New York City on 31 July 2008. In November of 2008, the HRF published a special request for proposals for research in connection with the recovery of American shad in the Hudson River. Contracts funded in responses to this request are expected to improve our understanding of the ecological role of American shad in the Hudson. Status of recovery plan activities and estimated costs will be updated annually.

1. Maintain American shad monitoring programs

We need to continue current annual stock monitoring to track current condition and progress in response to management actions. Two separate, fishery independent shad monitoring efforts must be maintained.

A. NYSDEC programs.

Objective: Monitor annual status of juvenile and adult American shad in the Hudson River.
Actions:
1) Obtain an annual abundance index for juvenile shad in the estuary by 30.5 m beach seine; and
2) Characterize annual size and age structure and survival rates of spawning American shad.

B. Hudson Valley Generating Companies (HVGC)

Objective: Provide annual indices of egg and larval fish abundance.
Background: Data are used by NYSDEC in conjunction with NYSDEC spawning stock age data to calculate an annual index of adult shad biomass (SSB Index).
Action: Continue the Long River Ichthyoplankton Survey.

2. Reduce Mortality – Short Term

The most important and meaningful action that we can take right now for shad recovery is to reduce mortality on all life stages as quickly as possible.

A. In River Fisheries

Objective: Minimize or eliminate losses to commercial and recreational fisheries that target American shad within the Hudson River to levels that will allow the population to grow.
Action: Implement fishing restrictions for American shad fisheries in the Hudson River.

B. NY Ocean Fisheries

Objective: Eliminate legal sale of shad caught while fishing for other species in NY ocean waters.
Action: Implement new regulations for NY marine waters. Issue is complex because many fisheries are involved and data on shad landings are limited.

C. Water Intakes

Objective: Reduce or eliminate losses of all shad life stages to Hudson River power generating plants.
Action: Ensure that permits include provisions to reduce losses of shad to water intakes.

3. Reduce Mortality – Long Term: Characterize and Reduce Bycatch

American shad from the Hudson River estuary are taken in commercial fisheries from Maine to Virginia. Unintended loss of shad in fisheries targeting other species is called bycatch. Knowledge of bycatch characteristics (quantity, location, and time of year) allows us to evaluate the impact of bycatch and to reduce it where needed through regulation in New York state waters and through ASMFC action in waters of other states and in federal waters. Since shad from many stocks are taken as ocean bycatch, we will also need to develop a method to identify that part of the bycatch from the Hudson River. This will allow New York to focus regulatory protection on those fisheries most affecting Hudson shad.

A. Available National Marine Fisheries Service (NMFS) bottom trawl data

Objective: Identify locations and seasonal timing of American shad concentrations in ocean waters
Background: NMFS conducts bottom trawl surveys of ocean fish abundance and distribution from Maine through North Carolina. Trawling occurs in spring and fall. Although few American shad are taken in this survey, enough are taken to characterize seasonal concentration areas. This information will facilitate the search for shad bycatch in existing and future bycatch monitoring databases.
Action: NYSDEC staff will analyze NMFS data with the assistance of NMFS staff at the Northeast Fisheries Science Center at Woods Hole, MA. Analyses will summarize abundance of American shad catch by bottom trawl by season and location.

B. Available NMFS Sea-sampling Data

Objective: Characterize American shad bycatch recorded in existing National Marine Fisheries Service (NMFS) sea sampling data.

Background: Current NMFS data were obtained by onboard sampling of commercial fishing operations to document catches of endangered marine mammals, sea birds, and reptiles. Coverage of fishing operations is patchy because it is concentrated on times and locations where bycatch of endangered biota is expected. These data have not been analyzed for presence of American shad.
Action: NYSDEC staff will analyze NMFS data with the assistance of NMFS staff at the Northeast Fisheries Science Center at Woods Hole, MA. Analysis will, where possible:

- Identify and characterize fisheries with shad bycatch and identify, quantify, and characterize bycatch of these fisheries by time and location. Analysis is expected to follow procedures identified in ASMFC (2007b) and Wigley et al. (2007).
- Identify times and locations of inadequate fishery monitoring coverage that can be resolved through additional onboard monitoring.

