Atlantic States Marine Fisheries Commission

Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring (American Shad Management)

ASMFC Vision Statement:
Healthy, self-sustaining populations for all Atlantic coast fish species or successful restoration well in progress by the year 2015

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Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring

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Atlantic States Marine Fisheries Commission
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This Amendment was developed through the concerted and dedicated efforts of several individuals, groups and agencies. Guidance was provided by the Atlantic States Marine Fisheries Commission's Shad and River Herring Management Board, chaired by Paul Diodati (Massachusetts Division of Marine Fisheries (2008-2009)) and Malcolm Rhodes (South Carolina (2010 – current). Technical assistance was provided by the Shad and River Herring Technical Committee (chaired by Robert Sadzinski (2008-2009) and Kathryn Hattala (2009 – current)), the American Shad Stock Assessment Subcommittee (chaired by Andrew Kahnle (2004-2007)), and the Shad and River Herring Advisory Panel (chaired by Patricia Jackson (2008) and Byron Young (2009 – current)).

Special assistance was provided by the following people: Robert Beal (ASMFC), Toni Kerns (ASMFC), Jessie Thomas (ASMFC) and Kathryn Hattala (NYSDEC). The Plan Development Team is also grateful to the many individuals who made contributions to the preparation of this Amendment. These include the professional and technical staff of the various state and federal agencies involved in the Atlantic States Marine Fisheries Commission who provided the editorial comments and suggestions to the Team. In addition, the Atlantic States Marine Fisheries Commission extends its gratitude to the numerous dedicated conservationists, commercial fishermen, and anglers who have written letters and attended public hearings to express their opinions and ideas about American shad management.

EXECUTIVE SUMMARY

INTRODUCTION: The Atlantic States Marine Fisheries Commission (ASMFC) developed Amendment 3 to its Interstate Fishery Management Plan (or FMP) for Shad and River Herring under the authority of the Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA 1993). Amendment 3 addresses only management measures for American shad. Management measures for alewife and blueback herring (collectively called river herring) are contained in Amendment 2. Shad and river herring management authority lies with the coastal states and is coordinated through the Commission.

Responsibility for compatible management action in the Exclusive Economic Zone (EEZ) from 3-200 miles from shore lies with the Secretary of Commerce through the ACFCMA in the absence of a federal fishery management plan.

STATEMENT OF THE PROBLEM: In 2007, the American Shad Stock Assessment Subcommittee (SASC) completed an American shad stock assessment report, which was accepted by the Peer Review Panel (PRP) and the Shad and River Herring Management Board in August 2007 (ASMFC 2007). The 2007 American shad stock assessment found that stocks were at all-time lows and did not appear to be recovering to acceptable levels. It identified the primary causes for the continued stock declines as a combination of excessive total mortality, habitat loss and degradation, and migration and habitat access impediments. Although improvement has been seen in a few stocks, many remain severely depressed compared to their historic levels.

Anadromous fish species, such as American shad, are unlike almost all other fish species that are cooperatively managed under ASMFC. Most other ASMFC species are exclusively oceanic and all of their habitat and life cycle needs can be satisfied in the marine environment (although some may utilize coastal shore or estuarine habitat for part of their life). Anadromous fish, as a result of their freshwater and estuarine spawning and nursery requirements, must come into close contact with human populations, and are therefore vulnerable to the many threats and potential sources of injury and mortality associated with human activity in and around rivers and estuaries.

IMPLEMENTATION BENEFITS: Implementation of Amendment 3 and consequent restoration of American shad stocks will produce significant ecological, cultural and economic benefits. Ecologically, American shad and other alosines played important ecological roles in freshwater, estuarine and marine environments during their life cycles. Cultural benefits will arise in part from the revitalization of traditional fisheries and the numerous shad festivals historically held along the east coast each spring during the spawning run. Cultural benefits to Native American tribes will arise through restoration of their traditional fisheries and fishing rights.

DESCRIPTION OF THE RESOURCE AND MANAGEMENT UNIT: The American shad is the largest North American member of the shad and herring family, and historically occurred in all major rivers from Maine through the east coast of Florida. The management units for American shad under this Fishery Management Plan Amendment include all migratory American shad stocks of the Atlantic coast of the United States.

LIFE HISTORY AND HABITAT REQUIREMENTS: American shad are a migratory anadromous fish that spend most of their life at sea along the Atlantic coast and enter freshwater as adults in the spring to spawn. Most young emigrate from their natal rivers during their first year of life. American shad stocks are river-specific; that is, each major tributary along the Atlantic coast appears to have a discrete spawning stock. Habitats used by American shad include adult spawning sites in coastal tributaries and larval and juvenile nursery areas in the freshwater portions of the rivers and their associated bays and estuaries.

GOALS AND OBJECTIVES:

Goal: Protect, enhance, and restore Atlantic coast migratory stocks and critical habitat of American shad in order to achieve levels of spawning stock biomass that are sustainable, can produce a harvestable surplus, and are robust enough to withstand unforeseen threats.

Objectives:

- Maximize the number of juvenile recruits emigrating from freshwater stock complexes.
- Restore and maintain spawning stock biomass and age structure to achieve maximum juvenile recruitment.
- Manage for an optimum yield harvest level that will not compromise Objectives 1 and 2.
- Maximize cost effectiveness to the local, state, and federal governments, and the ASMFC associated with achieving Objectives 1 through 3.

Strategies to Achieve Objectives:

- Quantify and effectively manage sources of bycatch mortality where possible.
- Quantify and effectively manage sources of predation where possible and appropriate.
- Restore and maintain access to historical spawning and nursery habitat (i.e., dam removal and fishway installation).
- Maintain total mortality (Z) of American shad stocks at or below stock assessment benchmarks.
- Ensure that adequate monitoring techniques are implemented to measure migratory success (i.e., upstream and downstream fish passage at barriers).
- Ensure that stock monitoring data are collected and that they are adequate to characterize stock status and stock response to management actions (i.e., develop a sampling program that provides an annual measurable output for spawning stock and juvenile production status)
- Achieve river specific restoration targets for American shad populations as specified in the recent shad assessment or in existing stock specific restoration plans.
- Ensure that the production of hatchery fish is used effectively during restoration efforts.
- Maximize cost effectiveness of data collection to minimize costs to states and jurisdictions through coordinated monitoring, flexibility in monitoring methods, and early vetting of monitoring and management plans.
- Identify interactions between other Commission species management plans (positive or negative) and the objectives stated above.

SUSTAINABLE FISHERY DEFINITION: This document defines a sustainable fishery as “those that demonstrate their stock could support a commercial and/or recreational fishery that will not diminish the future stock reproduction and recruitment*.”*

OVERFISHING DEFINITION: Amendment 1 to the American shad and River Herring Fishery Management Plan (ASMFC 1999) refined the definition of overfishing for American shad stocks to be an *instantaneous rate of fishing mortality* rate (F) from directed fisheries that was at or above a benchmark of F_{30}. The most recent stock assessment (ASMFC 2007) concluded that the Amendment 1 definition of overfishing was no longer valid for American shad stocks since they are subjected to several sources of human-induced mortality that includes: directed fishing (F), fish passage mortality at dams, river pollution, and bycatch and discard in indirect fisheries activity. As an interim solution, the recent ASMFC stock assessment (ASMFC 2007) combined all human-induced rates into a single overall human induced rate. Since the components of human-induced mortality (directed fishing, dam-induced, pollution, and bycatch) are difficult or impossible to quantify, ASMFC (2007) did not attempt to develop a benchmark for combined mortality that was analogous to F_{30} for directed fishing alone. Instead, ASMFC (2007) developed benchmark values for *total instantaneous mortality* or Z_{30} (see Table 1). Under this new definition, American shad stocks are affected by a combined human-induced instantaneous mortality rate and by natural mortality (M). Therefore, the total instantaneous mortality (Z) equals human induced mortality plus M. Since the total instantaneous mortality definition combines mortality that are both within and beyond the purview jurisdiction of the Commission, as well as currently unquantified mortality, the Board adopted the use of Z_{30} as a mortality benchmark to help guide management and gauge restoration progress. This amendment did not adopt an overfishing definition, defined as F.

MONITORING PROGRAM SPECIFICATIONS: The collection of adequate fish stock and fishery monitoring data is necessary to achieve the goal and objectives of the American Shad management program. A well designed monitoring program provides measurable outputs that can be used to judge the effectiveness of current management efforts in achieving the desired outcome. This amendment recommends that states increase coordination of data collection on American shad among states with shared water bodies, as well as between freshwater and marine sections of agencies. All available data must be reported in annual compliance reports to ASMFC.

States and jurisdictions will be required to conduct annual fisheries independent and dependent monitoring (See Table 2 and 3). Fisheries independent monitoring includes juvenile abundance, adult stock structure and abundance, and stocking success. Fisheries dependent monitoring includes monitoring of American shad commercial and recreational fisheries. States and jurisdictions may apply to the Management Board for *de minimus* status. Monitoring will be conducted using methods proposed by the state or jurisdiction and subject to Technical Committee review and Board approval.

States and jurisdictions may propose to the Management Board alternative monitoring if they develop a stock specific definition of a sustainable fishery or stock recovery targets, as per Section 6.0, and the proposed alternative monitoring measures progress to the definition or targets. If a states or jurisdiction cannot meet the monitoring requirements, the Commission will work with that state or jurisdiction to develop an acceptable alternative proposal, as per Section 6.0 or Section 7.0, which will be submitted for TC review and Board approval. The Technical Committee is tasked with reviewing and prioritizing the data collection elements in the monitoring program. The review should include a brief explanation of the importance of each element to the stock assessment process.

BYCATCH MONITORING AND REDUCTION: States and jurisdictions will be required to annually monitor bycatch and discard of American shad in fisheries that operate in state waters of rivers and estuaries. States and jurisdictions are required to submit a plan to conduct monitoring of bycatch and discards within the Implementation Plan. Ocean bycatch and discard, however, are coastwide problems that affect shad stocks in all coastal states. This amendment recommends that ocean bycatch and discards be monitored cooperatively by coastal states through the Commission, in cooperation with Fishery Management Councils and NOAA Fisheries.

REGULATORY PROGRAM: The management units for American shad under this Fishery Management Plan Amendment include all migratory American shad stocks of the Atlantic coast of the United States. States and jurisdictions must implement the regulatory program requirements as per Section 7. The Management Board has the ultimate authority to determine the approval of a regulatory program. States and jurisdictions must also submit proposals to change their required regulatory programs as per Section 7.1.2. The Management Board will determine final approval for changes to required regulatory programs.

COMMERCIAL FISHERIES MANAGEMENT MEASURES: States and jurisdictions shall submit a sustainable fisheries management plan for those systems that will remain open to commercial fishing. The request for a fishery will be submitted as part of the Fishing/Recovery Section in the Implementation Plan, as per Section 6.0. States or jurisdictions without an approved plan in place will close the commercial fishery by January 1, 2013.

RECREATIONAL FISHERIES MANAGEMENT MEASURES: States and jurisdictions shall submit a sustainable fisheries management plan for those systems that will remain open to recreational fishing. Catch and release fishing will be permitted on any system. The request for a fishery will be submitted as part of the Fishing/Recovery Section in the Implementation Plan, as per Section 6.0. States or jurisdictions without and approved plan in place will close their recreational fishery (with the exception of catch and release) by January 1, 2013.

HABITAT CONSERVATION AND RESTORATION: American shad stocks along the Atlantic coast are greatly diminished compared to historic levels of the 1880's and early 1900's when landings were near 50 million pounds per year. Much of this reduction has been related to spawning and nursery habitat degradation or blocked access to habitat, resulting from human activity (e.g.; human population increase; sewage and storm water runoff; industrialization; dam construction; increased erosion, sedimentation and nutrient enrichment associated with agricultural practices; and losses of riparian forests and wetland buffers associated with resource extraction and land development). Protection, restoration and enhancement of American shad habitat, including spawning, nursery, rearing, production, and migration areas, are critical objectives necessary for preventing further declines in American shad abundance, and restoring healthy, self-sustaining, robust, and productive American shad stocks to levels that will support the desired ecological, social, and economic functions and values of a restored Atlantic coast American shad population.

THREATS TO AMERICAN SHAD HABITAT: Threats to American shad habitats include the following: barriers to migration; water withdrawals; toxic and thermal wastewater discharge; channelization, dredging and instream construction; inappropriate land uses; atmospheric deposition; climate change; competition and predation by invasive and managed species; fisheries activities; and instream flow regulation.

RECOMMENDATIONS FOR HABITAT RESTORATION, ENHANCEMENT, USE AND PROTECTION: Detailed recommendations are provided to states and jurisdictions for avoiding, reducing or mitigating the impact of the following threats on American shad habitats: dams and other obstructions and water quality and contamination**.** Additional detailed recommendations are provided for habitat protection and restoration; state permitting programs; and American shad stock restoration and management of stocking programs. While this amendment proposes the development of habitat restoration and protection programs, implementation of these programs is not required.

IMPLEMENTATION PLANS: In order to be successful in achieving the stated goal of Amendment 3, states are required to develop Implementation Plans. Implementation Plans will consist of two parts: 1. Review and update of the fishing/recovery plans required under Amendment 1 for the stocks within their jurisdiction; and 2. Habitat plans. Separate Implementation Plans shall be developed for those systems listed in Tables 2 and 3 and which are under the state's or jurisdiction's authority. For states and jurisdictions which share a river or estuary, agencies should include those monitoring programs conducted or planned by the agencies, applicable agency regulations, and habitat and habitat threats applicable to the state or jurisdiction's waters. In shared water bodies where there is a management cooperative, the cooperative or a member state or jurisdiction can be appointed to write the Implementation Plan. States are encouraged to develop plans for any additional systems, as feasible. In some cases, the requirements of this section may be largely met by existing basinwide diadromous fish restoration plans prepared by the federal and state agencies to address the requirements of the Federal Energy Regulatory Commission hydropower licensing requirements.

FISHING/RECOVERY PLAN UPDATES: The updated Fishing/Recovery Plan must include a description of existing and planned monitoring and existing and planned regulatory measures. It may also include a request for commercial and/or recreational fishery, a definition of sustainability, development of benchmark goals (if different from or in addition to those identified in 2007 Stock Assessment), and a proposed timeframe to achieve stated objectives. Monitoring sections of the fishing/recovery plan updates should address the specific monitoring requirements specified in Tables 2 and 3. If states or jurisdictions cannot conduct required monitoring, the plan update should identify required monitoring that cannot be done and provide reasons why it cannot be conducted. It is the intention of this amendment to discuss such problems with implementation prior to plan adoption so that the Commission can work with the state or jurisdiction to obtain secure funding or to develop an alternative. The amendment contains a detailed framework for the Fishing/Recovery Plan updates (see Section 6.1). If a state or jurisdiction chooses to develop a definition of sustainability or stock restoration goals as part of its Fishing/Recovery Plan, it may propose for Management Board review an alternative monitoring plan that measure stock status relative to the definition or goal. Fishing/Recovery Plans are due August 1, 2011.

HABITAT PLANS: The Habitat Plans should include a summary of current and historical spawning and nursery habitat, threats to those habitats, and habitat restoration programs. States and jurisdictions may focus on those threats to habitats within their boundaries that are deemed most significant. A recommended framework for the Habitat Plans is included in the amendment (see Section 6.2). Many of the recommended assessments may have already been conducted by the states as part of their Wildlife Action Plans or Comprehensive Wildlife Conservation Plans. Habitat Plans are due August 1, 2013.

AMENDMENT REVISIONS: Once the American shad Management Board approves a management program, states and jurisdictions are required to obtain approval from the Management Board prior to changing their management program in any way that might alter a compliance measure. Changes to management programs that affect measures other than compliance measures must be reported to the Management Board but may be implemented without prior approval.

ADAPTIVE MANAGEMENT: It is important to note that this amendment provides the Management Board with the ability to re-evaluate and modify the management program very rapidly in response to stock conditions or public input.

COMPLIANCE: Full implementation of the provisions in this amendment is necessary for the management program to be equitable, efficient and effective. States and jurisdictions are expected to implement these measures faithfully under state laws.

MANDATORY COMPLIANCE ELEMENTS FOR STATES: A state or jurisdiction will be determined out of compliance with the provision of this fishery management plan according to the terms of Section 7 of the ISFMP Charter if:

- It's Implementation Plans and annual compliance reports have not been approved by the Shad and River Herring Management Board; or
- It fails to meet any scheduled action required by Section 9.2, or any addendum prepared under adaptive management (Section 7.2); or
- It has failed to implement a change to its program, when determined necessary by the Shad and River Herring Management Board; or
- It makes a change to its monitoring programs required under Section 3 or its regulations required under Section 4 without prior approval of the Shad and River Herring Management Board.

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1. INTRODUCTION

The Atlantic States Marine Fisheries Commission (Commission) was formed by the 15 Atlantic coast states in 1942 in recognition that fish do not adhere to political boundaries. The Commission serves as a deliberative body, coordinating the conservation and management of the states shared near shore fishery resources (marine, shell, and anadromous) for sustainable use. The Commission focuses on responsible stewardship of marine fisheries resources. It serves as a forum for the states to collectively address fisheries issues under the premise that as a group, using a cooperative approach, they can achieve more than they could as individuals. The Commission does not promote a particular state, jurisdiction, or a stakeholder sector.

The Commission's mission is to promote the better utilization of the marine, shell, and anadromous fishery resources of the Atlantic seaboard through the development of a joint program for the promotion and protection of such resources, and by the prevention of physical waste of the fisheries from any cause.

The vision statement of the Commission is: Healthy, self-sustaining populations for all Atlantic coast fish species or successful restoration well in progress by the year 2015.

The Commission has developed Amendment 3 to its Interstate Fishery Management Plan for Shad and River Herring (ACMFC 1985, 1999, 2000, and 2002), or FMP, under the authority of the Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA 1993). Shad and river herring management authority lies with the coastal states and is coordinated through the Commission. Responsibility for compatible management action in the Exclusive Economic Zone (EEZ) from 3-200 miles from shore lies with the Secretary of Commerce through ACFCMA in the absence of a federal fishery management plan. Further, each federal Fishery Management Council "...shall comment on and make recommendations to the Secretary and any Federal or State agency concerning any such activity that, in the view of the Council, is likely to substantially affect the habitat, including essential fish habitat, of an anadromous fishery resource under its authority" (from Magnuson-Stevens Fishery Conservation and Management Act, Section 305, P.L. 104-297, (b) FISH HABITAT (3)(B)).

PLEASE NOTE: While the FMP is the management document for American shad (*Alosa sapidissima*), hickory shad (*Alosa mediocris*), blueback herring (*Alosa aestivalis*), and alewife (*Alosa pseudoharengus*), **the required provisions of Amendment 3 pertain only to American shad.** This amendment does not alter the monitoring requirements or fishery management measures for alewife, blueback herring or hickory shad.

1.1 BACKGROUND INFORMATION

1.1.1 Historical Fishery and Management

Historically, American shad, hickory shad, alewife, and blueback herring (collectively termed alosines) were an extremely important fishery resource and supported very large commercial fisheries along the Atlantic coast of both the United States and Canada. Coastwide landings of American shad at the turn of the century were approximately 50 million pounds. However, by

1980, they decreased dramatically to 3.8 million pounds. Total landings of river herring (alewife and blueback herring) varied from 40-65 million pounds from 1950-1970, then declined steadily thereafter to less than 12 million pounds by 1980. These dramatic declines in commercial landings were perceived as an indication that a coordinated management action would be required to restore alosine stocks to their former levels of abundance. Therefore, in 1981, the members of the Atlantic States Marine Fisheries Commission recommended the preparation of a cooperative Interstate Fishery Management Plan (FMP) for American Shad and River Herrings. The initial FMP was completed in 1985 and recommended management measures that focused primarily on regulating exploitation and enhancing stock restoration efforts. At the time the FMP was completed, the implementation of its recommendations was at the discretion of the individual states, because the Commission did not have direct regulatory authority over individual state fisheries.

A supplement to the FMP was approved by the Commission in 1988. This document included reports prepared by the Shad and River Herring Stock Assessment Subcommittee and summaries of material presented at a 1987 Anadromous Alosine Research Workshop. The 1988 supplement also changed management recommendations and research priorities based on new research findings.

In spite of the efforts to develop and implement the FMP and supplements, alosines stocks continued to decline (Figure 1) and, in 1994, the Plan Review Team and the Management Board determined that the original FMP was no longer adequate for protecting or restoring the remaining shad and river herring stocks. They concluded that the declines may have been the result of overharvest by in-river and ocean-intercept fisheries; excessive striped bass predation (Savoy and Crecco 1995); biotic and abiotic environmental changes; and loss of essential spawning and nursery habitat due to water quality degradation and blockages of spawning reaches by dams and other impediments.

A second coastwide assessment was completed 1998 and Amendment 1 to the FMP was adopted in April 1999. The amendment was revised by addendums in 2000 and 2002. Amendment 1 and the addendums focused on maintaining directed fishing mortality below set benchmarks. These directives have defined ASMFC shad management until the adoption of Amendment 3 in 2010.

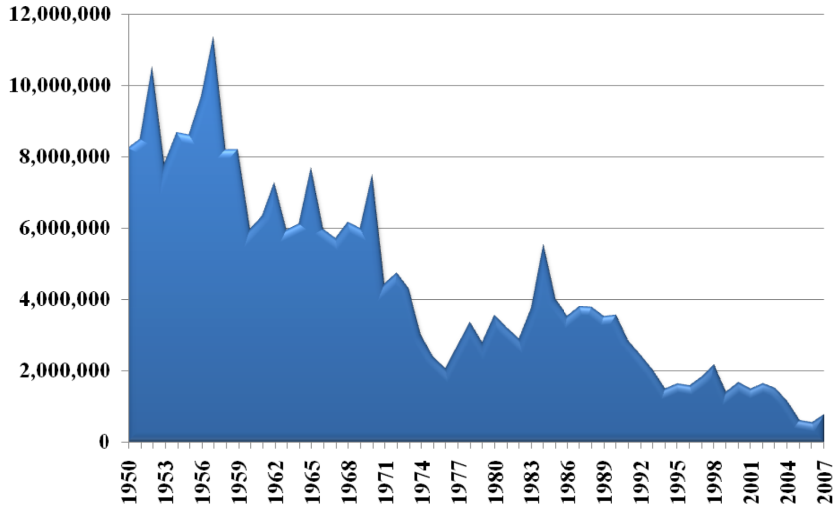

Figure 1. Total (in-river and ocean) commercial landings (pounds) of American shad for the U.S. Atlantic coast, 1950-2008 (Source: NMFS, Fisheries Statistics Division, Silver Spring, MD, pers. comm.).

1.1.2 Statement of the Problem

In 2007, the American Shad Stock Assessment Subcommittee (SASC) completed an American shad stock assessment report, which was accepted by the Peer Review Panel (PRP) and the Shad and River Herring Management Board in August 2007 (ASMFC 2007). The 2007 American shad stock assessment found that stocks were at all-time lows and did not appear to be recovering to acceptable levels. It identified the primary causes for the continued stock declines as a combination of excessive total mortality, habitat loss and degradation, and migration and habitat access impediments. Although improvement has been seen in a few stocks, many remain severely depressed compared to their historic levels.

Given these findings, the PRP recommended that current restoration actions need to be reviewed and new directives need to be developed and implemented. The SASC and PRP recommendations included actions to reduce fishing mortality, improve fish passage at mitigation barriers, reduce dam passage mortality and delay, increase larval stocking, and implement habitat restoration actions.

Anadromous fish species, such as American shad, are unlike almost all other fish species that are cooperatively managed under ASMFC. Most other ASMFC species are exclusively oceanic and all of their habitat and life cycle needs can be satisfied in the marine environment (although some may utilize coastal shore or estuarine habitat for part of their life). It has long been assumed that human impact on the ocean environment has been non-existent or minimal. It has also been assumed that the only major human-induced impact on oceanic fish species was from recreational and commercial fishing that resulted in direct mortality. However, anadromous fish, as a result of their freshwater and estuarine spawning and nursery requirements, must come into direct contact with human populations; therefore, they are vulnerable to the many sources of mortality associated with human activity in and around rivers and estuaries.

Extensive populations of anadromous fish species historically existed along the Atlantic coast prior to the Industrial Era. Since that time, non-fishery human-induced threats may have had a significant impact on anadromous fish stocks. Moreover it is likely that American shad stocks and the resulting Atlantic coast population may not reach its full potential until these other threats are adequately addressed.

1.1.3 Benefits of Amendment 3

1.1.3.1. Social and Economic Benefits

Restoring, enhancing and maintaining the stability and productivity of the Atlantic coast population of American shad will enhance the economic and social benefits for the Commission member states and the nation as a whole. The economic values associated with these benefits would include direct use values (e.g., consumptive use values related to commercial and recreational fishing, and non-consumptive use values such as observing spawning runs), indirect-use values (e.g., contribution to the forage of many other economically important species such as striped bass, and enrichment of freshwater system productivity through transfer of marine derived nutrients), and non-use values (i.e., existence and option values) for current and future generations. For example, an option value might be the value someone places on the potential of future generations having the option of harvesting American shad, which would then be a consumptive use value. The indirect-use values are mainly contributed through the ecological benefits attributed to American shad, which in turn provide ecosystem functions that enhance their numerous direct and non-use economic value.

Although the indirect-use and non-use economic values can be difficult to quantify in dollar terms, it is readily apparent that American shad have supported valuable commercial fisheries along the entire Atlantic coast. However, these fisheries have declined dramatically in recent years. The nominal ex-vessel unit price, which is the price received by the harvesters not adjusted for inflation, for American shad ranged from $0.325 to $1.022 per pound and averaged $0.534 per pound for the years 1980 through 2007. The nominal total (aggregate) ex-vessel value of the U.S. Atlantic coast American shad harvest has ranged from a high of over $2 million in 1984 to a low of about $540,000 in 2006, after the ocean-intercept fishery closure was implemented in all Atlantic coastal states, and it averaged $1.1 million for the years 1980 to 2007. Additionally, the market price paid by the final consumer can be 3 to 10 times or more than the ex-vessel price, yielding an increased economic benefit (i.e., direct use value) well above the price paid to the vessel owner/operator. See Appendix A for a discussion of methodology.

Recreational fisheries for American shad are often poorly documented, if at all. The National Marine Fisheries Service operates the Marine Recreational Fisheries Statistics Survey (MRFSS) to obtain information on recreational fisheries for marine species. MRFSS does not adequately capture information on anadromous fisheries, including those for American shad because the current survey design focuses on active fishing sites along coastal and estuarine areas rather than inland non-tidal waters where most recreational fishing for American shad occurs. However, the seasonal economic impact of shad recreational fisheries may be substantial. A 1986 study of shad anglers fishing on the Delaware River indicated that they collectively spent about $1.6 million during a nine week angling season (PFBC 2008), equivalent to approximately $3 million in 2007. Moreover, the aggregate willingness to pay (economic value) for these shad anglers was estimated to be about $3.2 million or an equivalent $6 million in 2007 (PFBC 2008). Similar recreational fisheries exist in many rivers along the Atlantic coast and each would likely contribute an equivalent economic value.

1.1.3.2. Ecological Benefits

American shad play an important ecological role in freshwater, estuarine, and marine environments during its anadromous life cycle. They influence food chains by preying on some species and serving as prey for others, throughout all life stages (Facey et al. 1986, MacKenzie et al. 1985, Weiss-Glanz et al.1986). During earlier periods of high abundance, American shad also played a significant role in ecosystem nutrient and energy cycling. This was most apparent in South Atlantic coastal river systems, where the percentage of repeat spawning is low and many of the fish die shortly after spawning, thus transferring nutrients and energy derived from the marine system into the freshwater interior rivers. Durbin et al. (1979) conducted a study of the effects of post spawning alewife on freshwater ecosystems. It was suggested that the potential influence of alosine migration on the nutrient and energetic dynamics of Atlantic coast ecosystems is equivalent to effects documented for similar systems in the Pacific Northwest for salmon rivers. Garman (1992) studied the fate and potential significance of post spawning anadromous fish carcasses in the James River, Virginia. He hypothesized that, before recent declines in abundance, the annual input of marine-derived biomass via alosine migrations was an important episodic source of energy and nutrients for the non-tidal James River.

As prey, American shad are important for other species that are themselves important commercially, recreationally and ecologically. American eels prey on American shad eggs, larvae and juveniles in freshwater and striped bass consume juveniles (Facey et al. 1986, Mansueti and Kolb 1953, Walburg and Nichols 1967). Savoy and Crecco (1995) also suggest a direct linkage between increased striped bass predation and the dramatic drop in American shad and blueback herring abundance in the Connecticut River. Predation on juvenile American shad by other large predators (e.g. weakfish, bluefish) is also perhaps a minor factor that could be delaying the recovery of American shad stocks in the Chesapeake Bay (Klauda et al. 1991). Once in the ocean, as a schooling species with no dorsal or opercula spines, American shad are undoubtedly preyed upon by many species including sharks, tunas, king mackerel, seals, and porpoises (Melvin et. al. 1985, Weiss-Glanz et al. 1986). American shad are also a seasonally important prey species for a number of riparian fish, birds, and wildlife species, with the adult spawning American shad arriving in the early spring when other prey may be scarce and the nesting/breeding season is just beginning for many wildlife predators.

1.1.3.3. Cultural Benefits

American shad were and are of cultural significance to Native Americans, European colonists and contemporary Americans who reside near and/or fish in rivers which supported or continue to support spawning runs (Brandywine Conservancy 2005, Day 2006, Groth 1996, McPhee 2002). American shad spawning runs in the spring were an essential element of Native American nutrition. One example is the run in the Penobscot River, Maine, which has been home to the Penobscot Indian Nation for more than 10,000 years. Historic findings of Penobscot fish nets, baskets and spears indicate the sustenance and subsistence significance of fish to the tribe (Day 2006). As noted in Day (2006, page 29), “Federally recognized rights to sustenance fishing rights today remain relatively meaningless for lack of sea-run fish and because resident fish are contaminated.” The same statements regarding the historic significance of the runs and the current meaninglessness of their rights could well be applied to every other Native American tribe along the entire east coast from Maine through Florida.

The cultural significance of American shad and other anadromous species is reflected in the traditions that took root which reflected the significance of sea-run fish in people’s lives (Day 2006). The first-caught salmon of the season from the Penobscot was sent to the President of the United States; families passed fishing traditions through the generations; and fishing clubs for salmon and shad sprang up along the river. The names of the fish are still etched on the inland landscape–for instance, Shad Pond on the Penobscot, where shad can no longer migrate due to downstream dams (Day 2006).

The State of Connecticut General Assembly designated American shad as its State Fish in 2003, the only state to select the species. It was selected because it 1) was a native Connecticut fish; 2) had great historical significance in that it provided food for Native Americans and colonists; 3) it was and is of great commercial value to the state; and 4) because the hardiness of this migratory fish reflects the true Connecticut spirit as reflected in the state's motto: "Qui Transtulit Sustinet" (*He who transplanted still sustains*).

Many communities celebrated and still celebrate the arrival of American (and also hickory) shad by holding festivals to mark the occasion. See Appendix B for a list of current and historic festivals held along the Atlantic coast. These festivals are held during the spring of the year to coincide with the American shad spawning run, and generally entail fishing for, and consumption of, American shad, along with a variety of other activities including running events, arts and crafts shows, music, and many other activities designed to promote social interactions among residents, attract tourists, and benefit the local economy.

Many of the cultural values associated with runs of American shad and other species provide significant incentives for restoration of the runs (Day 2006), as well as for the bolstering of states' economies. Additional benefits include restoration of meaning for Native American and other fishing rights; educational potential of fish bypasses; perpetuation and/or reestablishment of local festivals which are of economic benefit to the residents; and reinvigorating the traditions of fishing for sea-run fish on many East Coast rivers.

The most comprehensive account of the role which American shad has played in the culture of North America since colonization by Europeans is that by John McPhee (McPhee 2002). In *The Founding Fish,* McPhee's research documents the relevance of American shad in seventeenth and eighteenth-century America. He documents George Washington's prowess as a commercial shad fisherman (in 1771, Washington caught 7,760 American shad) and the role of the species in the lives of Henry David Thoreau and John Wilkes Booth. It is clear from his work that American shad have played a significant and largely continuous role in the lives of Americans since European colonization.

1.2 DESCRIPTION OF THE RESOURCE

A comprehensive description of the Atlantic coast stocks of American shad can be found in the 1985 Interstate Fishery Management Plan for Shad and River Herring and in the 2007 American shad stock assessment (ASMFC 2007). This section provides the basic information necessary to understand how anadromous American shad relate to their essential habitats and the significance of the commercial and recreational fisheries to the economy and culture of the Atlantic coast.

1.2.1 American Shad Life History

American shad are an anadromous fish that spend most of their life at sea along the Atlantic coast and enter freshwater as adults in the spring to spawn. American shad stocks are river-specific; that is, each major tributary along the Atlantic coast appears to have a discrete spawning stock. This is because American shad have been documented to have a high fidelity to return, in the spring, to their natal tributary to spawn. Young-of-year fish often migrate downstream to estuaries over the summer. In the fall or subsequent spring, juveniles emigrate from freshwater and estuarine nursery areas and join a mixed-stock, sub-adult coastal migratory population.

After four to six years individuals become sexually mature and migrate to their natal rivers during the spring spawning period that may vary by latitude (see Appendix C for a full description of the American shad life history and habitat requirements). The 2007 American shad stock assessment report identified 86 separate tributaries or potential individual stocks. Of the 86 tributaries identified, only 31 were deemed to have adequate data for a tributary specific stock assessment.

1.2.2 American Shad Stock Assessment Summary

ASMFC, 1988

The first stock assessment was conducted in 1988 (ASMFC 1988) and focused on American shad stocks in 12 Atlantic coast rivers. The Shepherd stock-recruitment model was used to estimate maximum sustainable yield (MSY) and maximum sustainable fishing rate (F_{msy}). They found that MSY was positively correlated to drainage area and that highest F_{msy} occurred in the central part of the species range.

ASMFC, 1998

The second coastwide stock assessment conducted by the ASMFC was completed in 1998 (ASMFC 1998). Generally, assessments were conducted on a river-specific basis, but some grouping of river systems occurred (e.g., Maine rivers were examined collectively, Upper Bay Maryland, Albemarle Sound, and Waccamaw and Pee Dee rivers).

A Thompson-Bell yield-per-recruit (YPR) model was used to derive the overfishing definition (F_{30}) for some shad stocks where possible. F_{30} is that level of fishing mortality that theoretically results in a female spawning stock biomass that is 30% of that possible when only natural mortality acts on the stock. This level of fishing mortality has been shown to be sustainable in other species with similar life history parameters. The assessment examined catch and harvest data, exploitation rates, fish-lift counts, current and historic coastal (Fc) and in-river (Fr) fishing mortality rates, and other indicators of stock status for American shad from selected stocks or river systems located from Maine to the Altamaha River, Georgia, with special attention on recent (1992 to 1996) stock dynamics.

The 1998 assessment concluded that there was evidence of recent (1992-1996) and persistent stock declines in the Hudson and York Rivers and of recent stock increases in the Pawcatuck and Connecticut Rivers. The assessment concluded that the drop in commercial landings in the Edisto River was largely due to a reduction in fishing effort and did not reflect stock abundance. In addition, the assessment reported that there was no evidence of recent stock declines for the Merrimack River, Delaware River, upper Chesapeake Bay tributaries, Rappahannock River, James River, Santee River, and the Altamaha River. Stock declines inferred from declining trends from river-specific commercial landings were evident for the Neuse River, Pamlico River, Cape Fear River, Waccamaw-Pee Dee River, Savannah River, Albemarle Sound tributaries, and rivers in the state of Maine.

Where estimation of recent F rates (1992-1996) was possible, all estimates of total F (Fc + Fr) were below $F_{30,}$ suggesting that these stocks were not overfished. At that time, the assessment also concluded that there was no evidence that the ocean-intercept fishery had an adverse impact on American shad abundance along the Atlantic coast and that there was no evidence of recent (1990-1996) recruitment failure for Maine rivers, Pawcatuck River, Connecticut River, Hudson River, Delaware River, Upper Chesapeake Bay tributaries, Altamaha River and Virginia rivers.

ASMFC, 2007

A coastwide American shad stock assessment was completed and accepted by the Management Board in August 2007. The 2007 stock assessment found that American shad stocks were at all-time lows and did not appear to be recovering. Recent declines of American shad were reported for Maine, New Hampshire, Rhode Island, and Georgia stocks, and for the Hudson (NY), Susquehanna (PA), James (VA), and Edisto (SC) rivers. Low and stable stock abundance was indicated for stocks in Massachusetts, Connecticut, Delaware, a tributary to the upper Chesapeake Bay, the Rappahannock River (VA), and some South Carolina and Florida stocks. Stocks in the Potomac and York Rivers (VA) have shown some signs of recovery in recent years. Data limitations and conflicting data precluded conclusions about status or trends of many of the stocks in North and South Carolina.

The 2007 stock assessment report identified primary causes for stock decline as a combination of overfishing, pollution, and habitat loss due to dam construction. In recent years, coastwide harvests have been 500-900 metric tons (1 – 2 million pounds), nearly two orders of magnitude lower than in the late 19th century. Given these findings, the Peer Review Panel recommended that current restoration actions need to be reviewed and new measures need to be identified and applied. The Peer Review Panel suggested considering a reduction of fishing mortality, enhancement of dam passage and mitigation of dam-related fish mortality, stocking, and habitat restoration.

1.3 HABITAT REQUIREMENTS

American shad utilize coastal tributaries and the associated bays and estuaries for spawning and larval and juvenile nursery habitat. In addition, migratory sub-adult and adult American shad utilize near shore ocean habitats. These habitats are distributed along the Atlantic coast from the Bay of Fundy, Canada to Florida. Use of these habitats by migratory American shad may increase or diminish as the size of the population changes, habitat quality deteriorates, or habitat access is impaired. For an in-depth description of American shad Habitat Requirements see Appendix C.

As noted in section 1.2.1 the migratory nature of anadromous American shad exposes them to numerous human-induced threats that can result in direct or indirect mortality and reduced juvenile and adult spawning stock recruitment which impact stock status. Some of the most important human-induced threats, from a management perspective, are those leading to freshwater or ocean pollution, habitat degradation or migratory impairment. Individual and cumulative negative impacts to American shad habitat results in reduced stock health, leading to a declining Atlantic coast population. The causes of many human-induced threats are often under some form of regulatory management already, which could be used as a means to avoid, minimize, or reduce the impact of the habitat threats associated with human activities.

1.4 DESCRIPTION OF THE FISHERIES

American shad historically supported important commercial and recreational fisheries along the entire Atlantic coast; however, these fisheries have declined dramatically in recent years. Two types of fisheries exploit spring spawning migrations of American shad: in-river and ocean-intercept. In-river fisheries only exploit the stock native to that system, whereas ocean-intercept fisheries exploit mixed stocks of different river origins. There are some estuarine fisheries (e.g., Delaware Bay, Winyah Bay) that also exploit mixed stocks.

Catch statistics for both ocean and in-river American shad fisheries on the Atlantic coast are compiled by the National Marine Fisheries Service (NMFS) and state agencies for both commercial and recreational fisheries; however, there are data gaps in these records. It is important to note that harvest from fishers operating in-river, or from fisheries that are not federally licensed, might not be reported to NMFS. In addition, bycatch in non-directed fisheries is poorly documented. Information provided below is based on state reports (e.g. annual Compliance Reports) and data available from NMFS.

1.4.1 Commercial Fishery

Since the early 1800s, the American shad supported major commercial fisheries along the Atlantic coast and was one of the most valuable food fish of the U.S. Atlantic coast before World War II (Rulifson et al. 1982). However, American shad, alewives, blueback herring, and other anadromous species were already declining in southern New England by 1870 (Bowen 1970; Moring 1986). Primary causes were impassable dams located on major New England Rivers as well as heavy pollution near towns and mills. For example, the first dam on the Connecticut River was constructed in 1798 at Turners Falls, Massachusetts, which was a 16-foot high structure impassable to all migrating fishes. The estimated U.S. Atlantic coast catch in 1896 was 50 million pounds, but it declined to approximately 10 million pounds per year between 1930 and 1960 (Weiss-Glanz *et al.* 1986) and to about 2 million by 1976.

Historically, aggregated commercial landings (coastal ocean and in-river) of American shad have shown major long-term declines, but coastal ocean landings of American shad did increase more than four-fold after 1978. In 1980, coastal ocean landings equaled approximately 623,000 pounds. By 1989, this number had peaked to 2.1 million pounds, and in 1996 landings were 1.1 million pounds. Ocean harvest contributed about 11 % of total Atlantic coast landings in 1978; this contribution increased yearly to approximately 67% by 1996 as ocean landings increased and in-river landings declined.

The closure of the ocean-intercept fishery in 2005 lowered the coastwide total landings of American shad. Based upon landings data provided in ASMFC Compliance Reports from individual states and jurisdictions, 2007 coastwide landings totaled 824,730 pounds (ASMFC, 2008). Combined landings from North Carolina and South Carolina accounted for 64% of the commercial harvest in 2007. Connecticut, Delaware, New York, New Jersey, and Georgia accounted for 35% of the commercial harvest in 2007. Maine, New Hampshire, Massachusetts, Rhode Island, Pennsylvania, Maryland, the District of Columbia, and Florida reported no directed shad harvest in their state. Shad bycatch landings from ocean waters in 2007 were reported at 4,562 pounds, or about 0.55% of the coastwide commercial harvest. However, it is important to note that only three states—Maine, Massachusetts, and New Jersey – reported landings of ocean bycatch.

An analysis of recent ex-vessel value trends for the commercial American shad fishery can be found in Appendix A. The analysis suggests that in times of generally declining commercial shad landings, market "signals" may have encouraged harvesters to perceive an ex-vessel market segment with the potential of offsetting declining harvest quantities with substantially higher ex-vessel prices. In other words, American shad harvesters in past decades may have continued to fish in response to continued market demand capable of supporting profitable ex-vessel revenues even though catch quantities declined, (i.e., a relatively inelastic own ex-vessel price situation). For open access fisheries, such relatively inelastic demand along with other factors has been implicated in the depletion of various fishery stocks (e.g., Brandt 1999).

1.4.2 Recreational Fishery

Data on recreational fisheries for American shad are limited or are non-existent. The National Marine Fisheries Service operates the Marine Recreational Fisheries Statistics Survey (MRFSS) to obtain information on recreational fisheries for marine species. MRFSS does not adequately capture information on anadromous fisheries, including those for American shad because the current survey design focuses on active fishing sites along coastal and estuarine areas rather than inland non-tidal waters where most recreational fishing for American shad occurs. Error associated with data on harvest, catch, and effort is often high.

Although data are limited, it is readily apparent that substantial shad sport fisheries occur on the Connecticut (CT and MA), the Hudson (NY), the Delaware (NY, PA and NJ), the Susquehanna (MD), the Santee and Cooper (SC), the Savannah (GA), and the St. Johns (FL) Rivers. Limited shad recreational fisheries occur on several other rivers in Massachusetts, Virginia, North Carolina, South Carolina, and Georgia. In 2007, recreational creel limits ranged from zero to 10 fish per day, with the exception of the Santee River (SC), which is permitted to have a 20 fish per day creel limit due to the approval of a conservation equivalency plan in 2000. It is estimated that tens of thousands of shad are caught by hook and line from large Atlantic coast rivers each year by recreational anglers. However, the actual harvest (i.e. catch and removal) may amount to only about 20-40% of total catch due to the prevalence of catch-and-release angling practices.

1.4.3 Tribal Fisheries

There are known tribal fisheries for American shad fisheries (see Section 1.1.3.3), but the extent of effort and harvest is undocumented.

1.4.4 Non-Consumptive Factors

People interested in conservation and wildlife have been known to actively engage in observation of American shad migration during the annual spawning migration as they pass through constricted natural corridors and fish passage facilities. In some regions, this non-consumptive use of the American shad resource is an important part of public education, local heritage, ecotourism, and outdoor recreation. Real-time video of spring spawning migrations of alosines are available via online webcams for both the fishway at Bosher's Dam on the James River and Fairmount Dam on the Schuyllkill River (available at: http://www.dgif.virginia.gov/fishing/shadcam and http:// fairmountwaterworks.com/fishcam.php, respectively). In addition, volunteer involvement in non-consumptive cooperative fishery projects has included activities related to American shad, including the "Shad-In-Schools" educational program and angler group larval shad hatcheries.

Some local governments also sponsor springtime shad festivals and/or related events that include non-fishing activities. According to the American Rivers organization (2008), shad fishing and related tourism along the Susquehanna River generate approximately $30 million annually in economic impacts and "…the estimated values of a restored shad run in Maryland range from $42 million to $178 million."

1.4.5 Interactions with Other Fisheries, Species and Other Uses

For an in-depth description of American shad bycatch, interactions with protected species and interactions with other invasive or managed species see Appendix E.

1.4.5.1 Bycatch

Catch of American shad that occurs in fisheries directed at other species is referred to as bycatch. Bycatch also refers to illegal or unmarketable fish caught in directed fisheries. Estimates of American shad bycatch are difficult to obtain since few studies have focused specifically on that issue. Bycatch losses contribute to the total mortality of American shad, and are important to consider in the current and future management of these fisheries.

Reported shad bycatch landings from ocean waters in 2007 decreased from 2006 levels and were 4,562 pounds, or about 0.55% of the coastwide commercial harvest. It is important to note that only three states—Maine, Massachusetts, and New Jersey—reported landings of ocean bycatch that were used in the calculation of the above statistics. There are concerns that the amount of bycatch that is actually occurring may be much higher than what is reported.

1.4.5.2 Interaction with Protected Species

The management of the American shad populations has the potential to intersect with the management and restoration efforts of a number of protected species. The resulting interactions can potentially have negative impacts for both American shad and the protected species. The protected species can place competitive and predatory pressures on American shad and vice versa. The protected species can also be impacted by regulated fishery activities directed at American shad. The potential for these interactions should be considered during the development of future American shad fishery management plans and actions. Also, the resource agencies responsible for management and restoration of protected species need to be made aware of the potential impacts of their plans and activities on American shad management and restoration efforts.

1.4.5.3 Interaction with Invasive and Other Managed Species

The management of the American shad population has the potential to intersect with the management of a number of invasive (e.g., snakehead fish), and managed species (e.g., commercial and recreational, freshwater and ocean). The resulting interactions are similar to those for protected species and require the same considerations.

2. AMENDMENT 3 GOALS AND OBJECTIVES

Goal: Protect, enhance, and restore Atlantic coast migratory stocks and critical habitat of American shad in order to achieve levels of spawning stock biomass that are sustainable, can produce a harvestable surplus, and are robust enough to withstand unforeseen threats.

Objectives:

- Maximize the number of juvenile recruits emigrating from freshwater stock complexes.
- Restore and maintain spawning stock biomass and age structure to achieve maximum juvenile recruitment.
- Manage for an optimum yield harvest level that will not compromise Objectives 1 and 2.
- Maximize cost effectiveness to the local, state, and federal governments, and the ASMFC associated with achieving Objectives 1 through 3.

Strategies to Achieve Objectives:

- Quantify and effectively manage sources of bycatch mortality where possible.
- Quantify and effectively manage sources of predation where possible and appropriate.
- Restore and maintain access to historical spawning and nursery habitat (i.e., dam removal and fishway installation).
- Maintain total mortality (Z) of American shad stocks at or below stock assessment benchmarks (Table 1).
- Ensure that adequate monitoring techniques are implemented to measure migratory success (i.e., upstream and downstream fish passage at barriers).
- Ensure that stock monitoring data are collected and that they are adequate to characterize stock status and stock response to management actions (i.e., develop a sampling program that provides an annual measurable output for spawning stock and juvenile production status)

- Achieve river specific restoration targets for American shad populations as specified in the recent shad assessment (Table 1) or in stock specific restoration plans.
- Ensure that the production of hatchery fish is used effectively during restoration efforts.
- Maximize cost effectiveness of data collection to minimize costs to states and jurisdictions through coordinated monitoring, flexibility in monitoring methods, and early vetting of monitoring and management plans.
- Identify interactions between other Commission species management plans (positive or negative) and the objectives stated above.

The Commission (2007) developed benchmark mortality rates and restoration targets (abundance) for some individual American shad stocks and for aggregate American shad stocks in selected regions (Table 1). Benchmark mortality rates are not targets, but are rates that should not be exceeded. Restoration targets for abundance indices are targets that should be reached before directed fishing can be initiated.

Table 1. Benchmark mortality rates and restoration targets developed by ASMFC (2007)

Region / River	**Mortality**		**Restoration Targets** [c]
	Z (instantaneous)	**A (%)**[a]	
New England	$Z_{30} = 0.98$	$A_{30} = 0.62$	
Hudson River, NY	$Z_{30} = 0.73$	$A_{30} = 0.51$	
York River, VA	$Z_{30} = 0.85$, Native American fishery $F_{30} = 0.27$	$A_{30} = 0.57$	Gill net monitoring index catch rate [b] = 17.44
Albemarle Sound, NC	$Z_{30} = 1.01$	$A_{30} = 0.63$	
Potomac River			Pound net landings = 31.1 lbs/net-day
James River, VA			Gill net monitoring index catch rate [b] = 6.4
Rappahannock River, VA			Gill net monitoring index catch rate [b] = 1.45
St. John's River, FL			Recreational angling CPUE > 1.0 fish/hour

[a] Total mortality defined as the percent of fish present at the start of the year that die from all causes.
[b] Calculated as area under the curve
[c] States and river basin cooperatives may have stock specific recovery targets that are used, but not included in this amendment.

2.1 MANAGEMENT UNIT

The management units for American shad under this Fishery Management Plan Amendment include all migratory American shad stocks of the Atlantic coast of the United States.

Recommendations on management for migratory American shad in the Exclusive Economic Zone (3-200 nautical miles offshore) can be found in Section 4.10

2.2 DEFINITION OF SUSTAINABLE FISHERY

This document proposes the adoption of a sustainable fisheries definition which is consistent with current coastwide management of river herring (alewife and blueback herring) as described in Amendment 2 to the Shad and River Herring FMP. Amendment 2 defines a sustainable fishery as "those that demonstrate their stock could support a commercial and/or recreational fishery that will not diminish the future stock reproduction and recruitment*."*

2.3 DEFINITION OF OVERFISHING

The classic definition of overfishing considers overfishing to occur whenever a fish stock is subjected to a level of fishing mortality that jeopardizes the capacity of that stock to produce a maximum yield on a continuing basis. Benchmark fishing mortality is the estimated mortality rate at and above which overfishing occurs.

Amendment 1 to the American shad & River Herring FMP (ASMFC 1999) refined the definition of overfishing for American shad stocks to be an instantaneous rate of fishing mortality rate (F) from directed fisheries that was at or above a benchmark of F_{30}. This benchmark was defined as the *level of directed fishing mortality* that theoretically resulted in a female spawning stock biomass that was 30 % of that in an unfished, "virgin" stock that only experienced natural mortality. Female spawning stock biomass is the total weight of females in all age classes in the spawning population. This definition ignored man-induced mortality from other sources.
The basis for this definition was the assumption that American shad stocks were only affected by F from directed fishing and by instantaneous natural mortality (M) and the total instantaneous mortality (Z), was equal to M plus F. Thus, an unfished stock that only experienced natural mortality would contain the maximum potential female spawning stock biomass. Any fishing on the stock would reduce this biomass to less than maximum. At some point, as the rate of fishing increased, the female spawning stock biomass would be reduced until it contained 30% of the maximum female biomass. The fishing rate that resulted in 30% of the maximum female spawning stock biomass was defined as F_{30}. This overfishing definition was not to be utilized as a target for fisheries to achieve, nor was it believed to be suitable for rebuilding depleted stocks, but was developed to serve as a benchmark that should not be exceeded in any given year. Amendment 1 assumed that fishing rates at or below F_{30} would be sustainable because such rates were documented to be sustainable in other stocks with similar population parameters to American shad. The amendment focused on the female component of the spawning stock because female abundance was considered to be the population factor that most limited reproduction and subsequent recruitment.

2.3.1 Mortality Benchmark

The most recent stock assessment (ASMFC 2007) concluded that the Amendment 1 definition of overfishing that focused only on directed fishing mortality (F) was no longer valid for American shad stocks because shad are affected by several sources of human-induced mortality. These include: directed fishing (F), fish passage mortality at dams, mortality from pollution, and bycatch and discard mortality in indirect fisheries activity. All of these sources of mortality can be substantial, can be controlled, and should therefore be considered when setting a benchmark mortality rate.

As an interim solution, the recent ASMFC stock assessment (ASMFC 2007) combined all human-induced rates into a single overall human induced rate. Since the components of human-induced mortality (e.g., directed fishing, dam-induced, pollution, and bycatch) are difficult or impossible to quantify, ASMFC (2007) did not attempt to develop a benchmark for the combined mortality that was analogous to F_{30} for directed fishing alone. Instead, ASMFC (2007) developed benchmark values for total instantaneous mortality or Z_{30} (Table 1). These benchmark values were defined as the *level of total instantaneous mortality (Z)* that resulted in a female spawning stock biomass that was 30% of the total female spawning stock biomass in a stock that experienced only natural mortality (Z=M). Z can be measured in fish stocks by a variety of methods.

The following explains how the Z_{30} benchmark was developed. American shad stocks are affected by a combined human-induced instantaneous mortality and by natural mortality. A stock that experienced only natural mortality, with no human-induced mortality, would contain the maximum potential female spawning stock biomass. As human-induced mortality from any source increases, female spawning stock biomass decreases. At some point of increased human-induced mortality and thus total mortality, the stock would contain a female spawning stock biomass that was 30% of the maximum. The rate of total mortality that resulted in a female spawning stock biomass that was 30% of the maximum is the Z_{30}. For example, in New England stocks of American shad, a Z that equals 0.98 reduces female spawning stock biomass to 30% of that present when only natural mortality acts on the stocks, assuming a natural mortality (M) of 0.38.

This amendment adopts Z_{30} as a mortality benchmark to help guide management and gauge restoration progress. It does not propose an overfishing definition. Under this mortality benchmark, a stock is considered to experience excessive mortality when the total instantaneous mortality rate (Z) equals or exceeds that at $Z_{30.}$ Excessive mortality is an indication that actions should be considered that reduce total mortality. The priority would be to reduce mortality from inadequate passage at dams and /or bycatch since these losses are avoidable and do not benefit society. Reducing mortality from directed fishing without reducing mortality from other man-induced causes is not encouraged because it transfers fish production from a beneficial use to nonbeneficial uses. Excessive mortality (i.e, at or above Z_{30}) on a stock with no directed fishery would be a warning that bycatch, dam passage mortality, or some other form of human-induced mortality should be addressed. Directed fishing could continue without reduction in stocks where total mortality was below Z_{30}.

American shad stocks of the Atlantic coast exhibit a range of life history attributes because shad stocks spawn in rivers with different morphologic characteristics over a broad latitudinal range. Differences in parameters such as age at maturity, weight at age, and frequency of repeat spawning affect how a stock responds to increased mortality and thus different stocks often have different values of Z_{30}. ASMFC (2007) provided Z_{30} estimates for stocks or aggregate stocks in regions with adequate data. However, many stocks remained without such benchmarks because needed data were lacking or non-existent.

American shad populations may contain multiple year classes in their spawning stocks. Annual total mortality can affect all of these year classes, with older year classes experiencing higher cumulative mortality. Consequently, the spawning stock biomass lost from human-induced factors may be greater than one would intuitively expect from an annual measured rate of mortality.

2.3.2 Future Refinement

Under this amendment, as resources become available, the TC and the SASC will define a more robust benchmark mortality rate definition for American shad stocks. The new definition should embrace the approach proposed by ASMFC (2007) and it should include, or address all sources of human-induced mortality (e.g., directed fishing, bycatch and discards, and losses from dams and other water development projects). These can be combined in a single human-induced rate or partitioned into separate human-induced rates as needed. They should NOT be added to natural mortality when calculating new benchmarks. Further, the TC and SASC should also develop target or rebuilding rates to allow population numbers to grow. These rebuilding targets would require developing a new lower mortality threshold that would increase spawning stock biomass.

3. MONITORING PROGRAM SPECIFICATIONS

The collection of adequate fish stock and fishery monitoring data is necessary to achieve the goal and objectives of the American Shad management program. A well designed monitoring program provides measurable outputs that can be used to judge the effectiveness of current management efforts in achieving the desired outcome. This amendment modifies and adds to some of the monitoring requirements specified in Addendum 1 to Amendment 1 of the Shad and River Herring Fishery Management Plan. All other monitoring requirements remain compliance criteria. Monitoring requirements of Amendment 3 and program specific modifications are summarized in the following sections.

States and jurisdiction specific requirements are listed in Tables 2 and 3 of this amendment. One modification of note involves states and jurisdictions which share a river or an estuary. Under this amendment, such states and jurisdictions are considered to be equally responsible for monitoring of the system. States and jurisdictions that share a resource, but do not conduct a commercial fishery, will be exempt from monitoring the commercial fishery. States and jurisdictions which share a river or estuary may elect which state or jurisdiction will conduct specific monitoring programs for the shared water body. In shared water bodies where there is some sort of management cooperative, such as the Delaware River Basin Fish and Wildlife Management Cooperative, the cooperative may be designated as the responsible party and should report results. States and jurisdictions will supply the Commission with copies of cooperative or interstate agreements when such agreements relieve from or assign states and jurisdictions the responsibility for monitoring activities. A single report summarizing monitoring results from a shared water body is preferred, but not required. Additionally, a second modification in

Amendment 3 is the removal of the recreational monitoring requirement from the Nanticoke River, DE (Table 3) due to the closure of this fishery.

In many states, both the freshwater and the marine sections of state resource agencies collect data on American shad. Often, only those collected by the marine section are provided to ASMFC. This amendment recommends that states and jurisdictions increase coordination of data collection on American shad between freshwater and marine sections of the agency, and that all data be provided to ASMFC through the annual compliance report.

Results of state monitoring will be reported annually to the Commission as per Section 9.3. One important change in Amendment 3 is that, in addition to a written report, all states and jurisdictions will be required to add annual monitoring data to Excel spreadsheets used in the recent ASMFC (2007) stock assessment. The ASMFC, in cooperation with the Technical Committee, will provide states with a template for the spreadsheets. Annual data updates on spreadsheets will be considered part of the compliance reports and will be due at the same time as the written annual compliance reports, unless otherwise determined by the Management Board. This change facilitates an annual summary of stock condition and the development of future benchmark assessments. Excel spreadsheet submittals have proven effective and helpful in other ASMFC species management plans.