C. NY Ocean Sea Sampling

Objective: Identify, quantify, and characterize the American shad bycatch in ocean commercial fishing operations based in New York State.
Background: American shad are rare in the existing NMFS sea sampling database. Thus, existing data may be inadequate to quantify and characterize shad bycatch and additional sea sampling may be needed.
Action: If needed, develop and conduct an at sea sample program of commercial vessels fishing in NY ocean waters. Since many fish species managed by NY are taken as bycatch in ocean fisheries and the cost to monitor additional species is insignificant, monitoring will cover all NY managed species. The result will be more useful and the program more defendable. Needed actions include:

- Develop sample design needed to achieve a given level of precision; contracted through the Pew Institute of Ocean Studies/SUNY Stonybrook.
- Execute a contract for onboard sampling of commercial vessels based on developed sample design; possible funding sources include the Hudson Estuary Program (HREP) and the Ocean and Great Lakes Ecosystem Conservation Council (OGLECC);
- If onboard monitoring identifies fisheries or specific times or locations of high shad bycatch, NYSDEC will take the necessary steps to reduce bycatch, including educational and regulatory or legal actions.

D. Port Sampling in the NY Bight

Objective: Obtain information on shad bycatch in commercial Atlantic herring and mackerel fisheries of the Atlantic Ocean in the NY Bight.
Background: American shad and river herring are taken in the Atlantic herring and mackerel fisheries that occur from the Gulf of Maine through Cape May. The fisheries operate in the Gulf of Maine in summer when juvenile river herring predominate the bycatch and from Cape Cod through Cape May in winter when American shad occur as bycatch. These are high volume fisheries where catch is vacuumed out of the nets and into the hold. Thus, onboard observers are ineffective. As an alternative, the state of

Maine samples harvest as it is unloaded in fish processing plants. Sampling has focused on ports north of Cape Cod because Maine is most concerned with bycatch of river herring.
Action: Expand port sampling of the Atlantic herring and mackerel fisheries to ports from Cape Cod, MA through Cape May, NJ in winter when American shad are more common in the bycatch.

E. Sea Sampling in Other Coastal States

Objective: Obtain information on shad bycatch in commercial fisheries of other coastal states and in Federal waters more than three miles from shore (EEZ).
Background: Will need support of other states and the federal government for a broad based bycatch monitoring program. Sampling will require funding from the federal government and private foundations.
Action: This will be best accomplished through the ASMFC Inter-State Fisheries Management Plan (ISFMP) program and Shad and river herring ISFMP Draft Amendment 3. This assures compatible sampling, data sharing and consistency with the Atlantic Coastal Cooperative Statistics Program (ACCSP). Possible funding sources include the Wildlife Conservation Society or the Pew Institute for Ocean Studies.

F. Ocean Harvest Stock Identification

Objective: Identify Hudson River American shad in ocean bycatch.
Background: Bycatch of American shad in ocean fisheries includes fish from many spawning stocks along the Atlantic coast. Researchers have developed several promising approaches to American shad stock identification including microchemistry of shad otoliths and various DNA based techniques.
Action: Support proposed studies with assistance in proposal development, letters of support, and biological samples as needed.

4. Characterize and restore critical spawning and nursery habitat.

Approximately 1,420 hectares of upriver shallow water habitat were lost through dredge and fill operations during construction of the federal navigation channel in the early and mid 1900s (Miller and Ladd 2004). Much of this area was potential shad spawning and nursery habitat. The identification, characterization, and restoration of lost habitat are important long-term components of Hudson River shad restoration.

A. Spawning Habitat

Objective: Identify and characterize current spawning habitat used by adult shad.
Background: Current knowledge of American shad spawning location in the Hudson River Estuary must be inferred from general location of shad eggs. These data are not adequate to pinpoint specific spawning location and thus do not allow characterization of that habitat. More precise spawning locations can be identified by sonic or radio tracking of spawning shad in conjunction with benthic maps and GPS location information. NYSDEC Hudson River Fisheries Unit (HRFU) has used this technology

on juvenile Atlantic sturgeon so equipment, vessels, and expertise reside within the Department.
Action: Implement a study of movement and habitat use of mature American shad in the Hudson River spring spawning migration.