Under this amendment, states and jurisdictions will review existing monitoring programs and submit Implementation Plans for existing and planned monitoring as per Section 6.1. States and jurisdictions may propose to the Management Board alternative monitoring if they develop a stock specific definition of a sustainable fishery and the proposed alternative monitoring measures progress toward the definition (See Section 6). Definitions of sustainable fisheries and restoration goals can be index-based or model-based (See Table 1 for examples). This amendment recognizes that sustainable fisheries may operate on stocks that are at lower than maximum abundance. However, such fisheries must not jeopardize long term stock persistence or the achievement of any stock recovery goals. States and jurisdictions may also submit proposals to change their required monitoring programs as per Section 7.1 of this document.). If states or jurisdictions cannot meet the monitoring requirements, they can work with the Commission to develop an acceptable alternative in their Fishing/Recovery plan as stated in Section 6.1. The Shad and River Herring Management Board and Technical Committee will review proposed monitoring programs submitted under Section 6 or 7 to determine if they meet the requirements of Section 3. It is the responsibility of the Technical Committee to prepare recommendations and technical advice for the Management Board. The Management Board will determine final approval for changes to required monitoring programs. Changes to sustainable fisheries definitions, stock recovery targets, and monitoring programs may be submitted for review and approval by the Management Board at any time (See Sections 6 and 7).

The Commission has attempted to minimize monitoring costs in this amendment through coordinated monitoring where possible, flexibility in monitoring methods, and early vetting of monitoring and funding issues through the submission of Implementation Plans (Section 6). Submission of Implementation Plans to the Management Board will facilitate discussion of state problems and allow the Commission to work with the states to explore opportunities to secure funding or develop alternatives.

The Board tasks the Technical Committee to review and prioritize the data collection elements in Tables 2 and 3, as possible. The review should include a brief explanation of the importance of each element to the stock assessment.

3.1 FISHERY-INDEPENDENT MONITORING

States and jurisdictions that are currently required to conduct fisheries independent monitoring will still be required to continue such sampling, unless otherwise noted. This amendment proposes additional annual monitoring for those systems listed in Table 2.

3.1.1 Juvenile Abundance Indices

Annual juvenile recruitment (i.e., appearance of young-of- year or Age-0 fish in the ecosystem) of American shad is measured to assess annual production, to predict future year-class strength, to provide a warning of recruitment failure or major habitat change, and to measure contribution of hatchery-released larvae. Juvenile recruitment is measured by sampling age zero juvenile fish abundance in or downriver of nursery habitat.

All annual juvenile abundance indices, or JAIs, shall be reported as a geometric mean as described by ASMFC (1992) and Crecco (1992), or area under the curve (AUC) as described by ASMFC (2007). Confidence intervals should be provided for geometric means. ASMFC will provide jurisdictions and states with a method to calculate confidence intervals on geometric means. Use of the geometric mean reduces the probability of a single value unduly influencing management action and is most appropriate for sampling that occurs within the nursery area. AUC is most useful when juvenile sampling occurs downriver of nursery areas and fish are sampled during emigration. Abundance of juveniles that emigrate is a function of average daily emigration and days of emigration. A simple geometric mean of catch rates would reflect only the average daily emigration, but not the number of days of such emigration. The AUC approach accounts for both the number of days that juveniles emigrate as well as the daily catch or catch rate and thus is a better measure of annual juvenile out migration when sampling is conducted downstream of the nursery area.

The sampling protocol (stations, sampling intensity and gear type) should be consistent over time for the period the index is to be calculated. Juvenile abundance indices can be biased if fish older than age zero are included. Since age-1 juvenile fish occasionally intermingle with age-zero fish in nursery areas, it is important that sampling programs include a protocol to correctly identify these fish so that they can be eliminated from the catch data prior to summary. Approaches to identifying older fish include length measurements and age estimates from scales or otoliths.

For new sampling programs, states and jurisdictions will document the details of the sampling design and proposed data summary approach. The Technical Committee shall review any proposed programs and either recommend to the Management Board that it accept or reject the new sampling program. If the recommendation is to reject the new sampling program, the Technical Committee will provide a written explanation to the Management Board.

Validation is not required for any particular JAI survey, but it is encouraged. A long time series of data and consistent inter-annual at-sea mortality rates are needed for successful validation, which makes validation of American shad juvenile indices difficult. Validation will not be a criterion for accepting or rejecting any given JAI survey.

3.1.1.1 Juvenile Abundance Index Surveys

States and jurisdictions are required to conduct a JAI survey, as specified in Table 2. States that do not currently conduct juvenile abundance monitoring will develop a program to implement such monitoring. The Management Board may require juvenile abundance surveys for newly reestablished American shad runs.

3.1.1.2 Definition of Juvenile Recruitment Failure

The criteria for judging juvenile recruitment failure should provide for an early warning of emerging problems in production of young from a given stock. The previous definition of juvenile recruitment failure in Amendment 1 (three consecutive JAI values that are lower than 90% of all other values in the river specific data set) is considered inadequate in that it would only flag extreme problems. This amendment institutes a new definition of juvenile recruitment failure, where failure is defined as occurring when three consecutive JAI values are lower than 75% of all other values in the stock specific data series. This definition is identical to that in Section 3.1.1 of Amendment 6 to the Interstate Fishery Management Plan for Atlantic Striped Bass.

3.1.1.3 Evaluation of Juvenile Abundance Indices

The Technical Committee will annually examine trends in all required juvenile abundance indices. If any JAI meets the juvenile recruitment failure trigger, then appropriate action shall be recommended to the Management Board.

3.1.2 Adult Stock Characteristics and Abundance

Annual data on characteristics and abundance of adult spawning stocks are needed to determine efficacy of management approaches. Coupled with juvenile abundance indices and mortality estimates, they clarify population dynamics and progress toward management goals.

States and jurisdictions are required to conduct adult spawning or population monitoring, as specified in Table 2, and may employ a variety of survey techniques to monitor their American shad stock. The objective is to obtain an annual measure of either absolute (population size estimate) or relative abundance. Measures may include mark-recapture studies, enumeration at fish passage facilities, catch-per-unit-effort (CPUE) by appropriate sample gear, or other indices of abundance. As part of spawning stock surveys, states will take representative samples of adults to determine size, sex and age composition and repeat spawning (for states north of South

Carolina) of fish in each stock they are monitoring. When possible, states and jurisdictions north of South Carolina will calculate mortality and survival estimates for each stock.

The recent stock assessment identified several populations where additional fishery independent stock monitoring was warranted. On fishways where passage is measured, passage efficiency will be reported when possible. In cases where passage efficiency is not known, passage numbers cannot be used as indices of stock abundance, because the percent of the population that is passed is unknown and is likely to vary annually. In these cases, it is recommended that states either determine passage efficiencies or develop stock abundance indices downriver of the first barrier.

3.1.2.1. Evaluation of Adult stock characteristics and abundance

The Technical Committee will annually review adult stock characteristics and abundance relative to benchmarks and targets listed in Table 1 or the objectives in state specific fishing/recovery plans and recommend appropriate management actions to the Board if and where appropriate.

3.1.3 Stocking and Hatchery Evaluation

Many Commission jurisdictions augment existing populations or re-introduce populations using fish culture or fish transfer programs. Techniques most frequently used include culture and stocking of larvae or juveniles, and stocking of pre-spawned adults that have been netted or trapped from nearby or distant waters. A detailed summary of current approaches is available through the Commission.

States and jurisdictions with active hatchery programs for American shad will be required to mark all stocked larval and juvenile fish for identification of hatchery products. River and year specific marks are recommended for determining age and year class when fish return as adults. If river and year specific marks are not logistically possible for all stocking programs coastwide, then priorities should be developed through the interstate process. States and jurisdictions with active hatchery programs for American will be required to annually report the number and life stage of stocked fish and estimates of hatchery contribution (percent wild versus hatchery) in the juvenile or adult population. These states or jurisdictions must submit proposals for evaluation under Section 6.0 and annual results as per Section 9.3. Any state wishing to initiate stocking programs for American shad must present a program description including marking and evaluation approach for Commission review. States should work in cooperation with appropriate federal or regional programs to ensure that marking schemes are coordinated with other states to prevent conflicts in operations.

3.2 FISHERY-DEPENDENT MONITORING

States that are currently required to conduct fishery-dependent monitoring will still be required to continue such programs, unless otherwise noted. This amendment requires additional annual fisheries dependent monitoring for those systems listed in Table 3. Monitoring requirements may be fulfilled by data collected by the Atlantic Coastal Cooperative Statistics Program (ACCSP) where appropriate. States and jurisdictions may petition the Management Board for *de minimis* status, which exempts them from fishery dependent monitoring requirements (See section 7.1.3).

3.2.1 Commercial Fishery-Dependent Surveys

States and jurisdictions are required to annually monitor the American shad commercial fisheries operating within their state or jurisdiction by methods developed by the state or jurisdiction and subject to Technical Committee review and Management Board approval. The survey approach should be appropriate to the fisheries monitored and should provide estimates of total catch (numbers or weight and water body), total landings (if different than total catch, numbers or weight, and water body), total effort in the fisheries, and length, weight, age, sex, and repeat spawning composition (for states north of South Carolina) from a subsample of the catch. These data will be reported annually. This requirement may be fulfilled by the commercial component of the ACCSP.

3.2.2 Recreational Fishery Surveys Required

States and jurisdictions are required to conduct annual monitoring and reporting of catch, landings, and effort in the recreational fishery by methods developed by the state or jurisdiction and subject to Technical Committee review and Management Board approval. Techniques used to gather these data may include, but are not limited to, creel surveys, angler logs, surveys of license/permit holders, MRFSS or Marine Recreational Information Program (MRIP) (where appropriate), and reporting requirements for obtaining/maintaining a license or permit. Note that the MRFSS does not survey fisheries above head of tide in coastal rivers where most recreational shad fisheries occur. The future MRIP program may address these deficiencies.

3.3 BYCATCH MONITORING AND REDUCTION

Bycatch and discard of American shad in commercial fisheries may be an important factor inhibiting the recovery of this species and this issue is given special emphasis in Amendment 3. As part of the Implementation Plan, states and jurisdictions are required to submit a plan to monitor bycatch and discards of American shad in fisheries that operate in state waters of rivers and estuaries.

Ocean bycatch and discard are coastwide problems that affect shad stocks in all coastal states. Therefore, this amendment recommends that ocean bycatch and discards be monitored cooperatively by coastal states through the ASMFC, in cooperation with Fishery Management Councils and NOAA Fisheries. The planned bycatch module of the Atlantic Coastal Cooperative Statistics Program may be the best approach to collecting this data.

It is known that many Atlantic coastal American shad stocks migrate to the Gulf of Maine and the Bay of Fundy in summer to feed. In Canadian waters, they are taken in directed fisheries and as bycatch. Size of losses to these sources is not known. The Commission should work with the Department of Fisheries and Oceans Canada to obtain information on American shad losses in the Bay of Fundy and on potential actions that could reduce bycatch.

Responsibility for reporting ocean bycatch should be decided by the Management Board and be based on future arrangements developed to cooperatively monitor ocean fisheries. Responsibility for reporting results of bycatch in river and estuarine fisheries remains with the states and jurisdictions. These results will be reported to the Commission annually as per Section 9.3. This amendment recommends that the Shad and River Herring Management Board coordinate American shad bycatch monitoring with other Commission species management boards to improve collection efficiency and coverage of bycatch data.

In documented cases of high American shad bycatch, the involved jurisdiction(s) shall recommend approaches to reduce such bycatch to the Management Board for review. Options may include gear restrictions and time/area closures.

Table 2 - SUMMARY OF MANDATORY FISHERY-INDEPENDENT MONITORING PROGRAMS FOR AMERICAN SHAD.

STATE / JURISDICTION	SYSTEM	SAMPLING PROGRAM
Maine	Androscoggin & Saco Rivers	• Annual spawning stock survey to include passage counts, CPUE, or some other abundance index and representative subsamples that describe size, age, and sex composition of spawning stock ~~•~~ Calculation of mortality and/or survival estimates where possible • Hatchery Evaluation
	Merrymeeting Bay & tributary rivers	• JAI: Juvenile abundance survey (GM)
New Hampshire	Exeter River	• Annual spawning stock survey to include passage counts, CPUE, or some other abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM)
	Merrimack River	• Annual spawning stock survey to include passage counts, CPUE, or some other abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • JAI: Juvenile abundance survey (GM) • Calculation of mortality and/or survival estimates where possible (Cooperative effort between New Hampshire, Massachusetts, and the USFWS)
Massachusetts	Merrimack River	• Annual spawning stock survey to include passage counts, CPUE, or some other abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • JAI: Juvenile abundance survey (GM) • Calculation of mortality and/or survival estimates where possible (Cooperative effort between New Hampshire and Massachusetts, and the USFWS)
	Connecticut River	• Annual spawning stock survey to include passage counts, CPUE, or some other abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • JAI: Juvenile abundance survey • Calculation of mortality and/or survival estimates where possible (Cooperative effort between Massachusetts and Connecticut)
Rhode Island	Pawcatuck River	• Annual spawning stock survey to include passage counts, CPUE, or some other abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM)
Connecticut	Connecticut River	• Annual spawning stock survey to include passage counts, CPUE, or some other abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) (Cooperative effort between Massachusetts and Connecticut)

STATE / JURISDICTION	**SYSTEM**	**SAMPLING PROGRAM**
New York	Hudson River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM)
	Delaware River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) (Cooperative effort among New Jersey, New York, Pennsylvania, and Delaware)
New Jersey	Delaware River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) (Cooperative effort among New Jersey, New York, Pennsylvania, and Delaware)
Pennsylvania	Delaware River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) (Cooperative effort among New Jersey, New York, Pennsylvania, and Delaware)
	Susquehanna River	• Annual spawning stock survey to include passage counts, CPUE, or some other abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) • Hatchery Evaluation (Cooperative effort between Pennsylvania and Maryland)
	Lehigh River	• Annual spawning stock survey to include passage counts, CPUE, or some other abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • Hatchery Evaluation
Delaware	Delaware River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) (Cooperative effort among New Jersey, New York, Pennsylvania, and Delaware)
	Nanticoke River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) • Hatchery Evaluation (Cooperative effort between Delaware and Maryland)

STATE / JURISDICTION	SYSTEM	SAMPLING PROGRAM
Maryland	Upper Chesapeake Bay / Susquehanna River	• Annual spawning stock survey to include passage counts, CPUE, or some other abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) • Hatchery Evaluation (Susquehanna River monitoring is a cooperative effort between Pennsylvania and Maryland)
	Nanticoke River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) (Cooperative effort between Delaware and Maryland)
	Potomac River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) • Hatchery Evaluation (Cooperative effort among Maryland, District of Columbia, Potomac River Fisheries Commission, and Virginia)
District of Columbia	Potomac River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) • Hatchery Evaluation (Cooperative effort among Maryland, District of Columbia, Potomac River Fisheries Commission, and Virginia)
Potomac River Fisheries Commission	Potomac River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) • Hatchery Evaluation (Cooperative effort among Maryland, District of Columbia, Potomac River Fisheries Commission, and Virginia)
Virginia	Potomac River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) • Hatchery Evaluation (Cooperative effort among Maryland, District of Columbia, Potomac River Fisheries Commission, and Virginia)
	James, York, and Rappahannock Rivers	• Annual spawning stock survey to include passage counts, CPUE, or some other abundance index and representative subsamples that describe size, age, and sex composition of the spawning stock • Calculation of mortality and/or survival estimates where possible • JAI: Juvenile abundance survey (GM) • Hatchery Evaluation
North Carolina	Albemarle Sound and its tributaries, Tar-Pamlico, Neuse, and Cape Fear Rivers	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of the spawning stock • Calculation of mortality and/or survival estimates where possible • Hatchery Evaluation • Juvenile Abundance Index (Albemarle Sound only)

STATE / JURISDICTION	**SYSTEM**	**SAMPLING PROGRAM**
South Carolina	Santee-Cooper system, Edisto River, Winyah Bay and tributaries (Waccamaw and Pee Dee Rivers)*	• Annual spawning stock survey to include passage counts, a relative abundance index, and/or population estimates and representative subsamples that describe size, age, and sex composition of the spawning stock * State may elect to sample these systems on a rotational basis (i.e., one system evaluated per year) • JAI: Juvenile abundance survey (GM)
	Savannah River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of the spawning stock • JAI: Juvenile abundance survey (GM) (Cooperative effort between South Carolina and Georgia)
Georgia	Altamaha and Ogeechee Rivers	• Annual spawning stock survey to include an abundance index or population estimates and representative subsamples that describe size, age, and sex composition of the spawning stock • JAI: Juvenile abundance survey (GM)
	Savannah River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of the spawning stock • JAI: Juvenile abundance survey (GM) (Cooperative effort between South Carolina and Georgia)
Florida	St. Johns River	• Annual spawning stock survey to include an abundance index and representative subsamples that describe size, age, and sex composition of the spawning stock • JAI: Juvenile abundance survey (GM)

Table 3 - SUMMARY OF MANDATORY FISHERY-DEPENDENT MONITORING PROGRAMS FOR AMERICAN SHAD

STATE / JURISDICTION	SYSTEM	SAMPLING PROGRAM (Bolded sections are proposed under Amendment 3)
ASMFC	Atlantic Ocean (State and Federal waters) – cooperative effort with ALL coastal states and the NOAA Fisheries.	• Coordinate cooperative inter-state effort of ALL coastal states for mandatory reporting or at sea monitoring of bycatch (numbers or weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch.
All states and jurisdictions	Rivers and estuaries	Mandatory reporting of bycatch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch.
Maine	In-river	• Monitor recreational landings, catch, and effort
New Hampshire	In-river	• Monitor recreational landings, catch, and effort.
Massachusetts	Merrimack River	• Monitor recreational landings, catch, and effort.
	Connecticut River	• Monitor recreational landings, catch, and effort. (Cooperative effort between Massachusetts and Connecticut)
Connecticut	Connecticut River	• Mandatory reporting of landings (numbers and weight), catch (numbers and weight), and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. • Monitor recreational landings, catch, and effort. (Cooperative effort between Massachusetts and Connecticut)
Rhode Island	Pawcatuck River	• Monitor recreational landings, catch and effort.
New York	Hudson River	• Mandatory reporting of landings (numbers and weight), catch (numbers and weight), and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. • Monitor recreational landings, catch, and effort.
	Delaware River	• Monitor recreational landings, catch, and effort. (Cooperative effort among New Jersey, New York, Pennsylvania, and Delaware)
New Jersey	Delaware River and Bay	• Mandatory reporting of landings (numbers and weight), catch (numbers and weight), and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. • Monitor recreational landings, catch, and effort. (Cooperative effort among New Jersey, New York, Pennsylvania, and Delaware)
Delaware	Delaware River and Bay	• Mandatory reporting of landings (numbers and weight), catch (numbers and weight), and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. • Monitor recreational landings, catch, and effort. (Cooperative effort among New Jersey, New York, Pennsylvania, and Delaware)
	Nanticoke River	• None required. Fishery closed.
Pennsylvania	Delaware River	• Monitor recreational landings, catch, and effort. (Cooperative effort among New Jersey, New York, Pennsylvania, and Delaware)
Maryland	Susquehanna River	• Monitor recreational landings, catch, and effort.
	Potomac River	• Monitor recreational landings, catch, and effort. (Cooperative effort among Maryland, District of Columbia, the Potomac River Fisheries Commission, and Virginia)
District of Columbia	Potomac River	• Monitor recreational landings, catch, and effort. (Cooperative effort among Maryland, District of Columbia, the Potomac River Fisheries Commission, and Virginia)
Potomac River Fisheries Commission	Potomac River	• Mandatory reporting of landings (numbers and weight), catch (numbers and weight), and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. • Monitor recreational landings, catch, and effort.

STATE / JURISDICTION	**SYSTEM**	**SAMPLING PROGRAM (Bolded sections are proposed under Amendment 3)**
		(Cooperative effort among Maryland, District of Columbia, the Potomac River Fisheries Commission, and Virginia)
Virginia	York, Rapahhanock, and James Rivers	• Monitor recreational landings, catch, and effort where appropriate
	Potomac River	• Monitor recreational landing, catch, and effort (Cooperative effort among Maryland, District of Columbia, the Potomac River Fisheries Commission, and Virginia)
North Carolina	Albemarle Sound and its tributaries, Tar-Pamlico, Neuse, and Cape Fear Rivers	• Mandatory reporting of landings (numbers and weight), catch (numbers and weight), and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. • Monitor recreational landings, catch, and effort where appropriate
South Carolina	Edisto River, Santee River, Winyah Bay and its tributaries (Waccamaw and Pee Dee Rivers)	• Mandatory reporting of landings (numbers and weight), catch (numbers and weight), and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. • Monitor recreational landings, catch, and effort where appropriate. • * South Carolina may elect to sample these systems on a rotational basis (i.e., one system evaluated per year)
	Savannah River	• Mandatory reporting of landings (numbers and weight), catch (numbers and weight), and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. • Monitor recreational landings, catch, and effort (Cooperative effort between South Carolina and Georgia
Georgia	Altamaha and Ogeechee Rivers	• Mandatory reporting of landings (numbers and weight), catch (numbers and weight), and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. • Monitor recreational landing, catch, and effort where appropriate.
	Savannah River	• Mandatory reporting of landings (numbers and weight), catch (numbers and weight) and effort from commercial fisheries; subsamples shall indicate size, age, and sex composition of catch. • Monitor recreational landings, catch, and effort (Cooperative effort between South Carolina and Georgia)
Florida	St. Johns River	• Monitor recreational landings, catch and effort.

3.4 SUMMARY OF MONITORING PROGRAMS

3.4.1 Biological Information

States and jurisdictions are mandated to implement the fishery-independent and dependent monitoring programs identified for American shad (Tables 2, 3, 4). States and jurisdictions may propose to the Board an alternative monitoring program if designed to measure progress toward restoration objectives or response to a defined sustainable fishery (Section 6). Whenever practical, state harvest and effort reporting requirements will coincide with current and future mandates of the ACCSP. Data needs not covered by the ACCSP will still be covered by annual reports submitted in conjunction with Amendment 3.

3.4.2 Social and Economic Information

Consumptive use (e.g. fishing activities before closures) and non-consumptive use (e.g. ecotourism activities) surveys focusing on social and economic data should be conducted periodically in a manner consistent with the intent of the Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA) and the ACCSP Implementation Plan.

Table 4. Summary of monitoring requirements for American shad

Fishery-Independent	Juvenile Abundance Index	
	Annual spawning stock survey and representative sampling for biological data	
	Calculation of mortality/survival estimates (when available)	
	Hatchery evaluation (hatchery vs. wild)--when in place	
	Fishway counts; report inefficiencies (when available)	
Fishery-Dependent	Commercial	Mandatory reporting of landings (numbers and weight), catch (numbers, weight) and effort. • Sub-samples shall characterize size, age, spawning marks, sex, and species composition of catch (when available)
	Recreational	Monitor recreational by water body of landings, catch and effort: • Creel surveys, or • Survey license/permit holders, or • MRFSS/MRIP, or • Reporting requirements for obtaining/maintaining license or permit, or • Angler logbooks, or • Other
	Bycatch	Require monitoring and reporting of harvest, bycatch and discards of American shad in all fisheries • Bycatch in rivers and estuaries to be monitored and reported by states • Bycatch in at sea and near shore ocean fisheries to be monitored and reported by cooperative interstate and Federal arrangements determined by the Board
		Increase observer coverage and employ portside monitoring
		Coordinate with other FMPs
Annual Summary Report		Annual data summaries to be added to Excel spreadsheets used by ASMFC (2007)

4. REGULATORY PROGRAM

States and jurisdictions must implement the regulatory program requirements as per Section 7. The Management Board has the ultimate authority to determine the approval of a regulatory program. States and jurisdictions must also submit proposals to change their required regulatory programs as per Section 7.1.2. The Management Board will determine final approval for changes to required regulatory programs.

4.1 COMMERCIAL FISHERIES MANAGEMENT MEASURES

The Shad and River Herring Management Board approved the following commercial fishery management measures:

Close Fisheries (Commercial) with Exceptions for Systems with a Sustainable Fishery

Systems with a sustainable fishery are defined as those that demonstrate their American shad stock could support a commercial fishery that will not diminish potential future stock reproduction and recruitment. In order to maintain a commercial American shad fishery, states and jurisdictions are required to submit a request for a fishery as part of the Fishing/Recovery Section of the Implementation Plan (See Section 6.1). The request must include a definition of sustainability, benchmark goals (if different from or in addition to those identified in 2007 Stock Assessment) and a proposed timeframe to achieve stated objectives. The request should also describe how the fishery will be conducted and annually monitored in order to show that the sustainability target(s) are being achieved. Data to substantiate the claim of sustainability include, but are not limited to, repeat spawning ratio, spawning stock biomass, juvenile abundance levels, fish passage counts, hatchery contribution to stocks and bycatch rates. Sustainability targets can be applied state-wide or can be river and species specific. Targets for river systems managed by more than one state/jurisdiction should be cooperatively developed. Targets should include a quantifiable means of estimating improvements in populations. As new information becomes available, states should review and update targets in a timely manner. The request for a fishery should be submitted to the Shad and River Herring Technical Committee no later than August 1, 2011.

States or jurisdictions without an approved plan in place will close their commercial fishery by January 1, 2013. Proposals to reopen closed fisheries may be submitted as part of the annual Compliance Report, and will be subject to review by the Plan Review Team, Technical Committee and Management Board.

4.2 RECREATIONAL FISHERIES MANAGEMENT MEASURES

The Shad and River Herring Management Board approved the following commercial fishery management measures:

- **Prohibit (Recreational) Harvest and Possession, with Exceptions for Systems with a Sustainable Fishery**
- **Allow States or Jurisdictions to Permit Catch and Release Fishing on any System**

Systems with a sustainable fishery are defined as those that demonstrate their American shad stock could support a recreational fishery that will not diminish potential future stock reproduction and recruitment. In order to maintain a recreational American shad fishery that harvests fish, states and jurisdictions are required to submit a request for a fishery as part of the Fishing/Recovery Section of the Implementation Plan (See Section 6.1). The request must include a definition of sustainability, benchmark goals (if different from or in addition to those identified in 2007 Stock Assessment) and a proposed timeframe to achieve stated objectives. The request should also describe how the fishery will be conducted and annually monitored in order to show that the sustainability target(s) are being achieved. Data to substantiate the claim of sustainability include, but are not limited to, repeat spawning ratio, spawning stock biomass, juvenile abundance levels, fish passage counts, hatchery contribution to stocks and bycatch rates. Sustainability targets can be applied state-wide or can be river and species specific. Targets for river systems managed by more than one state/jurisdiction should be cooperatively developed. Targets should include a quantifiable means of estimating improvements in populations. As new information becomes available, states should review and update targets in a timely manner. The request for a fishery should be submitted to the Shad and River Herring Technical Committee no later than 1 August 2011. If a state or jurisdiction does not have sufficient data to prove sustainability, the state or jurisdiction is allowed to maintain a catch-and-release recreational fishery.

States or jurisdictions without an approved plan in place will close their recreational fishery (with the exception of catch and release fisheries) by January 1, 2013. Proposals to reopen closed fisheries may be submitted as part of the annual Compliance Report, and will be subject to review by the Plan Review Team, Technical Committee and Management Board.

5. HABITAT CONSERVATION AND RESTORATION

American shad stocks along the Atlantic coast are greatly diminished compared to historic levels of the 1880's and early 1900's when landings were near 50 million pounds per year. Much of this reduction has been related to spawning and nursery habitat degradation, or blocked access to habitat, resulting from human activity (e.g.; human population increase; sewage and storm water runoff; industrialization; dam construction; increased erosion, sedimentation and nutrient enrichment associated with agricultural practices; and losses of riparian forests and wetland buffers associated with resource extraction and land development).

Protection, restoration and enhancement of American shad habitat, including spawning, nursery, rearing, production, and migration areas, are critical objectives necessary for preventing further declines in American shad abundance, and restoring healthy, self-sustaining, robust, and productive American shad stocks to levels that will support the desired ecological, social, and economic functions and values of a restored Atlantic coast American shad population. For more detailed information on Alosine habitat, please refer to Appendix C.

5.1 American shad Habitat

Freshwater Spawning, Egg Development and Larval Rearing Habitat

American shad spawning, egg development, and larval nursery habitat is geographically located in the freshwater portions of Atlantic coast rivers, and their associated tributaries and estuary (river complex). Each of these freshwater aquatic features is under exclusive jurisdiction of the state, states, or jurisdictions within which they are contained. Collectively, these associated freshwater aquatic features spatially define the primary juvenile production unit of a defined American shad stock.

The quality and quantity of habitat within a river complex has a direct bearing upon the juvenile recruitment capacity of the associated stock and ultimately its potential contribution to the Atlantic coast population.