B. Nursery Habitat

Objective: Identify and characterize shallow water habitat used by eggs, larvae, and juvenile American shad in the Hudson River Estuary.
Background: Early life stages of American shad are too small to tag and shallow vegetated areas are not sampled by existing sample programs in the Hudson River Estuary. However, larval push nets have been designed to sample early life stages of fish in shallow vegetated and unvegetated river habitat. This gear was very effective at collecting larval fish from vegetated shallows in the Kissimmee River in Florida (personal communication, Daniel Miller, NYSDEC, Staatsburg, NY).
Action: Sample existing vegetated shallow water habitat by larval push net mounted on the bow of a work boat. Although NYSDEC can develop sample apparatus, develop a sample design, and collect samples, sample identification would best be done by a contractor. Potential funding sources include HREP, SWG, HRF, or NRD.

C. Demonstration Restoration Project

Objective: Create a demonstration shad habitat restoration project.
Action: Craft experimental projects to increase the amount of spawning and nursery habitat similar to habitats identified in tasks A and B above. Experimental projects would cover a range of possible restoration approaches, include measurable objectives, and specify monitoring to verify results. Promising methodology could then be applied in conjunction with resource agencies such as the Army Corps of Engineers. Logistic challenges to this type of restoration have been identified and still need to be addressed. They include restoration dredge spoil disposal and regulatory and permitting issues (habitat trading).

5. Ecosystem Studies

During their first year of life, American shad are likely to be prey for a variety of predators and could compete with other species for critical food. Either interaction could be a factor in the recent decline in shad abundance. Studies of these interactions could clarify the role of juvenile American shad within the ecosystem, but most likely would not lead to effective restoration actions.

A. Predation.

Objective: Identify diets of estuarine predators of young of the year American shad that are abundant enough to affect the shad population.
Background: The most logical marine predator to evaluate is striped bass. This species has increased in abundance in the last 20 years and appears to congregate in the lower river in the fall when young shad emigrate. The most logical freshwater predators are

largemouth bass, smallmouth bass, white catfish, and channel catfish. These fish are relatively abundant in the middle and upper estuary in spring and summer when young shad are in shallow water nursery areas.

It should be noted that diet analyses of potential predators may be hampered at this time by the paucity of young shad in the river. Unless a predator focused on them, young shad would likely be a rare diet item. Moreover, diet studies of in-river predators ignore the potential impact of ocean predators, although diets of striped bass while in the ocean have been found to be focused on menhaden.

Action: Conduct a survey of available published and unpublished literature on diets of potential Hudson River Alosine predators. If available data are not conclusive, conduct diet studies of these predators when and where their presence overlaps that of juvenile American shad. Striped bass should be collected from the lower river in late summer and early fall. Freshwater predatory species should be collected in summer from shallow water nursery habitat in the mid and upper estuary. Sample size should be 200 to 300 stomachs for each species annually. Diet studies should continue for three consecutive years for each potential predator.

This work would best be done by contract. NYSDEC does not have the necessary expertise to efficiently identify food items. Contractors should work cooperatively with ongoing NYSDEC sampling programs to obtain all or a portion of the fish to be analyzed. Sample collection may require additional sampling by contractors. Potential researchers include Institute of Ecosystem Studies, SUNY Stonybrook, and SUNY Environmental Sciences and Forestry (ESF). The USGS-Columbia River Research Laboratory at Cook, WA is also exploring potential American shad predators and may partner with NYSDEC to conduct this work.

Potential funding sources include the HREP and the HRF.

B. Competition

Objective: Identify potential interactions between age zero American shad and other organisms within the estuary that may be competing for the same food source.