Estuarine Juvenile Rearing and Migration Corridors

The importance of estuaries to American shad as juvenile rearing habitat is not yet fully understood, however evidence suggests that estuaries are important to many American shad stocks. Estuaries are also often important migratory corridors for both spawning adult and emigrating juvenile American shad. Some potential threats in the estuarine environment include degraded juvenile habitat resulting from human-induced impacts, mortality from fisheries, and impediments to migration.

Coastal Production and Migration Corridors

The Atlantic coast ocean environment provides critical migration corridors and production habitat for sub-adult and adult American shad. Potential threats to coastal American shad habitat include: marine acidification; pharmaceutical disposal, wastewater discharge, pesticide contamination; invasive species; niche displacement; and global climate change.

5.2 Potential Threats to American shad Habitat

Barriers to migration – There has likely been considerable loss of production from historic American shad spawning and rearing habitat due to human activities that block access to habitat and/or impact safe, timely and effective fish migration in rivers along the Atlantic coast of the United States.

Water withdrawals - Large volume water withdrawals (e.g., drinking water, pumped-storage hydroelectric projects, irrigation, and snow-making, cooling), especially at pumped-storage facilities, can drastically alter local instream flow characteristics (e.g., reverse river flow). Withdrawals may also alter other physical characteristics of the river channel, including stream width, depth, current velocity, substrate and temperature. This can cause delayed movement past the facility, or impingement or entrainment at intakes causing mortality or injury.

Toxic and thermal wastewater discharge - Industrial and municipal discharges often contain toxic chemicals, such as heavy metals and various organic chemicals (e.g., insecticides, solvents, herbicides) that are harmful to aquatic life. Many contaminants have been identified as having deleterious effects on fish, particularly reproductive impairment. Chemicals and heavy metals can be assimilated through the food chain, producing sub-lethal effects such as behavioral and reproductive abnormalities, fin erosion, epidermal lesions, blood anemia, altered immune response, and egg mortality. Thermal discharges can block or impede migration, interfere with egg/larval development, and reduce water quality.

Channelization, dredging, and instream construction - Channelization has the potential to cause significant environmental impacts including bank erosion, elevated water velocity, reduced habitat diversity, increased drainage, and poor water quality. Dredging and disposal of spoils along the shoreline can also create spoil banks, which block access to sloughs, pools, adjacent vegetated areas, and backwater swamps. Dredging may also release contaminants resulting in bioaccumulation, direct toxicity to aquatic organisms, or reduced dissolved oxygen levels. Dredge spoil banks are often unsuitable habitat for fishes. Instream construction may harm habitat, disrupt migration, or result in direct or delayed mortality (e.g., underwater blasting).

Land use - The effects of land use and land cover on water quality, stream morphology, and flow regimes are numerous, and may be one of the most important factors determining quantity and quality of aquatic habitats. Studies have shown that land use influences dissolved oxygen, sedimentation and turbidity, water temperature, pH, nutrients, and flow regime.

Atmospheric deposition - Atmospheric deposition occurs when pollutants are transferred from the air to the earth's surface. Such deposition is a significant source of pollutants to many water bodies. Pollutants can get from the air into the water through rain and snow, falling particles, and absorption of the gaseous form of the pollutants into the water. Atmospheric deposition that causes low pH and elevated aluminum (acid rain) can contribute to water chemistry changes that result in direct or indirect mortality of young-of-year fish.

Climate change - As climate changes occur, modification of habitat is expected to occur in many aquatic environments. Such modifications could result in changes in large-scale distribution patterns for fish species, and consequent changes in the thermal niche space available. The linkage between fish production and thermal niche space is confounded when the habitat is made unsuitable by a low dissolved oxygen concentration. Annual events that seem related to the seasonal cycle of water temperature might increase in frequency. Temperature plays a dominant role in keying the actual spawning events. Survival of eggs and larvae is often dependent upon the relative timing of egg deposition and environmental vagaries within the spawning period. Predicted temperature changes could be accompanied by rising sea levels with attendant flooding of spawning habitats in estuaries and wetland nursery areas. Rising sea level requires consideration of many coastal processes, including: tidal ranges, storm surges, intrusion of groundwater and surface water, sedimentary processes, and the response by the plant communities of coastal ecosystems to changes in these processes. Resultant impacts are likely to be highly site-specific and to include changes both in temperature and dissolved oxygen structure and other physiographic features.

Competition and predation by invasive and managed species – Several aquatic and terrestrial species pose a potential threat to various life stages of American shad through direct or indirect competition, or predation. The presence and abundance of these species are often the result of human-induced activity (i.e., accidental or intentional introduction, level of population control or management, and propagation).

Fisheries Activities - Some fishing gear or practice may have unacceptable negative impacts on American shad habitat or migration (e.g., habitat damage, bycatch mortality).

Instream Flow Regulation - In rivers with flow regulation (e.g., storage and peaking hydroelectric power generation dams), and consumptive water withdrawals (e.g., irrigation, domestic water supply, industrial use) habitat quality and quantity, fish passage, and water for American shad may be impacted.

5.3 Habitat Utilization

States are encouraged to utilize existing production capacity of historic, but currently inaccessible freshwater spawning and larval rearing habitat through a process of trap and transport of excess spawning stock, or planting of aquaculture produced fry and fingerlings. This will help to both increase juvenile recruitment for the stock, and will develop a stock component imprinted to upstream habitat that can take advantage of it once access is restored through barrier removal or installation of fish passage.

5.4 Fisheries Practices

The use of any fishing gear or practice that is documented to have unacceptable negative impacts on American shad habitat or migration (e.g., habitat damage, bycatch mortality) should be prohibited within the area of that habitat or corridor, as determined by the appropriate jurisdiction(s).

5.5 Habitat Restoration, Enhancement, Utilization, and Protection Recommendations

Dams and Other Obstructions

General Fish Passage

1) States should work in concert with the United States Fish and Wildlife Service (USFWS) and the National Oceanic and Atmospheric Administration Fisheries Service (NOAA Fisheries) to identify hydropower dams that pose significant impediment to diadromous fish migration, and target them for appropriate recommendations during Federal Energy Regulatory Commission (FERC) relicensing.
2) States should identify and prioritize barriers in need of fish passage based on clear ecological criteria (e.g., amount and quality of habitat upstream of barrier, size, and

status of affected populations). These prioritizations could apply to a single species, but are likely to be more useful when all diadromous species are evaluated together.

3) A focused, coordinated, well supported effort among federal, state, and associated interests should be undertaken to address the issue of fish passage development and efficiency. The effort should attempt to develop new technologies and approaches to improve passage efficiency with the premise that existing technology is insufficient to achieve restoration and management goals for several Atlantic coast river systems.
4) Where obstruction removal is not feasible, install appropriate passage facilities, including fish lifts, fish locks, fishways, navigation locks, or notches (low-head dams and culverts).
5) At sites with passage facilities, evaluate the effectiveness of upstream and downstream passage; when passage is inadequate, facilities should be improved.
6) Facilities for monitoring the effectiveness of the fish passage devices should be incorporated into the design where possible.
7) When designing and constructing fish passage systems, the behavioral response of each species of interest to appropriate site-specific physical factors should be considered.
8) If possible, protection from predation should be provided at the entrance, exit, and throughout the passage.
9) The passage facility should be designed to work under all conditions of head and tail water levels that prevail during periods of migration.
10) Passages are vulnerable to damage by high flows and waterborne debris. Techniques for preventing damage include robust construction, siting facilities where they are least exposed to adverse conditions, and removing the facilities in the winter.
11) Passage facilities should be designed specifically for passing alosines at optimum efficiency.

Upstream Fish Passage

1) American shad must be able to locate and enter the passage facility with little effort and without stress.
2) Where appropriate, improve upstream fish passage effectiveness through operational or structural modifications at impediments to migration.
3) Fish that have ascended the passage facility should be guided/routed to an appropriate area so that they can continue upstream migration, and avoid being swept back downstream below the obstruction.

Downstream Fish Passage

1) To enhance survival at dams during emigration, evaluate survival of post spawning and juvenile fish passed via each route (e.g., turbines, spillage, bypass facilities, or a combination of the three) at any given facility, and implement measures to pass fish via the route with the best survival rate.

Other Dam Issues

1) Where practicable, remove obstructions to upstream and downstream migration. in lieu of fishway construction.
2) Locate water intakes where impingement/entrainment rates are likely to be lowest, employ intake screens or deterrent devices to prevent egg and larval mortality, and alter water intake velocities to reduce mortalities.
3) To mitigate hydrological changes from dams, consider operational changes such as turbine venting, aerating reservoirs upstream of hydroelectric plants, aerating flows downstream, and adjusting in-stream flows.
4) Natural river discharge should be taken into account when instream flow alterations are being made to a river (flow regulation) because river flow plays an important role in the migration of diadromous fish.
5) Ensure that decisions on river flow allocation (e.g., irrigation, evaporative loss, out of basin water transport, hydroelectric operations) take into account instream flow needs for American shad migration, spawning, and nursery use, and minimize deviation from natural flow regimes.
6) When considering options for restoring alosine habitat, include study of impacts and possible alteration of dam-related operations to enhance river habitat.

Water Quality and Contamination

1) Maintain water quality and suitable habitat for all life stages of diadromous species in all rivers with populations of American shad.
2) Reduce non-point and point sources of pollution in American shad habitat areas.
3) Implement best management practices (BMPs) along rivers and streams, restore wetlands, and utilize stream buffers to control non-point source pollution.
4) Implement erosion control measures and BMPs in agricultural, suburban, and urban areas to reduce sediment input, toxic materials, and nutrients and organics into streams.
5) Upgrade wastewater treatment plants and remove biological and organic nutrients from wastewater.
6) Reduce the amount of thermal effluent into rivers and require a thermal zone of passage for fish migration and movement.
7) Provide management options regarding water withdrawal and land use to minimize the impacts of climate change on temperature and flow regimes.
8) Discharge earlier in the year to reduce impacts to migrating fish.
9) Conduct studies to determine the effects of dredging on diadromous habitat and migration; appropriate best management practices, including environmental windows, should be considered whenever navigation dredging or dredged material disposal operations would occur in a given waterway occupied by diadromous species.
10) Introduction of new categories of contaminants should be prevented.

Habitat Protection and Restoration

1. States should identify, characterize, and quantify existing spawning and nursery habitat within its jurisdiction.
2. When states have identified habitat protection or restoration as a need, state marine fisheries agencies should coordinate with other agencies to ensure that habitat restoration plans are developed, and funding is actively sought for plan implementation and monitoring.
3. Any activity resulting in elimination of essential habitat (e.g., dredging, filling) should be avoided.
4. States should map substrate for freshwater tidal portions of rivers to determine suitable diadromous fish habitat, and that habitat should be protected and restored as needed.
5. States should notify, in writing, the appropriate federal and state regulatory agencies of the locations of habitats used by diadromous species. Regulatory agencies should be advised of the types of threats to diadromous fish populations, and recommended measures that should be employed to avoid, minimize, or mitigate any threat to current habitat quantity or quality from an activity regulated by that agency.
6. Each state encompassing diadromous fish spawning rivers and/or producer areas should develop water use and flow regime guidelines protective of diadromous spawning and nursery areas.
7. States should identify and quantify potential shad and river herring spawning and nursery habitat not presently utilized, including a list of areas that would support such habitat if water quality and access were improved or created, and analyze the cost of recovery within those areas. States may wish to identify areas targeted for restoration as essential habitat.
8. Resource management agencies in each state should evaluate their respective state water quality standards and criteria to ensure that those standards and criteria account for the special needs of alosines. Primary emphasis should be on locations where sensitive egg and larval stages are found.
9. ASMFC should designate important shad and river herring spawning and nursery habitat as Habitat Areas of Particular Concern (HAPCs).
10. States should endeavor to ensure that proposed water diversions or withdrawals from river tributaries would not reduce or eliminate American shad habitat.

Permitting

1. States should develop policies for limiting development projects seasonally or spatially in spawning and nursery areas; define and codify minimum riparian buffers and other restrictions where necessary.
2. Projects involving water withdrawal (e.g., power plants, irrigation, water supply projects) should be scrutinized to ensure that adverse impacts resulting from impingement, entrainment, and/or modifications of flow and salinity regimes due to water removal will not adversely impact diadromous fish stocks.
3. Each state should establish seasonal windows of compatibility for activities known or suspected to adversely affect freshwater American shad life stages and their habitats (e.g.,

dredging, filling, aquatic construction), and notify the appropriate state and federal regulatory agencies of the recommended windows.

4) State fishery regulatory agencies should develop protocols and schedules for providing input on Federal permits and licenses required by the Clean Water Act, Federal Power Act, and other appropriate vehicles, to ensure that diadromous fish habitats are protected.
5) All state and federal agencies responsible for reviewing impact statements for projects that may alter anadromous alosine spawning and nursery areas should ensure that those projects will have no impact or only minimal impact on those stocks. Of special concern are natal rivers of newly established stocks or stocks considered depressed or severely depressed.

Stock Restoration and Management

1) When populations have been extirpated from their habitat, states should coordinate alosine stocking programs, to restore habitat production including:
    a. Reintroduction to the historic spawning area
    b. Expansion of existing stock restoration programs, and
    c. Initiation of new strategies to enhance depressed stocks.
2) When releasing hatchery-reared larvae into river systems for purposes of restoring stocks, states should synchronize the release with periods of natural prey abundance to minimize mortality and maximize nutritional condition. States should determine functional response of predators on larval shad at restoration sites to ascertain appropriate stocking level so that predation is accounted for, and juvenile out-migration goals are met. Also, states should determine if night stocking will reduce mortality.
3) All stocked larvae and juveniles should be marked. Marking should allow identification of stocked fish by stocked river, age, and year class at the juvenile stage and when fish return to spawn as adults.

Other

1) States should promote cooperative interstate research, monitoring, and law enforcement. Establish criteria, standards, and procedures for plan implementation as well as determination of state compliance with management plan provisions.

2) Diadromous fish may be vulnerable to mortality in hydrokinetic power generation facilities, and such projects should be designed and monitored to eliminate, or minimize, fish mortality.

River-Specific Habitat Recommendations

River-specific habitat recommendations for American shad can be found in:

Atlantic States Marine Fisheries Commission. 2007. American shad stock assessment report for peer review, volumes II and III. Atlantic States Marine Fisheries Commission Stock Assessment Report No. 07-01 (Supplement), Washington, D.C.

6.0 IMPLEMENTATION PLANS

In order to be successful in achieving the stated goal of Amendment 3, states or jurisdictions are required to develop Implementation Plans. Implementation Plans will consist of two parts: 1. Review and update of the Fishing/Recovery Plans required under Amendment 1 for the stocks within their jurisdiction; and 2. Habitat Plans. The updated Fishing/Recovery Plan must include a description of existing and planned monitoring and existing and planned regulatory measures. It may also include, for those states or jurisdictions requesting a fishery, a definition of sustainability, development of benchmark goals (if different from or in addition to those identified in 2007 Stock Assessment), and a proposed timeframe to achieve stated objectives. The habitat plans are new and should include a summary of current and historical spawning and nursery habitat, threats to those habitats, and habitat restoration programs.

Monitoring sections of the Fishing/Recovery Plan updates should address the state or jurisdiction specific monitoring requirements specified in Tables 2 and 3. If states or jurisdictions cannot conduct required monitoring, the plan update should identify required monitoring that cannot be done and reasons why it cannot be conducted. It is the intention of this amendment to discuss identified implementation problems with the state or jurisdiction prior to plan adoption so that the Commission can work with the state or jurisdiction to explore the opportunity to secure adequate funding resources for implementation, or to develop an acceptable alternative that can be implemented with available resources.

If the state or jurisdiction chooses to develop a definition of sustainability and stock restoration goals, it may propose to the Management Board an alternate monitoring plan that measures stock status relative to the definition or goal. If approved by the board, this monitoring program will replace that specified in Tables 2 and 3.

Separate Implementation Plans shall be developed for those systems listed in Tables 2 and 3 and which are under the state or jurisdiction's authority. For states and jurisdictions which share a river or estuary, states should include those monitoring programs conducted or planned by the state, applicable state regulations, and habitat and habitat threats applicable to state waters. In shared water bodies where there is some sort of management cooperative, the cooperative or a member state or jurisdiction can be appointed to write the Implementation Plan. States are encouraged to develop plans for any additional systems, as feasible.

This amendment adopts the below frameworks for the updated Fishing/Recovery Plans and the Habitat Plans. Under this amendment the Technical Committee shall review each plan to ensure that the minimal technical specifications of Amendment 3 are met by the states and jurisdictions. States and jurisdictions are required to submit their Fishing/Recovery Plan to the Commission by August 1, 2011 and their Habitat Plan by August 1, 2013. Submission of these plans to the Management Board is a required action under Amendment 3. These plans are one time submissions under this amendment. They do not replace the annual state compliance reports discussed in Section 8. States without an approved plan for the sustainable fishery are required to close (with the exception of catch and release recreational fisheries) their fisheries by January 1, 2013.

It is understood that the review and update will take considerable time and resources on the part of the states, the federal agencies, and the Commission and its staff to fully develop and implement. It will require leadership and facilitation from the Commission and its staff. It will also require the technical expertise and input from the Plan Review Team, Plan Development Team, and Technical Committee. The federal agencies are strongly encouraged to lend their support and provide assistance in the form of facilitation, planning, technology, and training services.

All plans are to be regularly reviewed, assessed and updated as needed on five-year basis by the state or jurisdiction that prepared them, with a summary report of the review provided to the Board.

6.1 Updated Framework for the Fishing/Recovery Plans

The following is a framework for the updated Fishing/Recovery Plans. The Management Board should task the Technical Committee to review, modify as needed, and approve this framework.

1) **Sustainable Fishery Plan (If proposed)**
    a. Request for fisheries
    b. Definition of sustainability
    c. Summary of current stock status
    d. Benchmark goals and objectives or restoration goals/targets.
    e. Proposed time frame for achievement
    f. Discussion of management measure(s) to be taken if sustainable target is not achieved within indicated timeframe

2) **Stock Monitoring Programs** – Describe the monitoring currently used, or planned, to assess status and characteristics of the spawning stock and of progress toward goals. See requirements of Tables 2 and 3. States and jurisdictions should indicate any required monitoring that cannot be conducted (See Section 6.0).
    a. Fishery Independent
        i. Juvenile abundance indices
        ii. Adult stock monitoring
            1. Relative or absolute abundance
            2. Age, size, sex composition
            3. Total mortality (where possible)
            4. Upriver and downriver passage efficiencies (where possible)
        iii. Hatchery evaluation
            1. Proportion of hatchery fish present in juvenile or adult populations
    b. Fishery Dependent
        i. Commercial Fishery
            1. Total catch, landings, and effort
            2. Age, size, and sex composition of harvested fish
        ii. Recreational fishery
            1. Total catch, landings, and effort or catch per unit effort from a subsample
        iii. Bycatch and discards

3) **Fishery Management Program –** Summarize fisheries regulatory program for:
    a. Commercial fishery
    b. Recreational fishery
    c. Bycatch and discards

6.2. Habitat Plans

The following is the recommended framework for the Habitat Plan. The Management Board should task the Technical Committee to review, modify as needed, and approve this framework. This outline is designed to be an inclusive framework for organizing information on habitat, and threats to that habitat. As such, it is likely that data may not yet be available for some items. In those cases, states and jurisdiction should indicate data status (e.g., not available, being collected, being analyzed, under review).

1) **Habitat Assessment –** Assess the habitat (historic and currently available) and impediments to full utilization of the habitat.
    a. <u>Spawning Habitat</u>
        i. Amount of historical in-river and estuarine spawning habitat (e.g., river kilometers, water surface area (hectares)).
        ii. Amount of currently accessible in-river and estuarine spawning habitat (i.e., habitat accessible to adult fish during the upstream spawning migration).
    b. <u>Rearing Habitat</u>
        i. Amount of historical in-river and estuarine young-of-year rearing habitat (e.g., river kilometers, water surface area (hectares)).
        ii. Amount of currently utilized in-river and estuarine young-of-year rearing habitat (i.e., habitat available to larval stage and young-of-year fish through natural spawning or artificial stocking of hatchery reared juvenile fish).

2) **Threats Assessment –** Inventory and assess the critical threats to habitat quality, quantity, access, and utilization (see - *Appendix C* for a detailed habitat description). For those threats deemed by the state or jurisdiction to be of critical importance to restoration or management of an American shad stock, the state or jurisdiction should develop a threats assessment for inclusion in the Habitat Plan. Examples of potential threats to habitat quality, quantity, and access for American shad stocks include:
    a. <u>Barriers to migration inventory and assessment</u>
        i. Inventory of dams, as feasible, that impact migration and utilization of historic stock (river) specific habitat. Attribute data for each dam should be captured in an electronic database (e.g., spreadsheet) and include: name of dam, purpose of the dam, owner, height, width, length, impoundment size, water storage capacity, location (i.e., river name, state, town, distance from river mouth, geo-reference coordinates), fish passage facilities and measures implemented (i.e., fish passage type, capacity, effectiveness, and operational measure such as directed spill to facilitate downstream passage), and information source (e.g., state dam inventory).

    ii. Inventory of other human–induced physical structures (e.g., stream crossing/culverts), as feasible, that impact migration and utilization of historic habitat (data on each structural impediment should include: type, source, and location).
    iii. Inventory of altered water quality (e.g., low oxygen zones) and quantity (e.g., regulated minimum flows that impact migration corridors and/or migration cues), as feasible, impediments that impact migration and utilization of historic habitat (data on each water quality and quantity impediment should include: type, source, location, and extent).
    iv. Assess barriers to migration in the watershed and characterize potential impact on American shad migration and utilization of historic habitat.

b. <u>Water withdrawals inventory and assessment</u>
    i. Inventory of water withdrawals (both permitted and known unpermitted), as feasible, that impact or have the potential to impact (e.g., fish entrainment and impingement, instream habitat alteration, and/or alteration of instream flow) migration and utilization of historic habitat.
    ii. Assess water withdrawals in the watershed and characterize potential impact on American shad migration and utilization of historic habitat.

c. <u>Toxic and thermal discharge inventory and assessment</u>
    i. Inventory of toxic and thermal discharge of water, where applicable, that impact or have the potential to impact (e.g., create a barrier, lethal concentration, and/or reduce fitness) migration and utilization of historic habitat.
    ii. Assess toxic and thermal discharge in the watershed and characterize potential impact on American shad migration and utilization of historic habitat.

d. <u>Channelization and dredging inventory and assessment</u>
    i. Inventory of channelization and dredging projects, as feasible, that impact or have the potential to impact (e.g., create a barrier, degrade substrate, and/or reduce water quality) migration and utilization of historic habitat.
    ii. Assess stream channelization and dredging in the watershed and characterize potential impact on American shad migration and utilization of historic habitat.

e. <u>Land use inventory and assessment</u>
    i. Inventory of land use in the watershed that impact or have the potential to impact (e.g., alter run-off regimes, degrade riparian habitat, increase siltation, reduce water quality and/or diminish riparian buffers) migration and utilization of historic habitat.
    ii. Assess land use in the watershed and characterize potential impact on American shad migration and utilization of historic habitat.

f. <u>Atmospheric deposition assessment</u>
    i. Assess atmospheric deposition in the watershed and characterize potential impact on American shad migration and utilization of historic habitat.

g. <u>Climate change assessment</u>
    i. Assess potential climate change impacts in the watershed and characterize their impact on American shad migration and utilization of historic habitat.

h. <u>Competition and predation by invasive and managed species assessment</u>
    i. Assess competition and predation by invasive and managed species in the watershed and characterize potential impact on American shad migration and utilization of historic habitat.

3) **Habitat Restoration Program** – For threats deemed to be of critical importance to the restoration and management of American shad stocks within its jurisdiction, each state or jurisdiction should develop a program of actions to improve, enhance and/or restore habitat quality and quantity, habitat access, habitat utilization and migration pathways. These programs may include plans to take direct corrective actions within the state or jurisdictions' authority, or to consult with agencies that have management authority over the threat, inform them of the impacts the threat is having on American shad stocks, and recommend potential alternatives or corrective actions to alleviate that threat. Section 5.5 Habitat Restoration, Enhancement, Utilization, and Protection Recommendations should be consulted for potential actions that could be included in the Habitat Restoration Program. While this amendment proposes the development of such programs, the implementation of these programs is not required. Programs could include:

a. <u>Barrier removal and fish passage program</u> – Develop a program to eliminate, minimize, or mitigate impacts from barriers identified in 2 (a) above.

b. <u>Hatchery product supplementation program</u> – Consider the stocking of hatchery reared larvae or juveniles to spawning or rearing habitat that is underutilized due to migration barriers or to new habitat following barrier removal.

c. <u>Water quality improvement program</u> - A program should be developed to address identified impacts of poor water quality to spawning success and juvenile recruitment in 2 (b) and (c) above.

d. <u>Habitat improvement program</u> - A program should be developed to address identified impacts to habitat in 2 (d) and (e) above and to protect quality habitat.

e. <u>Project permit/licensing review program for water withdrawals, toxic and thermal discharge, channelization and dredging, and land use and development, that includes development of recommendations and conditions to avoid, minimize, or mitigate associated impacts to American shad migration and utilization of historic habitat</u> - A program should be developed to identify, review, assess, and comment or condition permitted/licensed development projects that could impact aquatic habitat or restoration efforts

f. <u>Programs to avoid, minimize, or mitigate associated impacts to American shad migration and utilization of historic habitat from atmospheric deposition and climate change</u> – Atmospheric deposition and climate change may impact restoration efforts and will need to be addressed through cooperative engagement with the public and regulatory bodies that can influence positive change, or eliminate/diminish the identified impacts. It is recommended that a program be developed to engage in the public debate and/or regulatory actions in order to attain full consideration of impacts of atmospheric deposition and climate change on American shad habitat and restoration efforts. It is also recommended that the ASMFC should consider developing a plan to engage as a unified body in the atmospheric deposition and climate change debate, and formulate a position statement on future action by regulatory agencies that address the identified impacts.

7. AMENDMENT REVISIONS

7.1 Future Changes to Management Regimes

Once the Shad and River Herring Management Board approves a management program (monitoring, regulatory and habitat), states and jurisdictions are required to obtain approval from the Management Board prior to changing their management program in any way that might alter a compliance measure. Changes to management programs that affect measures other than compliance measures must be reported to the Management Board but may be implemented without prior approval. States and jurisdictions submitting alternative proposals must demonstrate that the proposed management program will not contribute to excessive mortality of the resource or inhibit restoration of the resource. The Management Board can approve an alternative management program proposed by a state or jurisdiction if the state or jurisdiction can show to the Management Board’s satisfaction that the alternative proposal will have the same conservation value as the measure contained in this amendment or any addenda prepared under Adaptive Management (Section 7.2). All changes in state and jurisdictional plans must be submitted in writing to the Management Board and the Commission either as part of the annual FMP Review process or with the annual compliance report.

7.1.1 General Procedures

A state may submit a proposal to the Commission for a change to its regulatory program or any mandatory compliance measure under this amendment, including a proposal for *de minimis* status. Such changes shall be submitted to the Chair of the Plan Review Team, who shall then distribute the proposal to the Management Board, Plan Review Team. The Plan Review Team may request additional guidance from the Technical Committee, Stock Assessment Subcommittee and Advisory Panel, as necessary. The Plan Review Team is responsible for gathering the comments, if requested, from the Technical Committee, Stock Assessment Subcommittee and Advisory Panel, and presenting the comments to the Management Board in a timely fashion.

The Shad and River Herring Management Board can approve an alternative management program proposed by a state or jurisdiction if the state or jurisdiction can show to the Management Board’s satisfaction that the alternative proposal will have the same conservation value as the measure contained in this amendment or any addenda prepared under Adaptive Management (Section 7.2).

7.1.2 Management Program Equivalency

The Shad and River Herring Technical Committee, under the direction of the Plan Review Team, will review any alternative management program proposals and provide the Management Board its evaluation of the adequacy of the proposals.

7.1.3 *De Minimis* Fishery Guidelines

The Commission's Interstate Fisheries Management Program Charter defines *de minimis* as "a situation in which, under the existing condition of the stock and scope of the fishery, conservation and enforcement actions taken by an individual state would be expected to contribute insignificantly to a coastwide conservation program required by a Fishery Management Plan or amendment" (ASMFC 2003).

States that report commercial landings of American shad that are less than 1% of the coastwide commercial total are exempted from sub-sampling commercial and recreational catch for biological data, as outlined in Section 3.2.

States and jurisdictions may petition the Shad and River Herring Management Board at any time for *de minimis* status if their fishery falls below the threshold level determined by the Board. Once *de minimis* status is granted, designated states and jurisdictions must submit annual compliance reports to the Management Board and request *de minimis* status on an annual basis.

7.2 ADAPTIVE MANAGEMENT

The Shad and River Herring Management Board may vary the requirements specified in this amendment as part of adaptive management in order to conserve American shad resources. Specifically, the Management Board may change state and jurisdiction requirements under Sections 3 and 4 (see Section 7.1.2). Such changes will be instituted to be effective on January 1 or the first fishing day of the following year, but may be put in place at an alternative time when deemed necessary by the Management Board.

7.2.1 General Procedures

The Shad and River Herring Plan Review Team will monitor the status of the fishery and the resource and report on that status to the Management Board annually or when directed to do so by the Management Board. The Plan Review Team will consult with the Technical Committee, Stock Assessment Subcommittee and Advisory Panel, as necessary, when making such a review and report. The report may contain recommendations for proposed adaptive management revisions to the amendment.

The Management Board will review the Plan Review Team report and may consult further with the Technical Committee, Stock Assessment Subcommittee or the Advisory Panel. The Management Board can direct the Plan Development Team to prepare an addendum to make changes that it deems necessary. The addendum shall contain a schedule for the states and jurisdictions to implement its provisions.

The Plan Development Team will prepare a draft addendum as directed by the Management Board and, upon approval from the Board, shall distribute it for review and comment to all states and jurisdictions with declared interest in the fishery. A public hearing will be held in any state or jurisdiction that requests one. After a 30-day review period, the Plan Development Team will summarize the comments and present them to the Management Board.

After considering the comments, the Management Board will direct the Plan Development Team on what to include in the final addendum. The Management Board shall review the final version of the addendum. The Management Board shall then consider whether to adopt or revise and then adopt the addendum.

Upon the adoption of an addendum to implement adaptive management, states and jurisdictions shall prepare plans, when necessary, to implement the addendum and submit those plans to the Management Board for approval, following the schedule contained in the addendum.

7.2.2 Measures Subject to Change

The following measures are subject to change under adaptive management upon approval by the Management Board:

(1) Habitat considerations;
(2) Overfishing definition;
(3) Rebuilding targets and schedules;
(4) Fishery-independent monitoring requirements;
(5) Fishery-dependent monitoring requirements;
(6) Bycatch monitoring and reduction requirements;
(7) Reporting requirements;
(8) Effort controls;
(9) Area closures;
(10) Gear restrictions or limitations;
(11) Catch controls;
(12) Fishing year and/or seasons;
(13) Possession limits;
(14) Quotas;
(15) Bycatch limits and reporting;
(16) Observer requirements;
(17) Closures;
(18) Regulatory measures for the recreational fishery;
(19) Recommendations to the Secretaries for complementary actions in federal jurisdictions;
(20) *De minimis* specifications;
(21) Compliance report due dates; and
(22) Any other management measures currently included in the Shad and River Herring Interstate Fishery Management Plan.

7.3 EMERGENCY PROCEDURES

The Shad and River Herring Management Board may authorize or require emergency action that is not covered by, or is an exception or change to, any provision in Amendment 3. Procedures for implementation of emergency action are addressed in the Commission's Interstate Fisheries Management Program Charter, Section Six (c)(10) (ASMFC 2003).

8. MANAGEMENT INSTITUTIONS

The management institutions for shad and River herring shall be subject to the provisions of the ISFMP Charter (ASMFC 2003). The following are not intended to replace any or all of the provisions of the ISFMP Charter. All committee roles and responsibilities are included in detail in the ISFMP Charter and are only summarized here.

8.1 The Commission and the ISFMP Policy Board

The Atlantic States Marine Fisheries Commission and the ISFMP Policy Board are generally responsible for the oversight and management of the Commission's fisheries management activities. The Commission must approve all fishery management plans and amendments, including this Amendment 3, and must also make final determinations concerning state compliance or non-compliance. The ISFMP Policy Board reviews any non-compliance recommendations from the various management boards and sections and, if it concurs, forwards them on to the Commission for action.

8.2 Shad and River Herring Management Board

The Shad and River Herring Management Board is established by the Commission's ISFMP Policy Board and is generally responsible for carrying out all activities under this amendment. It establishes and oversees the activities of the Plan Review Team, Plan Development Team, Technical Committee and Stock Assessment Subcommittee, and requests the establishment of the Commission's Shad and River Herring Advisory Panel. Among other things, the Management Board makes changes to the management program under adaptive management and approves the state and jurisdictional programs implementing the amendment and alternative state programs under Sections 6 and 7. The Management Board reviews the status of state and jurisdiction compliance with the FMP at least annually and, if it determines that a state or jurisdiction is out of compliance, reports that determination to the ISFMP Policy Board under the terms of the ISFMP Charter.

8.3 Shad and River Herring Plan Review Team and Plan Development Team

The Shad and River Herring Plan Review Team and Plan Development Team are small groups whose responsibility is to provide all necessary staff support to carry out and document the decisions of the Management Board. Both teams are directly responsible to the Management

Board for providing all of the information and documentation necessary to carry out the Board’s decisions.

The teams shall be comprised of personnel from state and federal agencies who have scientific or management knowledge of shad and river herring and will be chaired by the Commission’s Shad and River Herring FMP Coordinator. The Plan Development Team will be responsible for preparing all documentation necessary for the development of Amendment 3, using the best scientific information available and the most current stock assessment information. Once the Commission adopts Amendment 3, the Plan Review Team will provide annual advice concerning implementation, review, monitoring and enforcement of the amendment.

8.4 Shad and River Herring Technical Committee

The Shad and River Herring Technical Committee will consist of representatives from each state, jurisdiction, and federal agency with a declared interest in shad and river herring fisheries. Its role is to act as a liaison to the individual jurisdictions and federal agencies, providing information to the management process and reviewing and making recommendations concerning the management program. The Technical Committee will provide scientific advice to the Management Board, Plan Development Team and Plan Review Team in the development and monitoring of a fishery management plan or amendment, when requested.

8.5 Shad and River Herring Stock Assessment Subcommittee

The Shad and River Herring Stock Assessment Subcommittee will consist of scientists with expertise in stock assessment methods or the assessment of shad and river herring populations. Its role is to assess shad and river herring populations and provide scientific advice concerning the implications of proposed or potential management alternatives for the stocks, as well as to respond to other scientific questions from the Management Board, Technical Committee, Plan Development Team or Plan Review Team. The Stock Assessment Subcommittee will report to the Management Board as well as to the Technical Committee, when requested.

8.6 Shad and River Herring Advisory Panel

The Shad and River Herring Advisory Panel is established according to the Commission’s Advisory Committee Charter. Members of the Advisory Panel are citizens who represent a cross-section of commercial and recreational fishing interests and other who are concerned about shad and river herring conservation and management. The Advisory Panel provides the Management Board with advice directly concerning the Commission’s shad and river herring management program.

8.7 Secretaries of Commerce and the Interior

Under the Atlantic Coastal Fisheries Cooperative Management Act, if the Commission determines that a state or jurisdiction is out of compliance with the Fishery Management Plan, it reports that finding to the Secretary of Commerce. The Secretary of Commerce must determine that the measures not taken by the state or jurisdiction are necessary for conservation and if such a finding is determined, the Secretary is then required by federal law to impose a moratorium on fishing for shad or river herring in that jurisdiction’s waters until the state comes back into compliance. In addition, the Commission has accorded the National Marine Fisheries Service and the U.S. Fish and Wildlife Service voting status on the ISFMP Policy Board and the Shad and River Herring Management Board; the federal agencies participate on the Plan Review Team, Plan Development Team, Technical Committee and Stock Assessment Subcommittee.

8.8 Recommendations to Secretaries

The ASMFC Shad and River Herring Management Board requests that the Secretary of Commerce direct the National Marine Fisheries Service to collaborate with the ASMFC Board and Technical Committee on shad and river herring bycatch reduction efforts in the New England Fishery Management Council and the Mid-Atlantic Fishery Management Council Fishery Management Plan process. The Commission also recommends the Secretaries of the federal agencies lend their support to states or jurisdictions in the development of the Implementation Plans and provide assistance in the form of facilitation, planning, technology, and training services.

9. COMPLIANCE

Full implementation of the provisions in this amendment is necessary for the management program to be equitable, efficient and effective. States (to include states as well as the District of Columbia and Potomac River Fisheries Commission) are expected to implement these measures faithfully under state laws. Although the Atlantic States Marine Fisheries Commission does not have authority to directly compel state implementation of these measures, it will continually monitor the effectiveness of state implementation and determine whether states are in compliance with the provisions of this amendment. This section sets forth the specific elements that the Commission will consider in determining state compliance with this amendment and the procedures that govern the evaluation of compliance. Additional details of the procedures are found in the 2003 ASMFC Interstate Fisheries Management Program (ISFMP) Charter. States and jurisdictions should be aware that federal law requires their compliance with the provisions of this amendment.

9.1 MANDATORY COMPLIANCE ELEMENTS FOR STATES

A state or jurisdiction will be determined out of compliance with the provision of this fishery management plan according to the terms of Section 7 of the ISFMP Charter if:

1. It’s Implementation Plan or its annual compliance reports have not been approved by the Shad and River Herring Management Board; or
2. It fails to meet any scheduled action required by Section 9.2, or any addendum prepared under adaptive management (Section 7.2); or

3. It has failed to implement a change to its monitoring program (Section 3) or its regulations when determined necessary by the Shad and River Herring Management Board; or
4. It makes a change to its monitoring programs required under Section 3 or its regulations required under Section 4 without prior approval of the Shad and River Herring Management Board.

9.1.1 Mandatory Elements of State Programs

A state will be found out of compliance if it's regulatory and management programs for shad and river herring have not been approved by the Management Board in section 3 and 4. A state or jurisdiction may propose an alternative management program under Section 7, which if approved by the Management Board, may be implemented as an alternative regulatory requirement for compliance under the law.

9.1.2 Regulatory Requirements

States and jurisdictions may begin to implement Amendment 3 after final approval by the Commission. Each state and jurisdiction must submit its required shad and river herring regulatory program to the Commission through Commission staff for approval by the Management Board. During the period between submission of the regulatory plan and the Management Board’s decision to approve or reject it, a state or jurisdiction may not adopt a less protective management program than contained in this Amendment or contained in current state law. Once a regulatory program is approved by the Management Board, states and jurisdictions may not implement any regulatory changes concerning shad and river herring, or any management program changes that affect their responsibilities under this Amendment, without first having those changes approved by the Management Board.

9.1.3 Monitoring Requirements

All state and jurisdictional programs must include the mandatory monitoring requirements contained in Section 3 unless the Management Board approves and alternative program as outlined in Section 6.0 and 7.0. States and jurisdictions must submit proposals as part of the Fishing/Recovery Plan for all intended changes to required monitoring programs that may affect the quality of the data or the ability of the program to fulfill the needs of the amendment. In the event that a state or jurisdiction realizes that it will not be able to fulfill its monitoring requirements, it should immediately notify the Commission in writing. The Commission will work with the state or jurisdiction to develop a plan to secure funding or plan an alternative program to satisfy the needs outlined in Amendment 3. If the plan is not implemented 90 days after it has been adopted, the state or jurisdiction may be found out of compliance with Amendment 3.

9.1.4 Research Requirements

No mandatory research requirements have been identified at this time; however, elements of state Implementation Plans may be added to address any needs identified during the course of developing Amendment 3.

9.1.5 Law Enforcement Requirements

All state and jurisdictional programs must include law enforcement capabilities adequate for successfully implementing the state's shad and river herring regulations. The adequacy of a state's enforcement activity will be measured by an annual report to the Commission's Law Enforcement Committee and the Plan Review Team.

9.1.6 Habitat Requirements

No mandatory habitat requirements have been identified at this time; however, elements of state habitat plans (Section 6) may be added to address any needs identified during the course of developing Amendment 3.

9.2 COMPLIANCE SCHEDULE

States and jurisdictions must implement the provisions of this Amendment according to the following schedule:

August 1, 2011 States/jurisdictions must submit their fishing/recovery plan(s), as part of the states/jurisdictions Implementation plan, for review by the Technical Committee and approval by the Management Board

January 1, 2013 States /jurisdictions must implement their approved fishing/ recovery plan(s).

August 1, 2013 States /jurisdictions must submit their habitat plan(s)

Reports on compliance should be submitted to the Commission by each jurisdiction annually, no later than July 1 each year. These reports are separate from the Implementation plans which are one time submissions to the Commission.

9.3 COMPLIANCE REPORT CONTENT

Each state must submit an annual report concerning its shad and river herring fisheries and management program for the previous years. The report shall cover:

1. The previous calendar year's fishery and management program including, activity and results of monitoring, regulations that were in effect, harvest, and estimates of non-harvest losses, following the outline contained in Table 5.
2. All data from monitoring programs must be added to Excel spreadsheets used in the 2007 stock assessment. Updated spreadsheets must be submitted annually as an appendix to the annual report and at the same time as the annual report unless determined otherwise by the Board.
3. The planned management program for the current calendar year, summarizing regulations that will be in effect and monitoring programs that will be performed, and highlighting any changes from the previous year.

Table 5. Required format for annual state compliance reports.

General Format

Introduction	Summary of the year: highlight any significant changes in monitoring, regulations or harvest.
Request for *de minimis*	If applicable.
Previous year's fishery and management program	Activity and result of fishery-dependent monitoring (provide general results and references to technical documentation) including bycatch monitoring.
	Activity and results of fishery-independent monitoring (provide general results and references to technical documentation).
	Copy of regulations that were in effect, including a reference to the specific compliance criteria as mandated in the FMP.
	Harvest broken down by commercial (gear type where applicable) and recreational fishing, and non-harvest losses, when available.
	Review of progress in implementing habitat recommendations.
Planned management programs for the current calendar year	Summarize regulations that will be in effect (copy of current regulations if different from previous year).
	Summarize monitoring programs that will be performed.
	Highlight any changes from the previous year.

Plan-Specific Requirements

Harvest and losses	Commercial Fishery	Characterization of the fishery (seasons, caps, gears, regulations).		
		Characterization of directed harvest.	Landings	
			Harvest composition	Age frequency
				Length frequency
				Sex ration
				Degree of repeat spawning (estimated from scales)
			Estimation of Effort	
		Characterization of other losses (poaching, bycatch, etc.).	Estimate and method of estimation	
			Estimate of composition (length and/or age)	
	Recreational Fishery	Characterization of the fishery (seasons, caps, gears, regulations).		
		Characterization of directed harvest.	Landings and method of estimation	
			Estimation of effort or Annual CPUE from a subsample	
		Characterization of other losses (poaching, catch-and-release mortality, etc.)	Estimate and method of estimation	
	Other Losses	Fish passage mortality, discarded males, brood stock capture, research losses, etc.		
	Harvest and Losses Table	Include all above estimates in numbers and weight (pounds) of fish and mean weight per fish for each gear type.		
	Protected Species	Atlantic sturgeon bycatch estimates.		
Required Fishery-Independent Monitoring	Description of requirement as outlined in Section 3.			
	Brief description of work performed.			
	Results	[*To be determined upon final approval of Amendment 3*]		

9.4 PROCEDURES FOR DETERMINING COMPLIANCE

Detailed procedures regarding compliance determinations are contained in the ISFMP Charter, Section Seven.

In brief, all states and jurisdictions are responsible for the full and effective implementation and enforcement of fishery management plans in areas subject to their jurisdiction. Written compliance reports as specified in the Plan or Amendment must be submitted annually by each state with a declared interest. Compliance with Amendment 3 will be reviewed at least annually. The Shad and River Herring Management Board, ISFMP Policy Board or the Commission may request the Plan Review Team to conduct a review of Plan implementation and compliance at any time.

The Management Board will review the written findings of the PRT within 60 days of receipt of a state or jurisdiction’s compliance report. Should the Management Board recommend to the Policy Board that a state or jurisdiction be determined to be out of compliance, a rationale for the recommended noncompliance finding will be included addressing specifically the required measures of Amendment 3 that the state or jurisdiction has not implemented or enforced, a statement of how failure to implement or enforce required measures jeopardizes shad and river herring conservation, and the actions a state must take in order to comply with Amendment 3 requirements.

The ISFMP Policy Board will review any recommendation of noncompliance from the Management Board within 30 days. If it concurs in the recommendation, it shall recommend at that time to the Commission that a state or jurisdiction be found out of compliance.

The Commission shall consider any noncompliance recommendation from the ISFMP Policy Board within 30 days. Any state or jurisdiction that is the subject of a recommendation for a noncompliance finding is given an opportunity to present written and/or oral testimony concerning whether it should be found out of compliance. If the Commission agrees with the recommendation of the ISFMP Policy Board, it may determine that a state or jurisdiction is not in compliance with the Amendment 3, and specify the actions the state or jurisdiction must take to come into compliance.

Any state or jurisdiction that has been determined to be out of compliance may request that the Commission rescind its noncompliance findings, provided the state or jurisdiction has revised its shad and river herring conservation measures.

10. MANAGEMENT AND RESEARCH NEEDS

The following list of research needs have been identified in order to enhance the state or knowledge of the shad and river herring resources, population dynamics, ecology and the various fisheries for alosine species. The Technical Committee, Advisory Panel, and Management Board will review this list annually and an updated prioritized list will be included in the Annual Shad and River Herring FMP Review. The below items should be prioritized, from most critical to least critical, by the Technical Committee.

10.1 STOCK ASSESSMENT AND POPULATION DYNAMICS

- Continue to assess current aging techniques for shad and river herring, using known-age fish, scales, otoliths and spawning marks. Known age fish will be available from larval stocking programs that mark each year class. Conduct biannual aging workshops to maintain consistency and accuracy in aging fish sampled in state programs.
- Investigate the relation between juvenile production and subsequent year class strength for alosine species, with emphasis on the validity of juvenile abundance indices, rates and sources of immature mortality, migratory behavior of juveniles, natural history and ecology of juveniles, and essential nursery habitat in the first few years of life.
- Validate estimates of M for American shad stocks.
- Establish management benchmarks for data poor river systems identified within the stock assessment.
- Estimate and evaluate sources of mortality for alosine species from bycatch, and bait and reduction fisheries.
- Determine fishery specific catch, harvest, bycatch, and discard reporting rates.
- Estimate and evaluate river specific mortality from upstream and downstream passage of adults and downriver passage of juveniles past migratory barriers.
- Determine which stocks are impacted by mixed stock fisheries (including bycatch fisheries). Methods to be considered could include otolith microchemistry, oxy-tetracycline otolith marking, and/or tagging.
- Evaluate assumptions critical to in-river tagging programs in Georgia, South Carolina, and Maryland that are used to estimate exploitation rate and population size.
- Develop approaches to estimating relative abundance of spawning stocks in rivers without passage facilities and in rivers with passage facilities with unknown passage efficiencies.
- Evaluate predation by striped bass and other predators as a factor of mortality for alosines. Research predation rates and impacts on alosines.
- Quantify fishing mortality (in-river, ocean bycatch, bait fisheries) for major river stocks after ocean closure of directed fisheries.
- Develop comprehensive and cost effective angler use and harvest survey techniques for use by Atlantic coastal states to assess recreational fisheries for American shad.
- Determine and update biological data inputs used in assessment modeling (fecundity-at-age, mean weight-at-age for both sexes, partial recruitment vector/maturity schedules) for American shad and river herring stocks in a variety of coastal river systems, including both semelparous and iteroparous stocks.
- Evaluate and ultimately validate large-scale hydroacoustic methods to quantify American shad escapement (spawning run numbers) in major river systems. Identify how shad respond (attract/repelled) by various hydroacoustic signals.

10.2 RESEARCH AND DATA NEEDS

10.2.1 Habitat

- Identify ways to improve fish passage efficiency using hydroacoustics to repel alosines from turbine intakes or discharges or pheromones or other chemical substances to attract them to passage entrances. Test commercially available acoustic equipment at existing fish passage facility to determine effectiveness. Develop methods to isolate/manufacture pheromones or other alosine attractants.
- Determine the effects of passage impediments on all life history stages of American shad including turbine mortality and river and barrier specific passage efficiencies. Highest priority would be the lowermost obstruction.
- Develop and implement techniques to determine shad and herring population targets for tributaries undergoing restoration (dam removals, fishways, supplemental stocking, etc.).
- Characterize tributary habitat quality and quantity for Alosine reintroductions and fish passage development.
- Determine impacts to American shad populations from changing ocean environment
- Identify and quantify potential American shad spawning and rearing habitat not presently utilized and conduct an analysis of the cost of recovery.
- Develop appropriate Habitat Suitability Index Models for alosine species in the fishery management plan. Possibly consider expansion of species of importance or go with the most protective criteria for the most susceptible species.
- Determine factors that regulate and potentially limit downstream migration, seawater tolerance, and early ocean survival of juvenile alosines.
- Review studies dealing with the effects of acid deposition on anadromous alosines.
- Determine effects of change in temperature and pH for all life stages.
- Determine optima and tolerance for salinity, dissolved oxygen, pH, substrate, current velocity, depth, temperature, and suspended solids.
- Determine hard limits and range levels for water quality deemed appropriate and defensible for all alosines with emphasis on freshwater migratory, spawning, and nursery areas.
- There has been little research conducted on habitat requirements for hickory shad. Although there are reported ranges of values for some variables, such as temperature or depth, there is no information on tolerances or optima for all life stages. Research on all life stages is necessary to determine habitat requirements.
- Determine impacts of declining submerged aquatic vegetation beds on juvenile cover and rearing habitat.
- Determine impacts of thermal power generation projects (e.g., nuclear and coal) that withdraw water for cooling (potential entrainment and impingement of fish) and discharge heated water (thermal barriers to migration, habitat degradation) on estuarine juvenile rearing and migration corridors.
- Determine impacts to migrating American shad (both spawning adults and out-migrating juveniles and adults) by proposed in-stream power generation developments such as tidal stream generation that draws energy from currents.
- Determine potential threats and their level of impact to coastal American shad habitat from: marine acidification; pharmaceutical, wastewater, pesticide contamination;

invasive species; niche displacement; and global climate change are in need of further study.

- Determine the impacts to migrating American shad (both spawning adults and migrating juveniles) by proposed wind power generation developments in near shore ocean environments.
- Conduct fish passage research and development with the goal of improving the efficiency of existing and future installations of fish passage measures and facilities in order to restore desired access to and utilization of critical American shad spawning and juvenile rearing habitat.
- Conduct studies to determine whether passing migrating adults upstream earlier in the year in some rivers would increase production and larval survival, and opening downstream bypass facilities sooner would reduce mortality of early emigrants (both adult and early-hatched juveniles).
- Conduct studies to determine the effects of dredging on diadromous habitat and migration.

10.2.2 Life History

- Conduct studies on energetics of feeding and spawning migrations of alosines on the Atlantic coast.
- Evaluate impacts of invasive species such as zebra mussels and flathead catfish on larval and juvenile survival.
- Conduct studies of egg and larval survival and development.
- Focus research on within-species variation in genetic, reproductive, morphological, and ecological characteristics, given the wide geographic range and variation at the intraspecific level that occurs in alosines.
- Ascertain how abundance and distribution of potential prey affect growth and mortality of early life stages.
- Conduct research on hickory shad migratory behavior. This may explain why hickory shad populations continue to increase while other alosines are in decline.

10.2.3 Stocking and Hatcheries

- Refine techniques for hormone induced tank spawning of American shad. Secure adequate eggs for culture programs using native broodstock.
- Refine larval marking techniques such that river and year class can be identified when year classes are later recaptured as juveniles or adults.

10.2.4 Socioeconomic

- Conduct and evaluate historical characterization of socio-economic development (potential pollutant sources and habitat modification) of selected alosine rivers along the Atlantic coast.

- Collect information from consumptive and non-consumptive users on: demographic information (e.g., age, gender, ethnicity/race), social structure information (e.g., historical participation, affiliation with NGOs, perceived conflicts), other cultural information (e.g., occupational motivation, cultural traditions related to resource's use), and community information.
- In order to improve the management-oriented understanding of historical stock trends and related assessments, the social and economic history of the river herring fisheries should be documented for time periods equivalent to the stock return level sought by the biological standards and this analysis should including documenting market trends, consumer preferences including recreational anglers, the role of product substitutes such as Atlantic herring and menhaden, and the levels of subsistence fisheries as can be obtained.
- Before recommending, re-authorizing and/or implementing stock enhancement programs for a given river system, it is recommended that state agencies or other appropriate management organization conduct *ex-ante* socioeconomic cost and benefit (e.g., estimate non-consumptive and existence values, etc.) analysis of proposed stocking programs.

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12. GLOSSARY

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

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

All other definitions were developed by the Plan Development Team.

Anadromous*
Fishes that migrate as juveniles from freshwater to saltwater and then return as adults to spawn in freshwater; most Pacific salmon are anadromous.

Area Under the Curve
An estimate of the relative annual abundance of a fish spawning run based on daily fish sample counts over the entire run period. Sample counts can be from fish passage counts at a fishway, or from systematic fishery sampling located downstream of the in-river spawning area, prior to spawning.

Baseline*
A set of reference data sets or analyses used for comparative purposes; it can be based on a reference year or a reference set of (standard) conditions.

Benchmarks**
A particular value of stock size, catch, fishing effort, fishing mortality, and total mortality that may be used as a measurement of stock status or management plan effectiveness. Sometimes these may be referred to as biological reference points.

Biological Reference Points*
1. A biological benchmark against which the abundance of the stock or the fishing mortality rate can be measured in order to determine its status. These reference points can be used as limits or targets, depending on their intended usage;
2. Specific values for the variables that describe the state of a fishery system which are used to evaluate its status. Reference points are most often specified in terms of fishing mortality rate and/or spawning stock biomass. These may indicate (a) a desired state of the fishery, such as a fishing mortality rate that will achieve a high level of sustainable yield, or (b) a state of the fishery that should be avoided, such as a high fishing mortality rate which risks a stock collapse and long-term loss of potential yield. The former are referred to as “target reference points,” and the latter are referred to as “limit reference points” or “thresholds.” Some common examples are $F_{0.1}$, F_{MAX}, and F_{MSY}.

Biomass (B)*
1. Or standing stock. The total weight of a group (or stock) of living organisms (e.g. fish, plankton) or of some defined fraction of it (e.g. spawners) in an area, at a particular time; 2. Measure of the quantity, usually by weight in pounds or metric tons (2,205 pounds or 1 metric ton), of a stock at a given time.

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

Carrying Capacity*
1. The maximum population of a species that an area or specific ecosystem can support indefinitely without deterioration of the character and quality of the resource;
2. The level of use, at a given level of management, at which a natural or man-made resource can sustain itself over a long period of time. For example, the maximum level of recreational use, in terms of numbers of people and types of activity that can be accommodated before the ecological value of the area declines.

Catch Curve**
An age-based analysis of the catch in a fishery that is used to estimate total mortality of a fish stock. Total mortality is calculated by taking the negative slope of the logarithm of the number of fish caught at successive ages (or with 0, 1, 2... annual spawning marks).

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

Catch Rate*
Means sometimes the amount of catch per unit time and sometimes the catch per unit effort.

Cohort*
1. In a stock, a group of fish generated during the same spawning season and born during the same time period;
2. In cold and temperate areas, where fish are long-lived, a cohort corresponds usually to fish born during the same year (a year class). For instance, the 1987 cohort would refer to fish that are age 0 in 1987, age 1 in 1988, and so on. In the tropics, where fish tend to be short lived, cohorts may refer to shorter time intervals (e.g. spring cohort, autumn cohort, monthly cohorts). (see *Year Class*)

Cohort Analysis*
A retrospective analysis of the catches obtained from a given year class at each age (or length interval) over its life in the fishery. Allows estimation of fishing mortality and abundance at each age as well as recruitment. Involves the use of a simplified algorithm based on an approximation that assumes that, in a given time period, all fishing takes place instantaneously in the middle of the time period.

De minimis**
Status obtained by states with minimal fisheries for a certain species and that meet specific provisions described in fishery management plans allowing them to be exempted from specific management requirements of the fishery management plan to the extent that action by the particular States to implement and enforce the plan is not necessary for attainment of the fishery management plan's objectives and the conservation of the fishery.

Depleted Stock*
A stock driven by fishing to very low level of abundance compared to historical levels, with dramatically reduced spawning biomass and reproductive capacity. It requires particularly energetic rebuilding

strategies and its recovery time will depend on the present condition, the level of protection, and the environmental conditions.

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

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

Economic Overfishing*
A level of fish harvesting that is higher than that of economic efficiency; harvesting more fish than necessary to have maximum profits for the fishery.

Economic Value*
The most people are willing to pay to use a given quantity of a good or service; or, the smallest amount people are willing to accept to forego the use of a given quantity of a good or service.

Ecosystem Approach to Fisheries (EAF)*
An approach to fisheries management that strives to balance diverse societal objectives by taking into account the knowledge and uncertainties about biotic, abiotic, and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries. The purpose of EAF is to plan, develop, and manage fisheries in a manner that addresses the multiple needs and desires of society, without jeopardizing the options for future generations to benefit from the full range of goods and services provided by marine ecosystems.

Ecosystem Approach to Management (EAM)*
Management that is adaptive, is specified geographically, takes into account ecosystem knowledge and uncertainties, considers multiple external influences, and strives to balance diverse social objectives.

Ecosystem Function*
An intrinsic ecosystem characteristic related to the set of conditions and processes whereby an ecosystem maintains its integrity. Ecosystem functions include such processes as decomposition, production, nutrient cycling, and fluxes of nutrients and energy.

Ecosystem-Based Management*
An approach that takes major ecosystem components and services—both structural and functional—into account in managing fisheries. It values habitat, embraces a multispecies perspective, and is committed to understanding ecosystem processes. Its goal is to rebuild and sustain populations, species, biological communities, and marine ecosystems at high levels of productivity and biological diversity so as not to jeopardize a wide range of goods and services from marine ecosystems while providing food, revenue, and recreation for humans.

Equilibrium Catch*
The catch (in numbers) taken from a fish stock when it is in equilibrium with fishing of a given intensity, and (apart from the effects of environmental variation) its abundance is not changing from one year to the next.