Background: The recent introduction and explosive growth of zebra mussels in the Hudson has substantially reduced phytoplankton, along with subsequent zooplankton production. Since young shad feed on zooplankton, it is likely that feeding by mussels has reduced food available to young shad. Preliminary analyses by Strayer et al. (2004) found decreased growth of juvenile shad following the introduction of zebra mussels. Moreover, the diet of blueback herring shifted from open water zooplankton and benthic drift to biota found in shallow water vegetation beds (personal communication, Dr. D. Strayer, CIES, Millbrook, NY). Presumably, this shift occurred because open water prey became less available. It is not known if a similar diet shift has occurred in American shad.

Effects of reduced zooplankton abundance on growth and survival of juvenile American shad would logically be exacerbated by any competition with other Alosines that use the same nursery areas. Both alewife and blueback herring utilize shad nursery areas and likely use the same zooplankton food resource. Diet work on Hudson River Alosines is limited and most occurred prior to the introduction of zebra mussels.

Action: Conduct a survey of available published and unpublished literature on diets of Hudson River Alosines. If data on post zebra mussel diets are inadequate, conduct diet analyses of early life stages of Alosines. This would involve annual collection for each species of 300 larvae and 300 young for three years. Early life stage samples can be obtained from the nursery habitat study described above in task 4B if studies are concurrent. NYSDEC can supply later stage juveniles from the annual beach seine survey. Coordination of sample collection and identification of gut contents should be done by a contractor. Potential researchers include Institute of Ecosystem Studies, SUNY ESF, and the USGS-Columbia River Research Laboratory. Possible sources of funding include the HREPand the HRF.

C. Ecosystem Modeling

Objective: Develop a bio-energetic model or models to assess the potential impacts of identified predators and competitors for food resources on Hudson River American shad.
Background: A description of predation or potential competitive interactions does not indicate that such interactions are significant. For example, the knowledge that striped bass prey on juvenile shad does not in itself prove that such predation has affected shad abundance. Potential impacts of predation can be evaluated by energetics-based population models. These models require substantial information about fish growth, consumption rates, diet, metabolic rates, survival, and abundance. Enough of these data are currently available for Hudson River fishes to warrant some exploratory model runs. Even if results are inconclusive, attempts at modeling will identify data needed to improve modeling and thus guide future research.
Action: Develop a proposal to collate the necessary data and to build a bio-energetic model. Potential researchers include CIES, SUNY-ESF, SUNY Stonybrook, and the USGS-Columbia River Research Laboratory. Possible funding sources include HREP and the HRF.

D. Climate Change

Objective: Evaluate the relationship between early life stage and adult abundance and various indices of ocean and river water temperatures.
Background: There is evidence that surface temperatures of the Atlantic Ocean have changed over the last 150 years (Kerr 2005, Sutton and Hodson 2005). Ocean temperatures have been relatively warm since about 1991. Moreover, Hudson River water temperatures have generally increased between 1920 and 1990 (Ashizawa and Cole 1994). Changes in ocean temperature could affect timing of shad ocean migration to spawning rivers as well as movement to summer feeding and overwintering locations. Changes in river temperatures could affect timing of spawning and early life stage growth relative to food supplies. Any of these changes could affect survival of Hudson River American shad and hinder recovery efforts.
Action: Develop a proposal for appropriate analyses using existing data. Potential researchers include CIES, SUNY-ESF, SUNY Stonybrook, and the University of Massachusetts. Possible funding sources include HREP and the HRF.

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Glossary

ACCSP- Atlantic Coastal Cooperative Statistics Program
ASMFC- Atlantic States Marine Fisheries Commission
CIES- Cary Institute of Ecosystem Studies
ESF- Environmental Science and Forestry
HREP- Hudson River Estuary Program
HRF- Hudson River Foundation
HRFU- Hudson River Fisheries Unit
NMFS- National Marine Fisheries Service
NRD- Natural Resources Damages [Unit- NYSDEC]
NYSDEC- New York State Department of Environmental Conservation
SUNY- State University of New York
SWG- State Wildlife Grants
USGS- United States Geological Survey

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