Equilibrium Yield (EY)*
The yield in weight taken from a fish stock when it is in equilibrium with fishing of a given intensity, and (apart from effects of environmental variation) its biomass is not changing from one year to the next. Also called: sustainable yield, equivalent sustainable yield.

Escapement*
The number or proportion of fish surviving (escaping from) a given fishery at the end of the fishing season and reaching the spawning grounds. The term is generally used for salmon management.

Exclusive Economic Zone (EEZ)*
The EEZ is the area that extends from the seaward boundaries of the coastal states (3 nautical miles (n.mi.) in most cases, the exceptions are Texas, Puerto Rico and the Gulf coast of Florida at 9 n.mi.) to 200 n.mi. off the U.S. coast. Within this area the United States claims and exercises sovereign rights and exclusive fishery management authority over all fish and all continental shelf fishery resources.

Existence Value*
The economic value of knowing that a resource exists, irrespective of the ability to use the resource now or in the future.9

Exploitable Biomass*
Refers to that portion of a stock's biomass that is available to fishing.

Exploitation**
The annual percentage of the stock removed by fishing either recreationally or commercially.

Exploitation Pattern*
The distribution of fishing mortality over the age composition of the fish population, determined by the type of fishing gear, area and seasonal distribution of fishing, and the growth and migration of the fish. The pattern can be changed by modifications to fishing gear; for example, increasing mesh or hook size, or by changing the ratio of harvest by gears exploiting the fish (e.g. gillnet, trawl, hook and line, etc.).

Exploitation Rate*
The proportion of a population at the beginning of a given time period that is caught during that time period (usually expressed on a yearly basis). For example, if 720,000 fish were caught during the year from a population of 1 million fish alive at the beginning of the year, the annual exploitation rate would be 0.72.

Ex-Vessel*
Refers to activities that occur when a commercial fishing boat lands or unloads a catch. For example, the price received by a captain (at the point of landing) for the catch is an ex-vessel price.

Fecundity*
The potential reproductive capacity of an organism or population expressed in the number of eggs (or offspring) produced during each reproductive cycle. Fecundity usually increases with age and size. The information is used to compute spawning potential.

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

Fish Passage Efficiency**
The percent of the fish stock captured or passed through an obstruction (i.e., dam) to migration.

Fishery-Dependent*
Data collected directly on a fish or fishery from commercial or sport fishermen and seafood dealers. Common methods include logbooks, trip tickets, port sampling, fishery observers, and phone surveys. (see *Fishery-Independent*)

Fishery-Independent*
Characteristic of information (e.g. stock abundance index) or an activity (e.g. research vessel survey) obtained or undertaken independently of the activity of the fishing sector. Intended to avoid the biases inherent to fishery-related data. (see *Fishery-Dependent*)

Fishery Management Unit (FMU)*
A fishery or a portion of a fishery identified in a fishery management plan (FMP) relevant to the FMP's management objectives. The choice of stocks or species in an FMU depends upon the focus of FMP objectives, and may be organized around biological, geographic, economic, technical, social, or ecological perspectives.

Fishing Mortality (F)*
1. F stands for the fishing mortality rate in a particular stock. It is roughly the proportion of the fishable stock that is caught in a year;
2. A measurement of the rate of removal from a population by fishing. Fishing mortality can be reported as either annual or instantaneous. Annual mortality is the percentage of fish dying in one year. Instantaneous mortality is that percentage of fish dying at any one time.

F_{30}
The fishing mortality rate that reduces the spawning stock biomass per recruit (SSB/R) to 30% of the amount present in the absence of fishing.

F_{MSY}*
The fishing mortality rate that, if applied constantly, would result in maximum sustainable yield (MSY). Used as a biological reference point, FMSY is the implicit fishing mortality target of many regional and national fishery management authorities and organizations. F_{MSY} can be estimated in two ways: a) from simple biomass aggregated production models; b) from age-structured models that include a stock-recruitment relationship.

F_{MAX}*
1. The level of fishing mortality (rate of removal by fishing) that produces the greatest yield from the fishery;
2. A biological reference point. It is the fishing mortality rate that maximizes equilibrium yield per recruit. FMAX is the F level often used to define growth overfishing. In general, FMAX is different (and higher) than FMSY depending on the stock-recruitment relationship. By definition, FMAX is always higher than $F_{0.1}$.

Index of Abundance*
A relative measure of the abundance of a stock; for example, a time series of catch per unit effort data.

Indicators*
1. A variable, pointer, or index. Its fluctuation reveals the variations in key elements of a system. The position and trend of the indicator in relation to reference points or values indicate the present state and dynamics of the system. Indicators provide a bridge between objectives and action;

2. Signals of processes, inputs, outputs, effects, results, outcomes, impacts, etc., that enable such phenomena to be judged or measured. Both qualitative and quantitative indicators are needed for management learning, policy review, monitoring, and evaluation;
3. In biology, an organism, species, or community whose characteristics show the presence of specific environmental conditions, good or bad.

Instantaneous Rate of Fishing Mortality (F)*
When fishing and natural mortality act concurrently, F is equal to the instantaneous total mortality rate, multiplied by the ratio of fishing deaths to all deaths. Also called: rate of fishing; instantaneous rate of fishing.

Instantaneous Rate of Mortality (Z)*
When fishing and natural mortality act concurrently, the natural logarithm of the survival rate (with sign changed) for deaths due to either natural causes (instantaneous rate of natural mortality, M) or due to fishing mortality (instantaneous rate of fishing mortality,
F). The instantaneous rate of total mortality, Z, is the sum of these two rates: $Z = F + M$, also called the coefficient of decrease.

Comment: Usually given on a yearly basis; the figure just described is divided by the fraction of a year represented by the “short interval” in question. This concept is used principally when the size of the vulnerable stock is not changing or is changing only slowly, since among fishes recruitment is not usually associated with stock size in the direct way in which mortality and growth are.

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

Life Cycle*
Successive series of changes through which an organism passes in the course of its development.

Limit Reference Points*
Benchmarks used to indicate when harvests should be constrained substantially so that the stock remains within safe biological limits. The probability of exceeding limits should be low. In the National Standard Guidelines, limits are referred to as thresholds. In much of the international literature (e.g. United Nations Food and Agricultural Organization, FAO) thresholds are used as buffer points that signal when a limit is being approached.

M
(see Natural Mortality)

Management Objective*
A formally established, more or less quantitative target that is actively sought and provides a direction for management action.

Management Reference Points*
Conventional (agreed values) of indicators of the desirable or undesirable state of a fishery resource of the fishery itself. Reference points could be biological (e.g. expressed in spawning biomass or fishing mortality levels), technical (fishing effort or capacity levels) or economic (employment or revenues levels). They are usually calculated from models in which they may represent critical values.

Management Strategy*
The strategy adopted by the management authority to reach established management goals. In addition to the objectives, it includes choices regarding all or some of the following: access rights and allocation of resources to stakeholders, controls on inputs (e.g. fishing capacity, gear regulations), outputs (e.g. quotas, minimum size at landing), and fishing operations (e.g. calendar, closed areas, and seasons).

Mature Individuals*
The number of individuals known, estimated, or inferred to be capable of reproduction.

Maturity*
Refers to the ability, on average, of fish of a given age or size to reproduce. Maturity information, in the form of percent mature by age or size, is often used to compute spawning potential.

Maximum Spawning Potential (MSP)*
This type of reference point is used in some fishery management plans to define overfishing. The MSP is the spawning stock biomass per recruit (SSB/R) when fishing mortality is zero. The degree to which fishing reduces the SSB/R is expressed as a percentage of the MSP (i.e. %MSP). A stock is considered overfished when the fishery reduces the %MSP below the level specified in the overfishing definition. The values of %MSP used to define overfishing can be derived from stock-recruitment data or chosen by analogy using available information on the level required to sustain the stock.

Maximum Sustainable Yield (MSY)*
The largest average catch or yield that can continuously be taken from a stock under existing environmental conditions. For species with fluctuating recruitment, the maximum might be obtained by taking fewer fish in some years than in others. Also called: maximum equilibrium catch; maximum sustained yield; sustainable catch.

Minimum Stock Size Threshold (MSST, $B_{threshold}$)*
Another of the status determination criteria (SDC). The greater of (a) 1/2 B_{MSY} , or (b) the minimum stock size at which rebuilding to B_{MSY} will occur within 10 years while fishing at the maximum fishing mortality threshold (MFMT). MSST should be measured in terms of spawning biomass or other appropriate measures of productive capacity. If current stock size is below $B_{threshold}$, the stock is overfished.

Moratorium*
A mandatory cessation of fishing activities on a species (e.g. the blue whale), in an area (e.g. a sanctuary), with a particular gear (e.g. large scale driftnets), and for a specified period of time (temporary, definitive, seasonal, or related to reopening criteria).

Mortality*
Measures the rate of death of fish. Mortality occurs at all life stages of the population and tends to decrease with age. Death can be due to several factors such as pollution, starvation, and disease but the main source of death is predation (in unexploited stocks) and fishing (in exploited ones).

Mortality Rate*
The rate at which the numbers in a population decrease with time due to various causes. Mortality rates are critical parameters in determining the effects of harvesting strategies on stocks, yields, revenues, etc. The proportion of the total stock (in numbers) dying each year is called the "annual mortality rate."

Native Species*
A local species that has not been introduced. (see *Introduced Species, Invasive Species*)

Natural Mortality (M)*
1. Deaths of fish from all causes except fishing (e.g. ageing, predation, cannibalism, disease, and perhaps increasingly pollution). It is often expressed as a rate that indicates the percentage of fish dying in a year; e.g. a natural mortality rate of 0.2 implies that approximately 20 percent of the population will die in a year from causes other than fishing;
2. The loss in numbers in a year class from one age group to the subsequent one, due to natural death.

Comment: These many causes of death are usually lumped together for convenience, because they are difficult to separate quantitatively. Sometimes natural mortality is confounded with losses of fish from the stock due to emigration. M has proven very difficult to estimate directly, and is often assumed based on the general life history. The M value is also often assumed to remain constant through time and by age, a very unlikely assumption.

Natural Mortality (M)**
The instantaneous rate at which fish die from all causes other than harvest or other human-induced cause (i.e., turbine mortality). Some sources of natural mortality include predation, spawning mortality, and senescence (old age).

Non-Consumptive Use*
Individuals may use (i.e. observe), yet not consume, certain living ocean resources, like whale watching, sight-seeing, or scuba diving. Additionally, individuals might value the mere existence of living ocean resources without actually observing them.

Non-Point Sources*
Sources of sediment, nutrients, or contaminants that originate from many locations.

Non-Target Species*
Species not specifically targeted as a component of the catch; may be incidentally captured as part of the targeted catch.

Ocean-Intercept Fishery**
A fishery for American shad conducted in state or federal ocean waters targeting the coastal migratory mixed-stock of American shad.

Optimum Yield (OY)*
1. The harvest level for a species that achieves the greatest overall benefits, including economic, social, and biological considerations. Optimum yield (OY) is different from maximum sustainable yield (MSY) in that MSY considers only the biology of the species. The term includes both commercial and sport yields;
2. The amount of fish that will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities and taking into account the protection of marine ecosystems. MSY constitutes a “ceiling” for OY. OY may be lower than MSY, depending on relevant economic, social, or ecological factors. In the case of an overfished fishery, OY should provide for the rebuilding of the stock to
BMSY.

Overexploited*
When stock abundance is too low. The term is used when biomass has been estimated to be below a limit biological reference point that is used as the threshold that defines “overfished conditions.”

Overfished*
1. An overfished stock or stock complex “whose size is sufficiently small that a change in management practices is required to achieve an appropriate level and rate of rebuilding.” A stock or stock complex is considered overfished when its population size falls below the minimum stock size threshold (MSST). A rebuilding plan is required for stocks that are deemed overfished;
2. A stock is considered “overfished” when exploited beyond an explicit limit beyond which its abundance is considered ‘too low’ to ensure safe reproduction. In many fisheries the term is used when biomass has been estimated to be below a limit biological reference point that is used as the signpost defining an “overfished condition.” This signpost is often taken as being F_{MSY}, but the usage of the term may not always be consistent. (see *Minimum Stock Size Threshold*)

Comment: The stock may remain overfished (i.e. with a biomass well below the agreed limit) for some time even though fishing pressure might be reduced or suppressed.

Overfishing*
1. According to the National Standard Guidelines, “overfishing occurs whenever a stock or stock complex is subjected to a rate or level of fishing mortality that jeopardizes the capacity of a stock or stock complex to produce maximum sustainable yield (MSY) on a continuing basis.” Overfishing is occurring if the maximum fishing mortality threshold (MFMT) is exceeded for 1 year or more;
2. In general, the action of exerting fishing pressure (fishing intensity) beyond the agreed optimum level. A reduction of fishing pressure would, in the medium term, lead to an increase in the total catch. (see *National Standard Guidelines*, *Maximum Fishing Mortality Threshold*, *Maximum Sustainable Yield*)

Comment: For long-lived species, overfishing (i.e. using excessive effort) starts well before the stock becomes overfished. The use of the term “overfishing” may not always be consistent.

Overfishing Limit (OFL)*
Point at which fishing seriously compromised a fishery’s continued, sustained productivity. Overfishing limits may be set based on standardized biological criteria established for a particular fishery. Overfishing limits may also incorporate economic and social considerations relevant to a particular fishery.

Oxytetracycline (OTC)**
An antibiotic used to internally mark otoliths of hatchery produced fish.

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

Pre-Recruits*
Fish that have not yet reached the recruitment stage (in age or size) to a fishery.

Production*
1. The total output especially of a commodity or an industry;
2. The total living matter (biomass) produced by a stock through growth and recruitment in a given unit of time (e.g. daily, annual production). The “net production” is the net amount of living matter added to the stock during the time period, after deduction of biomass losses through mortality;
3. The total elaboration of new body substance in a stock in a unit of time, irrespective of whether or not it survives to the end of that time.

Production Model*
1. The highest theoretical equilibrium yield that can be continuously taken (on average) from a stock under existing (average) environmental conditions without affecting significantly the reproduction process. Also referred to sometimes as potential yield;
2. Maximum sustainable yield (MSY) or sustainable yield (SY). The largest average catch or yield that can continuously be taken from a stock under existing environmental conditions. For species with fluctuating recruitment, the maximum might be obtained by taking fewer fish in some years than in others. (see *Carrying Capacity*, *Maximum Sustainable Yield*, *Sustainable Yield*)

Productivity*
Relates to the birth, growth and death rates of a stock. A highly productive stock is characterized by high birth, growth, and mortality rates, and as a consequence, a high turnover and production to biomass ratios (P/B). Such stocks can usually sustain higher exploitation rates and, if depleted, could recover more rapidly than comparatively less productive stocks.

Rebuilding*
1. Implementing management measures that increase a fish stock to its target size1; 2. For a depleted stock, or population, taking action to allow it to grow back to a predefined target level. Stock rebuilding at least back to the level (BMSY) at which a stock could produce maximum sustainable yield (MSY).

Rebuilding Analysis*
An analysis that uses biological information to describe the probability that a stock will rebuild within a given time frame under a particular management regime.

Rebuilding Plan*
1. A document that describes policy measures that will be used to rebuild a fish stock that has been declared overfished;
2. A plan that must be designed to recover stocks to the BMSY level within 10 years when they are overfished (i.e. when biomass [B] < minimum stock size threshold [MSST]). (see *Minimum Stock Size Threshold*)

Recruit*
1. A young fish entering the exploitable stage of its life cycle;
2. A member of "the youngest age group which is considered to belong to the exploitable stock."

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

Recruitment Overfishing*
A situation in which the rate of fishing is (or has been) such that annual recruitment to the exploitable stock has become significantly reduced. The situation is characterized by a greatly reduced spawning stock, a decreasing proportion of older fish in the catch, and generally very low recruitment year after year. If prolonged, recruitment overfishing can lead to stock collapse, particularly under unfavorable environmental conditions.

Recruits*
The numbers of young fish that survive (from birth) to a specific age or grow to a specific size. The specific age or size at which recruitment is measured may correspond to when the young fish become vulnerable to capture in a fishery or when the number of fish in a cohort can be reliably estimated by a stock assessment.

Reference Level*
A particular level of an indicator (e.g. level of fishing effort, fishing mortality, or stock size) used as a benchmark for assessment and management performance.

Reference Point*
1. A reference point indicates a particular state of a fishery indicator corresponding to a situation considered as desirable (target reference point) or undesirable and requiring immediate action (limit reference point and threshold reference point);
2. An estimated value derived from an agreed scientific procedure and/or model, which corresponds to a specific state of the resource and of the fishery, and that can be used as a guide for fisheries management. Reference points may be general (applicable to many stocks) or stock-specific;
3. Values of parameters (e.g. B_{MSY}, F_{MSY}, $F_{0.1}$) that are useful benchmarks for guiding management decisions. Biological reference points are typically limits that should not be exceeded with significant probability (e.g. MSST) or targets for management (e.g. OY).

Relative Exploitation**
An approach used when catch is known or estimated, but no estimates of abundance are available. For example, it may be calculated as the catch divided by a relative index of abundance. Long-term trends in relative exploitation are can be useful in evaluating the impact of fishing versus other sources of mortality.

Restoration**
In this assessment, this describes the stocking of hatchery produced young-of-year American shad to augment wild cohorts and the transfer of adult American shad to rivers with depleted spawning stocks. Restoration also includes efforts to improve fish passage or remove barriers to migration.

Risk*
1. In general, the possibility of something undesirable happening, of harm or loss. A danger or a hazard. A factor, thing, element, or course involving some uncertain danger;
2. In decision-theory, the degree or probability of a loss; expected loss; average forecasted loss. This terminology is used when enough information is available to formulate probabilities;
3. The probability of adverse effects caused under specified circumstances by an agent in an organism, a population, or an ecological system.

Risk Assessment*
A process of evaluation including the identification of the attendant uncertainties, of the likelihood and severity of an adverse effect(s)/event(s) occurring to man or the environment following exposure under defined conditions to a risk source(s). A risk assessment comprises hazard identification, hazard characterization, exposure assessment, and risk characterization.

Risk Management*
The process of weighing policy alternatives in the light of the result of a risk assessment and other relevant evaluation and, if required, selecting and implementing appropriate control options (which should, where appropriate, include monitoring or surveillance).

River Complex
The freshwater portions of an Atlantic coast river, and its associated tributaries and estuary that encompass the freshwater migration, spawning, and nursery habitat for an American shad stock.
Robustness*
The capacity of a population to persist in the presence of fishing. This depends on the existence of compensatory mechanisms. (see *Reliability*)

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

Run Size**
The magnitude of the upriver spawning migration of American shad.

Semelparous**
Life history strategy in which an organism only spawns once before dying.

Spawning Biomass*
The total weight of all sexually mature fish in the population.

Spawning Ground
The area of suitable spawning habitat associated with a stock.

Spawning Stock*
1. Mature part of a stock responsible for reproduction;
2. Strictly speaking, the part of an overall stock having reached sexual maturity and able to spawn. Often conventionally defined as the number or biomass of all individuals beyond "age at first maturity" or "size at first maturity"; that is, beyond the age or size class in which 50 percent of the individuals are mature.

Spawning Stock Biomass (SSB)*
1. The total weight of all fish (both males and females) in the population that contribute to reproduction. Often conventionally defined as the biomass of all individuals beyond "age at first maturity" or "size at first maturity," i.e. beyond the age or size class in which 50 percent of the individuals are mature;
2. The total biomass of fish of reproductive age during the breeding season of a stock.

Comment: Most often used as a proxy for measuring egg production, the SSB depends on the abundance of the various age classes composing the stock and their past exploitation pattern, rate of growth, fishing and natural mortality rates, onset of sexual maturity, and environmental conditions.

Spawning Stock Biomass**
The total weight of mature fish (often females) in a stock.

Spawning Stock Biomass per Recruit (SSB/R or SBR)*
The expected lifetime contribution to the spawning stock biomass for the average recruit, SSB/R is calculated assuming that fishing mortality is constant over the life span of a year class. The calculated value is also dependent on the exploitation pattern and rates of growth and natural mortality, all of which are also assumed to be constant.

Standing Stock*
1. The total weight of a group (or stock) of living organisms (e.g. fish, plankton) or of some defined fraction of it (e.g. spawners), in an area, at a particular time. Example: the spawning biomass of the cod stock on the Georges Bank in 1999;
2. The weight of a fish stock or of some defined portion of it. (see *Abundance*)

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

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

Stock-Recruitment Relationship (SRR)*
The relationship between the level of parental biomass (e.g. spawning stock size) and subsequent recruitment level. Determination of this relationship is useful to analyze the sustainability of alternative harvesting regimes and the level of fishing beyond which stock collapse is likely. The relation is usually blurred by environmental variability and difficult to determine with any accuracy.

Comment: Such a relationship always exists in principle, in that the existence of a parent stock is a prerequisite for the generation of recruitment. However, in many cases there exist regulatory mechanisms such that the number of recruits is not strongly related to the parent stock size over the range of stock sizes observed: this situation is sometimes described as the absence of a stock recruitment relationship, but is more logically described as a special case of a stock-recruitment relationship. Some stock assessment methods incorporate the estimation of such a relationship directly into the model, either explicitly (e.g. some age-structured assessments) or implicitly (most stock production models).

Stock Status**
The agreed perspective of the SASC of the relative level of fish abundance.

Sub-adult**
Juvenile American shad which are part of the ocean migratory mixed stock fish.

Surplus Production*
1. The amount of biomass produced by the stock (through growth and recruitment) over and above that which is required to maintain the total stock biomass at a constant level between consecutive time periods;
2. Production of new biomass by a fishable stock, plus recruits added to it, less what is removed by natural mortality. This is usually estimated as the catch in a given year plus the increase in stock size (or less the decrease). Also called: natural increase, sustainable yield, and equilibrium catch.

Survival Rate*
Number of fish alive after a specified time interval, divided by the initial number. Usually on a yearly basis.

Survival Ratio*
1. Ratio of recruits to spawners (or parental biomass) in a stock-recruitment analysis. Changes in survival ratios indicate that the productivity of a stock is changing;
2. Number of fish alive after a specified time interval, divided by the initial number. Usually calculated on a yearly basis.

Sustainability*
1. Ability to persist in the long-term. Often used as “short hand” for sustainable development;
2. Characteristic of resources that are managed so that the natural capital stock is non-declining through time, while production opportunities are maintained for the future.

Sustainable Catch (Yield)*
The number (weight) of fish in a stock that can be taken by fishing without reducing the stock biomass from year to year, assuming that environmental conditions remain the same.

Sustainable Fishery
Systems that demonstrate their stocks could support a commercial and/or recreational fishery that will not diminish potential future stock reproduction and recruitment.

Sustainable Fishing*
Fishing activities that do not cause or lead to undesirable changes in the biological and economic productivity, biological diversity, or ecosystem structure and functioning from one human generation to the next.
Comment: Fishing is sustainable when it can be conducted over the long-term at an acceptable level of biological and economic productivity without leading to ecological changes that foreclose options for future generations.

Sustainable Yield*
1. Equilibrium yield;
2. The amount of biomass or the number of units that can be harvested currently in a fishery without compromising the ability of the population/ecosystem to regenerate itself.

Target Reference Point (TRP)*
1. Benchmarks used to guide management objectives for achieving a desirable outcome (e.g. optimum yield, OY). Target reference points should not be exceeded on average;
2. Corresponds to a state of a fishery or a resource that is considered desirable. Management action, whether during a fishery development or a stock rebuilding process, should aim at bringing the fishery system to this level and maintaining it there. In most cases a TRP will be expressed in a desired level of output for the fishery (e.g. in terms of catch) or of fishing effort or capacity, and will be reflected as an explicit management objective for the fishery.

Target Species*
Those species primarily sought by the fishermen in a particular fishery. The subject of directed fishing effort in a fishery. There may be primary as well as secondary target species.

Thresholds*
1. Levels of environmental indicators beyond which a system undergoes significant changes; points at which stimuli provoke significant response;
2. A point or level at which new properties emerge in an ecological, economic, or other system, invalidating predictions based on mathematical relationships that apply at lower levels. For example, species diversity of a landscape may decline steadily with increasing habitat degradation to a certain

point, and then fall sharply after a critical threshold of degradation is reached. Human behavior, especially at group levels, sometimes exhibits threshold effects. Thresholds at which irreversible changes occur are especially of concern to decision-makers.

Total Mortality (Z)*
1. A measurement of the rate of removal of fish from a population by both fishing and natural causes. Total mortality can be reported as either annual or instantaneous. Annual mortality is the percentage of fish dying in 1 year. Instantaneous mortality is that percentage of fish dying at any one time;
2. The sum of natural (M) and fishing (F) mortality rates.

Turbine Mortality**
American shad mortalities that are caused by fish passing through the turbines of hydroelectric dams during return migrations to the sea.

Unit Stock*
A population of fish grouped together for assessment purposes, which may or may not include all the fish in a stock. (see *Stock*)

Variable*
Anything changeable. A quantity that varies or may vary. Part of a mathematical expression that may assume any value.

Virgin Biomass (B_0)*
The average biomass of a stock that has yet not been fished (in an equilibrium sense). Biomass of an unexploited (or quasi unexploited) stock. Rarely measured. Most often inferred from stock modeling. Used as a reference value to assist the relative health of a stock, monitoring changes in the ratio between current and virgin biomass (B/B_0). It is usually assumed that, in absence of better data, $B = 0.30\ B_0$ is a limit below which a stock should not be driven.

Comment: Virgin Biomass corresponds to a stock's theoretical carrying capacity.

Vulnerability*
A term equivalent to catchability (q) but usually applied to separate parts of a stock, for example those of a particular size, or those living in a particular part of the range.

Water Quality*
The chemical, physical, and biological characteristics of water in respect to its suitability for a particular purpose.

Water Quality Criteria*
Specific levels of water quality desired for identified uses, including drinking, recreation, farming, fish production, propagation of other aquatic life, and agricultural and industrial processes.

Watershed*
The areas which supplies water by surface and subsurface flow from rain to a given point in the drainage system.

Year Class*
Fish in a stock born in the same year. For example, the 1987 year class of cod includes all cod born in 1987. This year class would be age 1 in 1988, age 2 in 1989, and so on. Occasionally, a stock produces a

very small or very large year class that can be pivotal in determining stock abundance in later years. (see *Cohort*)

Yield*
1. The yield curve is the relationship between the expected yield and the level of fishing mortality or (sometimes) fishing effort;
2. Catch in weight. Catch and yield are often used interchangeably. Amount of production per unit area over a given time. A measure of agricultural production.

Yield per Recruit (Y/R or YPR)*
1. A model that estimates yield in terms of weight, but more often as a percentage of the maximum yield, for various combinations of natural mortality, fishing mortality, and time exposed to the fishery;
2. The average expected yield in weight from a single recruit. Y/R is calculated assuming that fishing mortality is constant over the life span of a year class. The calculated value is also dependent on the exploitation pattern, rate of growth, and natural mortality rate, all of which are assumed to be constant.

Yield-per-Recruit Analysis*
Analysis of how growth, natural mortality, and fishing interact to determine the best size of animals at which to start fishing them, and the most appropriate level of fishing mortality. The yield-per-recruit models do not consider the possibility of changes in recruitment (and reproductive capacity) due to change in stock size. They also do not deal with environmental impacts.

Young-of-Year
(see Age 0)

Z
(see Total Mortality)

Appendix A – Economic Trends

An analysis of ex-vessel value trends for American shad landings, 1980 through 2007.
Raymond Rhodes, College of Charleston, Charleston, SC

Ex-vessel values reported with all U.S. Atlantic American shad landings during the 1980-2007 were used as an overall indicator of recent shad ex-vessel value trends (Table 1). The nominal total (aggregate) ex-vessel value of the U.S. Atlantic coast American shad harvest has ranged from a low of about $540,000 in 2006, after the ocean-intercept fishery closure was implemented in 2005 by all Atlantic states, to a high of over $2 million in 1984 (Table 1)**.** This 1984 value was also highest nominal total ex-vessel value reported since 1949 and associated with modest resurgences of shad landings previously described during the 1980's. Annual average nominal, ex-vessel value during the 1980-1993 period, ~$1.5 million, declined to an average of about $969,000 after 1993 (Table 1). Moreover, when shad total ex-vessel values are adjusted for inflation using the Producer Price Index[1], the average total ex-vessel value of American shad landings was only about $730,000 coastwide after 1993 (Table 1), only 52% of the total real ex-vessel value for previous period (1980-1993). Since 1980, nominal U.S. Atlantic coast dockside prices per pound for American shad have generally varied over time (Figure 2) but it did increase substantially after 2004 and peaked at $1.02 per pound in 2005 (Table 1), the first year of the ocean-intercept fishery closure. In contrast, the U.S. Atlantic real (deflated) price peaked in 1994 at a ~$0.77 per pound. The average real ex-vessel price for American shad during the 1993-2007 period, ~$0.53 per pound, was only about 26% higher than the average real ex-vessel price, $0.42 per pound, during the previous 14-year period despite declining stocks and related state various imposed moratoriums during the 1990's.

American shad data (see Table 1) were used to estimate a simple annual ex-vessel price model for characterizing how changes in American shad landings could have recently affected ex-vessel market prices. The following semi-log price model[2] was specified:

$$\textit{Real Ex-vessel Price}_t = \alpha + \beta(\ln)\textit{Landings}_t;$$

where the *Real Ex-vessel Price* is the observed annual (deflated) ex-vessel price per pound for American shad landings in U.S. Atlantic states, *(ln)Landings* is the natural log of the annual amount (poundage) of reported landings, *t* is time and α and β are parameter coefficients to be estimated for the above model. There are many complicated models or functional forms that could be used to explore the relationship between landings and ex-vessel prices but the choice of this semi-linear form was based on the limitations of the available data and the related need to have a relatively simple price model that is capable of adequately representing the variation in American shad ex-vessel prices associated with different levels of landings. Additionally, since the expected relationship between reported landings and ex-vessel prices is not likely to be linear, a semi-log (non-linear) functional form was selected. The semi-log model was estimated using ordinary least squares (OLS).

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[1] Given the scope of this analysis, the Producer Price Index was selected for deflating ex-vessel prices out of convenience. Regardless, deflating prices should be approached with caution especially when applying consumer oriented price index series to producer prices (Tomek & Robinson 2003).

[2] This simple model is often described as an inverse semi-log demand model; however, it usually includes more than one explanatory (independent) variable.

The estimated model parameters were the following:

$$\text{Real Ex-vessel Price}_t = 2.201 - 0.118(\ln)\text{Landings}_t$$

t-Statistics: (5.280) (-4.140)
Durbin-Watson statistic: 0.854

The adjusted R^2 was 0.374 (N=28) and the F-value (17.144) for the equation was significant ($p \leq 0.0001$).

The t-statistic for the American shad landings parameter is statistically significant at the 1% level, and landings are estimated to be negatively (inversely) related to annual American shad ex-vessel price. The estimated model as indicated by the R^2 "explains" only about 37% of the ex-vessel price trend variability during the 1980-2007 period. Of course, a more complex supply-demand system is definitely needed to consider many other factors (e.g., fishery regulatory actions, American shad substitutes, regional market structure changes, etc.) that may have influenced American shad ex-vessel prices. Regardless, the inverse relationship between prices and landings is consistent with supply-demand relationship over a relatively long time period (i.e., 21 years). Using the estimated coefficient of the landings parameter, *– 0.118*, and the means of the annual prices and quantities landed, the price flexibility[3], F_P, was estimated to be approximately *–3.6*. While recognizing the limitations of this simple price trend analysis, the calculated F_P value suggests that the ex-vessel own-price elasticity of demand for American shad during the years analyzed and perhaps American shad in general is inelastic since the absolute value of F_P coefficient is greater than one (Tomek and Robinson 2003).

This apparent relative flexibility of If American shad ex-vessel prices were relatively flexible in regard to its own landings during the 1980-2007 period, this may have also been symptomatic of a market that could have historically encouraged harvesters to actually escalate their fishing effort because they perceived an ex-vessel market segment with the potential of offsetting declining harvest quantities with higher ex-vessel prices. For open access fisheries, flexible prices (i.e., relatively inelastic demand) along with other factors have been implicated in the depletion of various fishery stocks (e.g., Brandt 1999). Consequently, from a historical perspective, total revenue changes at the harvester level associated with declining American shad stocks, including declines independent of commercial fishing effort, such as habitat degradation, may have been partially buffered if American shad prices were generally flexible relative to its own landings.

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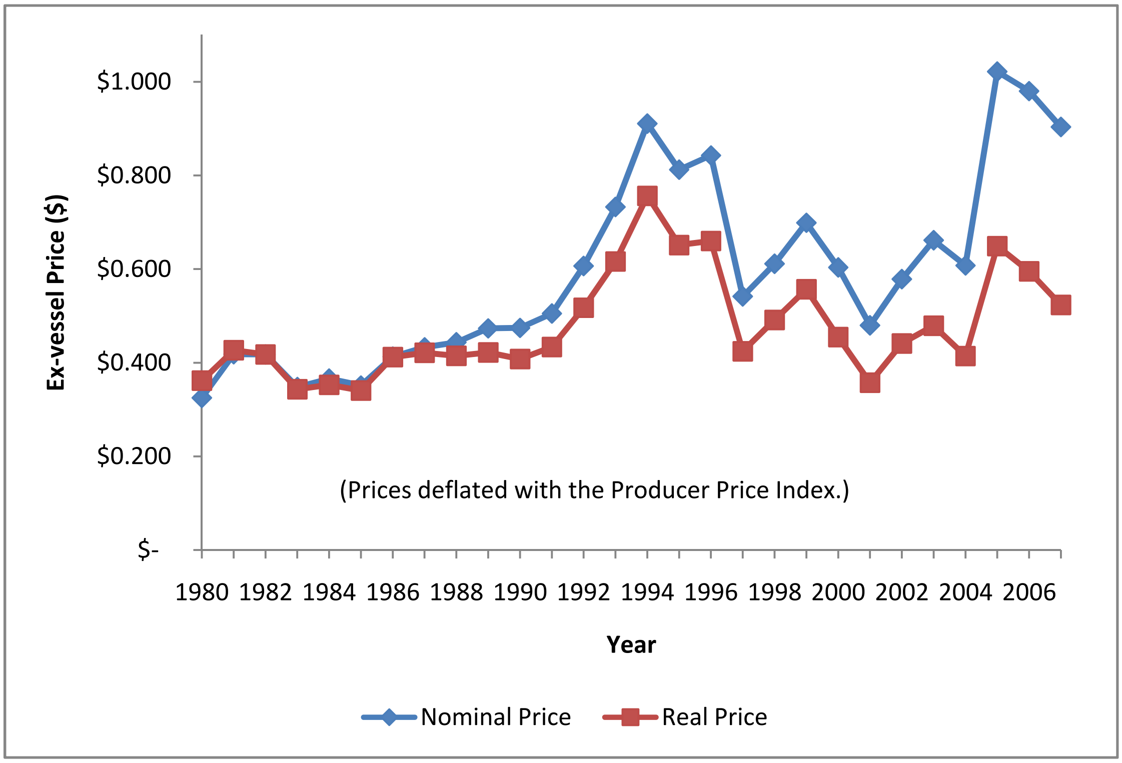
[3] It is actually the estimated own-price flexibility coefficient which is predicated on the causality of price changes stemming from quantity changes to the ex-vessel price, instead of the usual price to quantity causality (Tomek & Robinson 2003).

Table 1. Total annual U.S. Atlantic landings, ex-vessel values and prices of the American shad as reported to the National Marine Fisheries Service, 1980-2007 (Source: NMFS, Fisheries Statistics Division, Silver Spring, MD, pers. comm.).

	Landings	Total Ex-vessel Value ($):		Ex-vessel Price ($/lb):	
Year	(Lbs)	Nominal	Real[a]	Nominal	Real
1980	3,558,690	1,156,135	1,287,455	0.325	0.362
1981	3,207,067	1,341,312	1,368,686	0.418	0.427
1982	2,891,200	1,207,413	1,207,413	0.418	0.418
1983	3,753,052	1,305,500	1,288,746	0.348	0.343
1984	5,549,458	2,030,236	1,957,797	0.366	0.353
1985	3,994,868	1,403,789	1,360,261	0.351	0.341
1986	3,526,570	1,455,594	1,452,689	0.413	0.412
1987	3,801,049	1,646,246	1,601,407	0.433	0.421
1988	3,781,141	1,676,451	1,568,242	0.443	0.415
1989	3,521,651	1,666,895	1,485,646	0.473	0.422
1990	3,559,078	1,688,504	1,451,852	0.474	0.408
1991	2,829,719	1,429,109	1,226,703	0.505	0.434
1992	2,435,435	1,476,891	1,260,146	0.606	0.517
1993	2,015,913	1,476,996	1,242,217	0.733	0.616
1994	1,494,092	1,360,658	1,130,115	0.911	0.756
1995	1,637,349	1,329,852	1,066,441	0.812	0.651
1996	1,582,837	1,333,969	1,044,612	0.843	0.660
1997	1,833,467	992,832	778,082	0.542	0.424
1998	2,175,395	1,329,858	1,069,018	0.611	0.491
1999	1,406,080	982,818	783,122	0.699	0.557
2000	1,675,359	1,011,091	761,937	0.604	0.455
2001	1,490,404	714,801	532,639	0.480	0.357
2002	1,643,238	950,372	724,921	0.578	0.441
2003	1,509,898	998,804	723,247	0.662	0.479
2004	1,136,520	690,619	470,770	0.608	0.414
2005	609,592	622,779	395,666	1.022	0.649
2006	550,664	539,755	327,720	0.980	0.595
2007	776,316	701,408	406,378	0.904	0.523
Means, All Years:		**$ 1,151,690**	**$ 535,249**	**$ 0.534**	**$ 0.477**
Means, 1980-1993:		**$ 1,497,219**	**$ 1,411,376**	**$ 0.450**	**$ 0.421**
Means, 1994-2007:		**$ 968,544**	**$ 729,619**	**$ 0.732**	**$ 0.532**

[a] Total ex-vessel values and prices deflated with the Producer Price Index.

Figure 1. Real and nominal ex-vessel price ($/lb) for U.S. Atlantic American shad landings, 1980-2007 (Source: NMFS, Fisheries Statistics Division, Silver Spring, MD, pers. comm.).



Appendix B - Historic and current festivals, races and tournaments held in celebration of American shad spawning migrations

The following is a preliminary list of historic and current American shad festivals. This list is not comprehensive and is subject to update and modification. If you have any information of the status of listed events, or know of additional events not included, please contact Kate Taylor, Shad and River Herring FMP Coordinator, at ktaylor@asmfc.org.

EVENT	COMMUNITY	ORGANIZER/SPONSOR	DATE(S)	STATUS
Great American Shad Run	Manchester, NH	Unknown	June 18, 2000	Unknown
Connecticut River Museum Shad Festival	Essex, CT	Connecticut River Museum;	May 14, 2005 May 20, 2006 May 19, 2007	Unknown
Connecticut River Shad Bake [www.essexrotary.com/fundraisers/CT-Shad-Bake-Picnic/index.html]	Essex, CT	Essex Elementary School; Essex Rotary Club	June 6, 2009	51st annual, Active
Planked Shad Supper	Old Saybrook, CT	Connecticut Freemasons, Siloam Lodge #32	2005	Active?
Shad Derby Festival [www.windsorshadderby.org/events]	Windsor, CT	Shad Fest Bureau, Windsor Jaycees, Chamber of Commerce, Rod and Gun Club, others	May 2-4, 2009	Begun 1954, Active
Holyoke Gas and Electric Shad Derby [www.hged.com/html/shadderby.html]	Holyoke, MA	Holyoke Gas and Electric Company	May 10-18, 2008 May 2009	Begun 2003, Active
Shad Bake and Native American Technology Day [www.naihrv.org/]	Albany, NY	Corning Preserve; Native American Institute of the Hudson River Valley	May 11, 2008 May 16, 2009	Active
Shad Festival	Beacon, NY	Unknown	May , 1987	Believed to be inactive since 1993
Hudson Day	Bronx, NY	Unknown	June 14, 1987	Unknown

EVENT	**COMMUNITY**	**ORGANIZER/SPONSOR**	**DATE(S)**	**STATUS**
Hudson River Shad Festival [www.midhudsonnews.com/Catskill.htm]	Catskill, NY	The Catskill Point; Hudson River Foundation	May 21, 2005 May 21, 2009	Active
Annual Shad Bake and Country Barbecue [www.clctrust.org/Shad]	Chatham, NY	Columbia Land Conservancy	May 29, 2005	Active; but shad dropped from title for 2009
Riverlovers Shadfest [www.riverlovers.org/shadfest.htm]	Croton-on-Hudson, NY	Croton Point Park; Westchester County Parks, Riverlovers, Inc.	May 16, 2004 May 20, 2007 May 18, 2008 May 17, 2009	Active
Riverkeeper Shad Festival [www.riverkeeper.org]	Garrison, NY	Historic Boscobel Mansion; Boscobel Restoration	May 15, 2005 May 18, 2008	20th anniversary event will occur in 2010
Rondout Shad Festival [www.hrmm.org/museum/festival.htm]	Kingston, NY	Rondout; Hudson River Maritime Museum	May 12, 2007 May 10, 2008	Unknown
Drums Along the Hudson: a Native American Festival and Shad Fest [www.drumsalongthehudson.org/]	Manhattan, NY	Inwood Hill Park; New York City Department of Parks and Recreation, Lotus Music and Dance, WABC-TV, New York City Department of Cultural Affairs	April 30, 2006 May 3, 2008 May 17, 2009	Active; but shad dropped from title for 2009
Shad Festival	Montrose, NY	George’s Island Park; Ferry Sloops, Inc.	May, 1987 May 16, 1993	Unknown
Shad Festival	North Tarrytown, NY	?; Hudson River Foundation	May, 1987	Unknown
Nyack Shad Festival, aka Riverfest	Nyack, NY	Nyack Waterfront Park; Hudson River Foundation, Clearwater, Friends of the Nyacks	May 14, 2005 May 5, 2007	Unknown
Hudson River Festival and Shad Bake	Sparkill, NY	St. Charles A.M.E. Zion Church	April 30, 1994 April 30, 2005	Unknown
Shad Festival	Yonkers, NY	John Fitzgerald Kennedy Marina; Ferry Sloops, Inc.	April 25, 1993	Unknown

EVENT	COMMUNITY	ORGANIZER/SPONSOR	DATE(S)	STATUS
Annual Shad Bake	Edgewater, NJ	Veterans' Field; Farrell Huber American Legion Hall Post	June 6, 1987	Unknown
Shad Fest 2009 [bestofnj.com/2009/04/03/shad-fest-saturday-april-25-sunday-april-26-lambertville/]	Lambertville, NJ	multiple venues, multiple sponsors, including Lewis Island; Delaware River Basin Commission	April 26-27, 2008 April 25-26, 2009	Active
Hooked on the Hudson [www.stripedbassderby.com/HOH/]	Fort Lee, NJ	Ross Dock Recreation Area; Palisades Interstate Park Commission, Hudson River Fishermen's Association, others	May, 1987 May 6, 2001 April 25, 2009	Active; but no mention of shad in 2009
Bethlehem Shad Festival [mgfx.com/fishing/assocs/drsfa/shadfest.htm]	Bethlehem, PA	18th Century Industrial Area; Delaware River Shad Fishermen's Association	May 5, 1996 May 10, 1997	Begun 1978; Unknown
Fishtown Shad Festival [www.fishtownshadfest.org]	Fishtown, PA	Penn Treaty Park; Fishtown Area Business Association	April 25, 2009	Begun 2009, Active
Shad Run 5K [www.fishtownshadfest.org/2009_02_01_archive.html]	Fishtown, PA	Penn Treaty Park, Delaware Avenue; Fishtown Beer Runners, others	April 25, 2009	Active
Forks of the Delaware Shad Fishing Tournament and Festival [shadtournament.com/]	Easton, PA	Scott Park; City of Easton	April 25-May 9, 2009	Begun 1983, Active
Nanticoke River Shad Festival [www.nanticokeriver.org/shad%20fest%2009.html]	Vienna, MD	Vienna Waterfront; Chesapeake Bay Foundation, Nanticoke Watershed Alliance, City of Vienna, others	April 25, 2009	Begun 1995, Active
National Casting Call (shad fishing) RSVP REQUIRED, SEE WEB SITE [www.nationalcastingcall.com/]	District of Columbia	Fletcher's Cove; American Fly Fishing Trade Association, National Fish Habitat Action Plan, Association of Fish and Wildlife Agencies, U.S. Fish and Wildlife Service, many others (see web site)	April 27, 2009	Active
Annual Shad Planking [www.shadplanking.com/2009_planking_info.html]	Wakefield, VA	Wakefield Sportsmens Club; Wakefield Ruritan Club	April 15, 2009	61st annual, Active

EVENT	COMMUNITY	ORGANIZER/SPONSOR	DATE(S)	STATUS
Grifton Shad Festival (includes both species but primarily hickory) [www.grifton.com/shadfest.html]	Grifton, NC	Town Common Area and other venues, Town of Grifton	April 14-19, 2009	Begun 1969, 35th annual, Active
Cape Fear River Shad Festival [http://thingstodo.msn.com/riegelwood-nc/events/show/86706795-cape-fear-river-shad-festival]	Riegelwood, NC	Lock and Dam #1; Lower Bladen-Columbus Historical Society	April 11, 2009	Active

Appendix C – Alosine Habitat

Greene, K. E., J. L. Zimmerman, R. W. Laney, and J. C. Thomas-Blate. 2009. Atlantic coast diadromous fish habitat: A review of utilization, threats, recommendations for conservation, and research needs. Atlantic States Marine Fisheries Commission Habitat Management Series No. 9, Washington, D.C.

American shad Habitat Description

Habitats used by all Atlantic anadromous alosine species include spawning sites in coastal rivers and nursery areas, which include primarily freshwater portions of the rivers and their associated bays and estuaries. In addition to the spawning and nursery areas, adult habitats also consist of the nearshore ocean. Adult American shad have also been found to migrate up to 60 miles off the coast (Neves and Depres 1979). These habitats are distributed along the East Coast from the Bay of Fundy, Canada to Florida. Use of these habitats by migratory alosines may increase or diminish as the size of the population changes.

Spawning Habitat

Geographical and Temporal Patterns of Migration

The existing Atlantic coast stocks of American shad have a geographic range that currently extends from the St. Johns River, Florida, to the St. Lawrence River, Canada (see above for historic range). Scientists estimate that this species once ascended at least 130 rivers along the Atlantic coast to spawn, but today fewer than 70 systems have runs (Limburg et al. 2003). Most American shad return to their natal rivers and tributaries to spawn (Fredin 1954; Talbot 1954; Hill 1959; Nichols 1966; Carscadden and Leggett 1975), although on average, 3% stray to non-natal river systems (Mansueti and Kolb 1953; Williams and Daborn 1984; Melvin et al. 1985). In fact, Hendricks et al. (2002) demonstrated that hatchery-reared American shad homed to a specific tributary within the Delaware River system several years after stocking, and also preferred the side of the tributary influenced by the plume of their natal river.

The degree of homing by American shad may depend on the nature of the drainage system. If so, mixing of stocks and consequent straying would more likely occur in large and diversified estuarine systems, such as the Chesapeake Bay, while more precise homing could be expected in systems that have a single large river, such as the Hudson River (Richkus and DiNardo 1984).

Timing	Month	Location	Citation
Begin	December	St. Johns River, FL	Williams and Bruger 1972
Peak	January	St. Johns River, FL	Leggett 1976
Begin	mid-January	GA and SC	Walburg and Nichols 1967; Leggett and Whitney 1972
Begin	mid-February	NC and VA	Walburg and Nichols 1967; Leggett and Whitney 1972
Peak	March	NC and VA	Walburg and Nichols 1967; Leggett and Whitney 1972
Peak	April	Potomac River	Walburg and Nichols 1967; Leggett and Whitney 1972
Peak	early May	Delaware River	Walburg and Nichols 1967; Leggett and Whitney 1972
Range	March-June	Hudson & Connecticut rivers	Walburg and Nichols 1967; Leggett and Whitney 1972
Range	June-August	Androscoggin River, Maine	Brown and Sleeper 2004
End	July-August	Canadian rivers	MacKenzie et al. 1985; Scott and Scott 1988

Table 1. American shad temporal spawning trends along the Atlantic coast of North America

American shad spring spawning migrations begin in the south and move gradually north as the season progresses and water temperatures increase (Table 1; Walburg 1960). Spawning runs typically last 2-3 months, but may vary depending on weather conditions (Limburg et al. 2003). The diel timing of migration may not vary greatly from region to region. In the James River, Virginia, spawning adults ascended mostly between 0900 and 1600 hours (Weaver et al. 2003). Arnold (2000) reported similar results in the Lehigh River, Pennsylvania, where American shad passed primarily between 0900 and 1400 hours.

American shad show varied preferences for migration distance upstream depending on the river system. There does not seem to be a minimum distance from brackish waters at which spawning occurs (Leim 1924; Massmann 1952), but upstream and mid-river segments appear to be favored (Massmann 1952; Bilkovic et al. 2002). It is not unusual for American shad to travel 25 to 100 miles upstream to spawn; some populations historically migrated over 300 miles upstream (Stevenson 1899; Walburg and Nichols 1967). In the 18th and 19th centuries, American shad runs were reported as far inland as 451 miles along the Great Pee Dee and Yadkin rivers in North Carolina (Smith 1907) and over 500 miles in the Susquehanna River (Stevenson 1899).
Male American shad arrive at riverine spawning grounds before females (Leim 1924). Females release their eggs close to the water surface to be fertilized by one or several males. Diel patterns of egg release depend upon water turbidity and light intensity. In clear open water, eggs are released and fertilized after sunset (Leim 1924; Whitney 1961), with peak spawning around midnight (Massmann 1952; Miller et al. 1971; 1975). In turbid waters (or on overcast days; Miller et al. 1982), eggs are released and fertilized during the day (Chittenden 1976a). For example, in the Pamunkey River, Virginia, spawning has been observed throughout the day, which may be due to relatively turbid waters damping light intensity (Massmann 1952). These

findings support the hypothesis of Miller et al. (1982) that daily spawning is regulated by light intensity.

Another interesting aspect of American shad migration is the regional difference in spawning periodicity. American shad that spawn north of Cape Hatteras are iteroparous (repeat spawners), while almost all American shad spawning south of Cape Hatteras are semelparous (die after one spawning season). This may be due to the fact that south of North Carolina the physiological limits of American shad are stretched during long oceanic migrations; higher southern water temperatures may also have an effect (Leggett 1969). Moreover, Leggett and Carscadden (1978) suggest that southern stocks produce more eggs per unit of body weight than northern populations to compensate for not spawning repeatedly.

Location	**% of repeat spawners**	**Citations**
Neuse River, NC	3	Leggett and Carscadden 1978
York River, VA	24	Leggett and Carscadden 1978
Connecticut River	63	Leggett and Carscadden 1978
Saint John River, Canada	73	Colette and Klein-MacPhee 2002

Table 2. Percentage of repeat spawners for American shad along the Atlantic coast of North America

Studies show the percentage of iteroparous adult American shad increases northward along the Atlantic coast (Table 2). However, the percentage of repeat spawners may fluctuate over time within the same river due to pollution, fishing pressure, land-use change, or other factors (Limburg et al. 2003). Furthermore, almost 59% of American shad in the St. Lawrence River did not spawn every year following the onset of maturation, skipping one or more seasons (Provost 1987). Additionally, some fish spawn up to five times before they die (Carscadden and Leggett 1975).

Members of this species exhibit asynchronous ovarian development and batch spawning. In addition, American shad spawn repeatedly as they move upriver (Glebe and Leggett 1981a), which some researchers think may be a function of their high fecundity (Colette and Klein-MacPhee 2002). Estimates of egg production for the York River, Virginia, are 20,000 to 70,000 eggs per kg somatic weight spawned every four days (Olney et al. 2001).

However, some researchers believe that fecundity in American shad may be indeterminate, and that previous annual or lifetime fecundity estimates may not be accurate (Olney et al. 2001). Researchers examining batch fecundity of semelparous American shad in the St. Johns River, Florida, and iteroparous individuals in the York and Connecticut rivers in Virginia and Connecticut, respectively, found no statistically significant differences in batch fecundity among the populations. Until spawning frequency, duration, and batch size throughout the spawning season are known, lifetime fecundity for various stocks cannot be determined and previous methods to determine fecundity throughout the coastal range will be inadequate (Olney and McBride 2003). Nevertheless, the habitat productivity potential estimate used in Maine is 2.3 shad per 100 square yards of water surface area (Brown and Sleeper 2004).

It is interesting to note that Olney et al. (2001) found that approximately 70 percent of post-spawning American shad females leaving the York River had only partially spent ovaries, which suggests that the maximum reproduction level of most females in the river system each year is not achieved. Researchers hypothesize that these females utilize partially spent ovaries by reabsorbing unspawned, yoked oocytes to supplement somatic energy sources as they return to the ocean. These fish likely have a greater potential for surviving multiple spawning events than individuals that are fully spent and have no such energy reserves (Olney et al. 2001). Even with energy reserves, spent adults are usually very emaciated and return to sea soon after spawning (Chittenden 1976b), sometimes feeding before reaching saltwater (Atkins 1887).

Layzer (1974) found that American shad selected discrete spawning sites in the Connecticut River and remained there for most of the season despite the large area available for spawning. Sometimes spawners forego areas with highly suitable habitats that are further downstream, suggesting that there are other variables that influence habitat choice (Bilkovic 2000). Ross et al. (1993) suggest that choice of spawning habitat may be unrelated to physical variables, but rather may reflect a selective pressure such as fewer egg predators in selected habitats.

Spawning Salinity Association

Adult American shad may spend two to three days in estuarine waters prior to upriver migration (Dodson et al. 1972; Leggett 1976). Leim (1924) observed spawning by American shad in brackish waters, but other researchers believe that spawning occurs only in freshwater (Massman 1952; MacKenzie et al. 1985). Spawning typically occurs in tidal and non-tidal freshwater regions of rivers and tributaries (Chittenden 1976a). While in the Hudson River, American shad ascend beyond the saltwater interface and go as far upstream as they can travel (Schmidt et al. 1988), eggs are typically deposited slightly above the range of tide in the Shubenacadie River, Canada (Leim 1924). In many rivers, adult spawners historically migrated beyond tidal freshwater areas, but they can no longer reach these areas due to dam blockages (Mansueti and Kolb 1953).

Interestingly, American shad tolerate a wide range of salinities during early developmental stages (Chittenden 1969) and adult years (Dodson et al. 1972), even though their eggs are normally deposited in freshwater (Weiss-Glanz 1986). Additionally, Limburg and Ross (1995) concluded that a preference for upriver spawning sites may be genetically fixed, but its advantage or significance was not related to salt intolerance of eggs and larvae.

Leggett and O'Boyle (1976) conducted an experiment to see if American shad require a period of acclimation to freshwater. The researchers determined that fish transferred from seawater to freshwater, with a 6°C temperature increase over a 2.5-hour period, experienced physiologic stress and a 54% mortality rate five hours later. Furthermore, adults did not survive transfers from saltwater (27 ppt) to freshwater with a 14°C temperature increase. Mortality rates varied from 0 to 40% for transfers from waters with salinities ranging from 13 to 25 ppt to freshwater and temperature increases up to 6°C. However, adult American shad may be better adapted to transfers from freshwater to saltwater. They tolerated transfers from freshwater to 24 ppt and temperature increases of up to 9°C (Leggett and O'Boyle 1976).

Spawning Substrate Association

Spawning often occurs far upstream or in river channels dominated by flats of sand, silt, muck, gravel, or boulders (Mansueti and Kolb 1953; Walburg 1960; Walburg and Nichols 1967; Leggett 1976; Jones et al. 1978). The importance of substrate type to American shad spawning behavior is still debated. Bilkovic et al. (2002) concluded that substrate type was not predictive of spawning and nursery habitat in two Virginia rivers that were surveyed. Similarly, Krauthamer and Richkus (1987) do not consider substrate type to be an important factor at the spawning site since eggs are released into the water column.

However, eggs are semi-buoyant and may eventually sink to the bottom. Thus, areas predominated by sand and gravel may enhance survival because there is sufficient water velocity to remove particles and prevent suffocation if eggs settle to the bottom (Walburg and Nichols 1967). Furthermore, Layzer (1974) noted that survival rates of shad eggs were highest where gravel and rubble substrates were present. Likewise, Hightower and Sparks (2003) hypothesize that larger substrates are important for American shad reproduction, based on observations of spawning in the Roanoke River, North Carolina. Other researchers have also observed American shad spawning primarily over sandy bottoms free of mud and silt (Williams and Bruger 1972).

Spawning Depth

Depth is not considered a critical habitat parameter for American shad in spawning habitat (Weiss-Glanz et al. 1986), although Witherell and Kynard (1990) observed adult American shad in the lower half of the water column during the upstream migration. Once they reach preferred spawning areas, adults have been found at river depths ranging from 0.45 to 10 m (Mansueti and Kolb 1953; Walburg and Nichols 1967). However, depths less than 4 m are generally considered ideal (Bilkovic 2000).

Ross et al. (1993) observed that the greatest level of spawning occurred where the water depth was less than 1 m in the Delaware River. Other studies suggest that adults select river areas that are less than 10 ft deep (3.3 m) or have broad flats (Mansueti and Kolb 1953; Leggett 1976; Kuzmeskus 1977). Adults may reside in slow, deep pools during the day, and in the evening move to shallower water where riffle-pools may be present to spawn (Chittenden 1969; Layzer 1974). During the spawning event, females and males can be found close to the surface for the release and fertilization of eggs (Medcof 1957).

Stier and Crance (1985) suggest that for all life history stages, including spawning, egg incubation, larvae, and juveniles, the optimum depth range is between 1.5 and 6.1 m. Depths less than 0.46 m (for spawning adults, larvae, and juveniles) and 0.15 m (for egg incubation), and depths greater than 15.24 (for all life history stages) are considered unsuitable (Stier and Crance 1985). However, recent studies on optimal habitat for spawning events have found that these areas may be defined more narrowly than indicated by studies focused primarily on egg collection. For example, sites deeper than 2 m in the Neuse River, North Carolina, were used less extensively than expected for spawning based on depth availability within the spawning grounds and over the entire river (Beasley and Hightower 2000; Bowman and Hightower 2001).

Spawning Water Temperature

Spawning for American shad may occur across a broad range of temperatures (Table 3). Water temperature is the primary factor that triggers spawning, but photoperiod, water flow and velocity, and turbidity also exert some influence (Leggett and Whitney 1972). Based on the temperature range reported by Leggett and Whitney (1972), Parker (1990) suggests that pre-spawning adults tolerate higher temperatures as they undergo physiological changes and become sexually ripe.

Most spawning occurs in waters with temperatures between 12-21°C (Walburg and Nichols 1967; Leggett and Whitney 1972). Generally, water temperatures below 12°C cause total or partial cessation of spawning (Leim 1924). However, Jones et al. (1978) reported American shad moving into natal rivers when water temperatures were 4° C or lower. Additionally, Marcy (1976) found that peak spawning temperatures varied from year to year. For example, peak spawning temperatures in the Connecticut River were 22°C and 14.8°C in 1968 and 1969, respectively (Marcy 1976).

Other factors, such as the pace of gonadal and egg development may also be related to water temperature. Mansueti and Kolb (1953) found that shad ovaries developed more slowly at 12.8°C than at 20 to 25°C. In theory, eggs may develop slowly at first then mature rapidly with higher temperatures (DBC 1980).

Activity	**Temperature (^{o}C)**	**Location**	**Citation**
Migration	5 - 23	Throughout range	Walburg and Nichols 1967
Migration (peak)	8.6 - 19.9 (16 - 19)	North Carolina	Leggett and Whitney 1972
Peak migration	16.5 - 21.5	Southern rivers	Leggett 1976
Spawning	8 - 26	Throughout range	Walburg and Nichols 1967; Stier and Crance 1985
Optimum spawning	14 - 20	Throughout range	Stier and Crance 1985
Optimum spawning	14 – 24.5	Throughout range	Ross et al. 1993

Table 3. American shad migration and spawning temperatures for the Atlantic coast

Dissolved oxygen associations

American shad require well-oxygenated waters in all habitats throughout their life history (MacKenzie et al. 1985). Jessop (1975) found that migrating adults require minimum dissolved oxygen (DO) levels between 4 and 5 mg/L in the headwaters of the Saint John River, New Brunswick. Dissolved oxygen levels below 3.5 mg/L have been shown to have sub-lethal effects on American shad (Chittenden 1973a); levels less than 3.0 mg/L completely inhibit upstream migration in the Delaware River (Miller et al. 1982). Additionally, dissolved oxygen levels less than 2.0 mg/L cause a high incidence of mortality (Tagatz 1961; Chittenden 1969), and below 0.6 mg/L cause 100% mortality (Chittenden 1969). Although minimum daily dissolved oxygen concentrations of 2.5 to 3.0 mg/L should be sufficient to allow American shad to migrate through polluted areas, Chittenden (1973a) recommends that suitable spawning areas have a minimum of

4.0 mg/L. Miller et al. (1982) propose even higher minimum concentrations, suggesting that anything below 5.0 mg/L should be considered potentially hazardous to adult and juvenile American shad.

Spawning water velocity/flow

Water velocity (m/sec) is an important parameter for determining American shad spawning habitat (Stier and Crance 1985). Walburg (1960) found that spawning and egg incubation most often occurred where water velocity was 0.3 to 0.9 m/s. In support, Stier and Crance (1985) suggested that this was the optimum range for spawning areas. Ross et al. (1993) observed that American shad spawning activity was highest in areas where water velocity ranged from 0.0 to 0.7 m/s; this suggested that there was no lower suitability limit during this stage and that the upper limit should be modified. However, Bilkovic (2000) determined that the optimum water velocity range for eggs and larvae was 0.3 to 0.7 m/s, and hypothesized that some minimum velocity was required. A minimum velocity is needed in order to prevent siltation and ensure that conditions conducive to spawning and egg incubation occur (Williams and Bruger 1972; Bilkovic 2000).

Appropriate water velocity at the entrance of a fishway is also important for American shad migrating upstream to spawning areas. Researchers found that water velocities of 0.6 to 0.9 m/s at the entrance to a pool-and-weir fishway was needed to attract American shad to the structure (Walburg and Nichols 1967). The Conowingo Dam fish lift on the Susquehanna River uses entrance velocities of 2 to 3 m/s to attract American shad to the lift (R. St. Pierre, U.S. Fish and Wildlife Service, personal communication). At other sites, such as the Holyoke Dam in Massachusetts, American shad have trouble locating fishway entrances among turbulent discharges and avoid the area; thus, too much water velocity and/or turbulence may actually deter this species (Barry and Kynard 1986).

Ross et al. (1993) noted that habitat selection among spawning adult American shad favored relatively shallow (0.5 to 1.5 m) mid-river runs with moderate to high current velocity (0.3-0.7 m/s). To a lesser degree, adults also were located in channels (deeper, greater current velocities, little if any SAV) and SAV shallows (inshore, high densities of SAV, low current velocities). The researchers found adults seemed to avoid pools (wide river segment, deep, low current velocities) and riffle pools (immediately downstream of riffles, deep water, variable current velocity and direction) that contained both deep and slow water. This avoidance of pools and riffle pools may be explained by the fact that the preferred run habitat contained both swift and shallow water characteristics. Channels and SAV shallows may be either swift or shallow; these characteristics may lead to higher survivability of newly spawned eggs compared to deep pool habitat (Ross et al. 1993). Similarly, Bilkovic et al. (2002) found the greatest level of spawning activity in runs.

Water velocity may also contribute in some way to weight loss and mortality during the annual spawning migration, especially for male American shad. Males typically migrate upstream earlier in the season when water velocities are greater, thus expending more energy than females (Glebe and Leggett 1973; DBC 1980).

In addition, areas with high water flows provide a cue for spawning American shad (Orth and White 1993). In 1985, a rediversion canal and hydroelectric dam constructed between the Cooper River and Santee River, South Carolina, increased the average flow of the Santee River from 63 m^3/s to 295 m^3/s. (Cooke and Leach 2003). The increased river flow and access to spawning grounds through the fish passage facility have contributed to increases in American shad populations. Although the importance of instream flow requirements has been previously recognized with regard to spawning habitat requirements or recruitment potential (Crecco and Savoy 1984; ASMFC 1985; Crecco et al. 1986; Ross et al. 1993; Moser and Ross 1994), Cooke and Leach (2003) suggested that river flow might be an important consideration for restoring alosine habitat.

Water flow may have additional importance for American shad populations in the future. Although Summers and Rose (1987) did not detect direct relationships between stock size and river flow or water temperature, they found that spawning stock size, river flow rate, and temperature were important predictors of future American shad population sizes. These researchers suggested that future studies incorporate a combination of environmental variables, rather than a single environmental variable, to determine what stimuli affect stock size.

Suspended solids

Adults appear to be quite tolerant of turbid water conditions. In the Shuebenacadie River, Nova Scotia, suspended solid concentrations as high as 1000 mg/L did not deter migrating adults (Leim 1924). Furthermore, Auld and Schubel (1978) found that suspended solid concentrations of 1000 mg/L did not significantly affect hatching success of eggs.

Feeding

Early research suggested that adult American shad did not feed in freshwater during upstream migration or after spawning (Hatton 1940; Moss 1946; Nichols 1959) because the most available food source in the freshwater community was too small to be retained by adult gillrakers (Walburg and Nichols 1967). Atkinson (1951) suggested that American shad stopped feeding due to the physical separation from suitable food sources rather than a behavioral or physiological reduction in feeding.

More recent studies of feeding habits of American shad in the York River, Virginia, found that individuals did, in fact, feed as they migrated from the oceanic to coastal waters (Chittenden 1969, 1976b; Walters and Olney 2003). Walters and Olney (2003) compared stomach fullness of migrating American shad with individuals in the ocean and estuary, and found that as American shad moved from oceanic waters to coastal and estuarine waters their diet composition changed from oceanic copepods, such as *Calanus finmarchicus*, to other copepods, such as *C. typicus* and *Acartia* spp. (Walters and Olney 2003). The estuarine mysid shrimp *Neomysis americana* became an important component, replacing euphausids in spent and partially spent adults. Minor amounts of other crustaceans were also found in spent American shad stomachs including cumaceans, sevenspine bay shrimp (*Crangon septemspinosa*), and gammarid amphipods, as well as woody and green plant debris that had little or no nutritional value (Walters and Olney 2003). This finding suggested that these fish fed if there was suitable prey available (Atkinson 1951).

The ability to feed during migration and after spawning may be an important factor in decreasing post-spawning mortality of American shad (Walters and Olney 2003). Migration requires significant energetic expenditures and causes weight loss (Glebe and Leggett 1981a; 1981b); the resumption of feeding likely represents a return to natural feeding patterns, which allows the fish to begin regaining lost energy reserves (Walter and Olney 2003). Finally, the ability to survive spawning has been correlated with the degree of energy lost (Glebe and Leggett 1981b; Bernatchez and Dodson 1987). Therefore, American shad that feed actively before and after spawning may have a higher likelihood of repeat spawning. Additionally, individuals whose spawning grounds are in closer proximity to estuarine food sources (and do not expend as much energy as those that have to travel farther), and emigrating fish that have partially spent ovaries that can be reabsorbed for energy (Olney et al. 2001), may have a higher frequency of repeat spawning and lower energy expenditures (Walter and Olney 2003).

Competition and predation

Early studies found that seals and humans preyed upon adult American shad (Scott and Crossman 1973), but the species appeared to have few other predators (Scott and Scott 1988). Erkan (2002) found that predation of alosines has increased in Rhode Island rivers, noting that the Double-crested Cormorant often takes advantage of American shad staging near fishway entrances. Predation by otters and herons has also increased, but to a lesser extent (D. Erkan, Rhode Island Division of Fish and Wildlife, personal communication). A recent study strongly supports the hypothesis that striped bass predation on adult American shad in the Connecticut River has resulted in a dramatic and unexpected decline in American shad abundance since 1992 (Savoy and Crecco 2004). Researchers further suggest that striped bass prey primarily on spawning adults because their predator avoidance capability may be compromised at that time, due to a strong drive to spawn during upstream migration. Rates of predation on ages 0 and 1 alosines was also much lower (Savoy and Crecco 2004).

In south Atlantic coastal rivers where the percentage of repeat spawning is low or non-existent, adult American shad that die after spawning may contribute significant nutrient input from the marine system into freshwater interior rivers (ASMFC 1999). Garman (1992) hypothesized that before recent declines in abundance, the annual input of marine-derived biomass of post-spawning alosines was an important seasonal source of energy and nutrients for the non-tidal James River.

Egg and Larval Habitat

Geographical and temporal movement patterns

American shad eggs and larvae have been found at, or downstream of, spawning locations. Upstream areas typically have extensive woody debris where important larval and juvenile American shad prey items reside, and spawning there may ensure that eggs develop within favorable habitats (Bilkovic et al. 2002).

Once American shad eggs are released into the water column, they are initially semi-buoyant or demersal. Survival of eggs is dependent on several factors, including current velocity, dissolved oxygen, water temperature, suspended sediments, pollution, and predation (Krauthamer and Richkus 1987; Bailey and Houde 1989). Whitworth and Bennett (1970) monitored American shad eggs after they were broadcast and found that they traveled a distance of 5 to 35 m downstream before they sank or became lodged on the bottom. Other researchers reported similar observations (Barker 1965; Carlson 1968; Chittenden 1969).

Laboratory experiments suggested that sinking rates for American shad eggs were around 0.5 to 0.7 m/min (1.6 to 2.4 ft/min), with newly spawned eggs sinking at a quicker rate, although hydrodynamic and tidal effects were not accounted for in the experiments (Massmann 1952; Chittenden 1969). Other factors, such as amount of woody debris, influence how far eggs travel and may prevent eggs from settling far from the spawning site (Bilkovic 2000). Once eggs sink to the bottom, they are swept under rocks and boulders and are kept in place by eddy currents. In addition, eggs may become dislodged and swept downstream to nearby pools (DBC 1980).

American shad yolk-sac larvae may not use inshore habitat as extensively as post-yolk-sac larvae (Limburg 1996). One early study (Mitchell 1925, cited by Crecco et al. 1983) found that yolk-sac larvae were near the bottom and swam to shore as the yolk-sac reabsorbed. Metzger et al. (1992) also found yolk-sac larvae mostly in offshore areas along the bottom, while post yolk-sac larvae were more concentrated in quiet areas near shorelines (Cave 1978; Metzger et al. 1992). Yolk-sac larvae are typically found deeper in the water column than post-larvae, due to their semi-buoyant nature and aversion to light. Post-larvae, in contrast, are more abundant in surface waters, especially downstream of spawning sites (Marcy 1976).

Yolk-sac larvae exhaust their food supply within 4 to 7 days of hatching (Walburg and Nichols 1967), usually when they are approximately 10 to 12 mm total length (TL) (Marcy 1972). Survival is affected by water temperature, water flow, food production and density, and predation (State of Maryland 1985; Bailey and Houde 1989; Limburg 1996). Larvae may drift passively into brackish water shortly after hatching occurs, or can remain in freshwater for the remainder of the summer (State of Maine 1982); often they aggregate in eddies and backwaters (Stier and Crance 1985). Ross et al. (1993) reported that American shad larvae frequent riffle pools where water depth is moderate and velocity and direction vary. Alternatively, larvae in the Mattaponi and Pamunkey rivers, Virginia, were dispersed from the upper through the downriver areas. Unlike the presence of eggs, which can be predicted in most cases using physical habitat and shoreline/land use ratings, distinct habitat associations could not be discerned for larval distributions. This may be due to the fact that larvae were carried further downstream than eggs, dispersing them into more variable habitats (Bilkovic et al. 2002).

Eggs, larvae, and the saltwater interface

Although American shad eggs are generally deposited in freshwater, it is unknown whether they hatch in freshwater, brackish water, or in both (Weiss-Glanz 1986). Early attempts to acclimate larval shad to seawater resulted in high mortality rates (Milner 1876). Leim (1924) purported that successful development of embryos and larvae occurs under low salinity conditions. In the Shubenacadie River, Canada, eggs and larvae were most often observed in areas with a salinity of 0 ppt (range 0 to 7.6 ppt). Additionally, while larvae may tolerate salinities as high as 15 ppt, these conditions often result in death. Leim (1924) also found that temperature may influence salinity sensitivities, with lower temperatures (i.e., 12°C) resulting in more abnormalities at 15 and 22.5 ppt than higher temperatures (i.e., 17°C).

In another study, Limburg and Ross (1995) found that salinities of 10 to 20% were favorable for post-yolk sac American shad larvae, and concluded that estuarine salinities neither depressed growth rates nor elevated mortality rates of larval American shad compared with freshwater conditions. These researchers concluded that other ecological factors may play a greater role in influencing spawning site selection by American shad than the physiological effects of salinity.

Egg and larval substrate association

Areas with sand or gravel substrates may be better for egg and larval survival because they allow sufficient water velocity to remove silt or sand that can suffocate eggs (Walburg and Nichols 1967). Additionally, survival rates of American shad eggs have been found to be highest among gravel and rubble substrates (Layzer 1974). According to Krauthamer and Richkus (1987), bottom composition is not a critical factor in the selection of spawning locations for American shad. After American shad eggs are fertilized, they either sink to the bottom where they become lodged under rocks and boulders, or they are swept by currents to nearby pools (Chittenden 1969). Bilkovic (2000) concluded that substrate type was not a good predictor of spawning and nursery habitat in rivers.

Egg and larval depth

Eggs are slightly heavier than water, but may be buoyed by prevailing currents and tides. Most eggs settle at, or near, the bottom of the river during the water-hardening stage (Leim 1924; Jones et al. 1978). In the Connecticut River, American shad eggs are distributed almost uniformly between the surface and the bottom of the river. Larvae are more than twice as abundant in surface waters, and are even more abundant in the water column as they move downstream (Marcy 1976).

Walburg and Nichols (1967) found 49% of American shad eggs in waters shallower than 3.3 m (10 ft), 30% in water 3.7 to 6.7 m (11 to 20 ft), and 21% in water 7 to 10 m (21 to 30 ft). Similarly, Massman (1952) reported that five times more eggs per hour were collected at depths ranging from 1.5 to 6.1 m (4.9 to 20.0 ft), than in deeper waters of the Pamunkey and Mattaponi rivers. In the same river systems, Bilkovic et al. (2002) found eggs at depths of 0.9 to 5.0 m, and larvae at 1 to 10 m.

Egg and larval water temperature

Rate of development of shad eggs is correlated with water temperature (Table 4; Mansueti and Kolb 1953). According to Limburg (1996), within the temperature range of 11 to 27°C, the time it takes for eggs to develop can be expressed as:

$$\log_e(\mathrm{EDT}) = 8.9 - 2.484 \times \log_e(\mathrm{T})$$

where EDT is egg development time in days and T is temperature in degrees Celsius.

Days	**Temperature**	**Reference**
15.5	12° C	Leim 1924
17	12° C	Ryder 1887
7	17° C	Leim 1924
3	24° C	MacKenzie et al. 1985
2	27° C	Rice 1878

Table 4. American shad egg development time at various temperatures

Estimates of near-surface water temperatures suitable for development and survival of American shad eggs range from 8 to 30°C (Walburg and Nichols 1967; Bradford et al. 1968; Stier and Crance 1985; Ross et al. 1993). Leim (1924) suggests that optimal conditions for American shad egg development occur in the dark at 17°C and 7.5 ppt salinity.

Characterization	**Temperature (°C)**	**Citation**
Suitable	10 - 27	Bradford et al. 1968
Suitable	13.0 - 26.2	Ross et al. 1993
Suitable	10 - 30	Stier and Crance 1985
Optimal	15.5 - 26.5	Leim 1924
Optimal	15 - 25	Stier and Crance 1985

Table 5. American shad larval temperature tolerance ranges

Water temperatures above 27°C can cause abnormalities or a total cessation of larval American shad development (Bradford et al. 1968). Few larvae have been found living in temperatures above 28°C (Table 5; Marcy 1971; 1973), and no viable larvae develop from eggs incubated above 29°C (Bradford et al. 1968). Ross et al. (1993) recommend that further sampling be conducted for post-larval stages at temperatures greater than or equal to 27°C to confirm upper optimal temperature preferences. In this study, the researchers found no reduction in density of larvae at the upper thermal limit (26 to 27°C) in areas sampled along the Delaware River (Ross et al. 1993).

Laboratory experiments have shown that American shad eggs can tolerate extreme temperature changes as long as the exposure is of relatively short duration (Klauda et al. 1991). Temperature increases after acclimation at various temperatures produced variable results; however, some eggs were found to withstand temperatures of 30.5°C for 30 minutes and 35.2°C for 5 minutes (Schubel and Koo 1976). Furthermore, sensitivity to temperature change decreases as eggs mature (Koo et al. 1976).

Shoubridge (1977) analyzed temperature regimes in several coastal rivers throughout the range of American shad, and found that as latitude increases: 1) the duration of the temperature optima for egg and larval development decreases, and 2) the variability of the temperature regime increases. Based on Shoubridge’s work, Leggett and Carscadden (1978) suggest that variation in American shad egg and larval survival, year-class strength, and recruitment also increases with latitude.

Crecco and Savoy (1984) found that low water temperatures (with high rainfall and river flow) were significantly correlated with low American shad juvenile abundance during the month of

June in the Connecticut River, while high water temperatures (with low river flow and rainfall) were significantly correlated with high juvenile abundance. In addition, depressed water temperatures can retard the onset and duration of American shad spawning (Leggett and Whitney 1972), larval growth rate (Murai et al. 1979), and the production of riverine zooplankton (Chandler 1937; Beach 1960).

Egg and larval dissolved oxygen associations

Miller et al. (1982) concluded that the minimum dissolved oxygen level for both eggs and larvae of American shad is approximately 5 mg/L. This is the value that Bilkovic (2000) assigned for optimum conditions for survival, growth, and development of American shad.

Although specific tolerance or optima data for eggs and larvae is limited, there are studies that note the presence or absence of eggs and larvae under certain dissolved oxygen conditions (Bilkovic et al. 2002). In the Neuse River, North Carolina, American shad eggs were collected in waters with dissolved oxygen levels ranging from 6 to 10 mg/L (Hawkins 1979). Marcy (1976) did not find any American shad eggs in waters of the Connecticut River where dissolved oxygen concentrations were less than 5 mg/L. Bilkovic (2000) found variations in dissolved oxygen concentrations for eggs (10.5 mg/L), yolk-sac larvae (9.0 mg/L), and post-larvae (8.1 mg/L) in the Mattaponi and Pamunkey rivers.

Marcy (1976) determined that the dissolved oxygen LC_{50} values (i.e., concentration that causes 50% mortality) for American shad eggs in the Connecticut River were between 2.0 and 2.5 mg/L. In the Columbia River, the LC_{50} was close to 3.5 mg/L for eggs and at least 4.0 mg/L for a high percentage of hatched eggs and healthy larvae; less than 1.0 mg/L dissolved oxygen resulted in total mortality (Bradford et al. 1968). Klauda et al. (1991) concluded that a good hatch with a high percentage of normal larvae required dissolved oxygen levels during egg incubation of at least 4.0 mg/L, based on observations by both Maurice et al. (1987) and Chittenden (1973a). Finally, it is worth noting that cleanup of the Delaware River has had a measurably positive effect on increasing dissolved oxygen concentrations in that system (Maurice et al. 1987).

Egg and larval pH and aluminum associations

Level	pH	Citation
Tolerance- egg	5.5 - 9.5	Bradford et al. 1968
Tolerance- egg	6.0 – 7.5	Klauda 1994
Tolerance- egg	6.5 - 8.5	Bilkovic et al. 2002
LD_{50}- egg	5.5	Klauda 1994
Mortality- egg	<5.2	Bradford et al. 1968
Tolerance- larvae	6.7 – 9.9	Klauda 1994
Tolerance- larvae	6.5 - 9.3	Bilkovic et al. 2002
Optimal- larvae	>7.0	Leach and Houde 1999
Tolerance- both	6.0 - 9.0	Leim 1924

Table 6. American shad egg and larval environmental pH tolerance ranges

A number of researchers have examined the effects of pH on American shad eggs and larvae (Table 6). Klauda (1994) hypothesized that even infrequent and temporary episodes of critical or lethal pH and aluminum exposures in spawning and nursery areas could contribute to significant reductions in egg or larval survival and slow stock recovery. Similarly, Leach and Houde (1999) noted that sudden drops in pH levels, such as those associated with rainfall, could cause sudden mortalities for American shad larvae.

In a laboratory study, Klauda (1994) subjected eggs, yolk-sac larvae, and post-larvae to an array of acid and aluminum conditions; larvae appeared to be more sensitive to acid and aluminum pulses than eggs. When eggs were subjected to aluminum pulses, critical conditions were met at pH 5.7 (with 50 or 200 µg/L Al) and pH 6.5 (with 100 µg/L Al) for 96-hour treatments. The least severe treatment that resulted in critical conditions for 1 to 3 day old yolk-sac larvae was a 24 h exposure to pH 6.1 with 92 µg/L Al. The least severe treatment that resulted in a lethal condition for yolk-sac larvae was a 24 h exposure to pH 5.5 with 214 µg/L Al. Furthermore, post-larvae (6 to 16 days old) were found to be more sensitive to acid and aluminum pulses than both eggs and yolk-sac larvae. Critical conditions occurred at pH 5.2 (with 46 µg/L Al) and pH 6.2 (with 54 or 79 µg/L Al) for 8 hours, and lethal conditions occurred at pH 5.2 (with 63 µg/L Al) for 16 hours (Klauda 1994).

Egg and larval water velocity/flow

Several studies report water velocity preferences for larval American shad, with 0 to 1.0 m/s the most commonly reported range (Walburg 1960; Walburg and Nichols 1967; Stier and Crance 1985; Bilkovic et al. 2002). Kuzmeskus (1977) found freshly spawned eggs in areas with water velocity rates between 0.095 and 1.32 m/s. Williams and Bruger (1972) noted that increased siltation may result if water velocities are less than 0.3 m/s, causing increased egg mortality from suffocation and bacterial infection.

Freshwater discharge can influence both eggs and larvae of American shad. Increased river flow can carry eggs from favorable nursery habitat to unfavorable areas that reduce their chance for survival. Lower flows may result in favorable hydrodynamic, thermal, and feeding conditions (Crecco and Savoy 1987a; Limburg 1996). Larval and juvenile American shad may select eddies and backwater areas where water flow is reduced (Crecco and Savoy 1987b). Limburg (1996) found that high spring river discharges coupled with low temperatures and low food availability contributed to high larval mortality in the Hudson River. Larvae that hatched after May, when the highest discharges occurred, had a higher survival rate (Limburg 1996). Furthermore, year-class strength and river flow showed a significant negative correlation in studies conducted on the Connecticut River (Marcy 1976). Larval survival rates have also been negatively correlated with increased river flow in June, but positively correlated with June river temperatures (Savoy and Crecco 1988).

Although hydrographic turbulence may affect larval American shad survival rates, the precise mechanisms of this influence are uncertain because daily river flow and rainfall levels are nonlinear, time-dependent processes that may act singularly or in combination with other factors, such as temperature and turbidity (Sharp 1980). Decreased temperatures can affect larval growth rates (Murai et al. 1979) and riverine zooplankton production that American shad may require for nourishment (Chandler 1937; Beach 1960). Turbulence can also cause turbidity, which may compromise the ability of larval fish to see their prey (Theilacker and Dorsey 1980). Increased turbidity may also affect the food web. Turbidity can cause reduced photosynthesis by phytoplankton, which in turn may lead to elimination of the cladocerans and copepods that American shad feed upon (Chandler 1937; Hynes 1970; Crecco and Blake 1983; Johnson and Dropkin 1995).

Suspended solids

American shad eggs are less vulnerable to the effects of suspended solids than larvae. For example, Auld and Schubel (1978) found that suspended solid concentrations of up to 1000 mg/L did not significantly reduce hatching success, while larvae exposed to concentrations of 100 mg/L, or greater, had significantly reduced survival rates.

Feeding Behavior

Predation and starvation are considered the primary causes of mortality among larval fish of many marine species (May 1974; Hunter 1981). Newly hatched American shad larvae must begin feeding within 5 days, or they will die from malnutrition (Wiggins et al. 1984). Furthermore, older larvae have significantly reduced survival rates if they are deprived of food for as little as 2 days (Johnson and Dropkin 1995). Researchers have also found that larvae fed at intermediate prey densities of 500 L^{-1} survived as well as those fed at high prey densities, and significantly higher than starved larvae, which indicates that some minimal level of feeding in riverine reaches can increase survival (Johnson and Dropkin 1995).

Crecco et al. (1983) suggest that larval American shad survival rates are related to spring and summer zooplankton densities. Additionally, despite larval American shad abundance being highest during May, Limburg (1996) determined that year-class was established by cohorts hatched after June 1 due to more favorable conditions, including warmer temperatures, lower flow rates, and higher zooplankton densities.

Once the yolk-sac is absorbed, American shad larvae consume zooplankton, copepods, immature insects, and adult aquatic and terrestrial insects (Leim 1924; Mitchell 1925; Maxfield 1953; Crecco and Blake 1983; Facey and Van Den Avyle 1986). Several researchers have noted varying levels of selectivity for copepods and cladocerans (Crecco and Blake 1983; Johnson and Dropkin 1995), but zooplankton and chironomids generally comprise the bulk of larval diets (Maxfield 1953; Levesque and Reed 1972). Larval American shad feeding occurs most actively in late afternoon or early evening, usually peaking between 1200 h and 2000 h (Johnson and Dropkin 1995); feeding is least intensive near dawn (Massman 1963; Grabe 1996). Larval American shad are opportunistic feeders, shifting their diet depending on availability, river location, and their size (Leim 1924; Maxfield 1953; Walburg 1956; Levesque and Reed 1972; Marcy 1976).

Researchers have also attempted to determine if the patchiness of planktonic prey has any effect on cohort survival. Letcher and Rice (1997) found that increasing levels of patchiness enhances survival when productivity or average prey density is low, but will reduce cohort survival when productivity is high. Thus, except when average prey densities of plankton are particularly high, prey patchiness may be a requirement for survival of fish larvae (Letcher and Rice 1997).

Competition and predation

American shad eggs and larvae are preyed upon primarily by American eels (*Anguilla rostrata*) and striped bass (*Morone saxatilis*) (Mansueti and Kolb 1953; Walburg and Nichols 1967; Facey et al. 1986), although they may be preyed upon by any fish that is large enough to consume them (McPhee 2002). According to Johnson and Ringler (1998), American shad larvae that were stocked in the Susquehanna River, Pennsylvania, experienced the lowest percentage mortality at releases of 400,000 to 700,00 larvae. A high rate of larval mortality at releases up to 400,000 may have been due to depensatory mechanisms, and releases above 700,000 may have resulted in increased predator aggregation at the site. Although some individual predators consumed up to 900 American shad larvae, mortality of larvae at the stocking site was usually less than 2% (an insignificant source of mortality) (Johnson and Ringler 1998).

Contaminants

Bradford et al. (1968) found that the lethal dose (LD_{50}) of sulfates for American shad eggs is >1000 mg/L at 15.5° C. The LD_{50} of iron for eggs is greater than 40 mg/L between pH 5.5 and 7.2 (Bradford et al. 1968). American shad eggs that are exposed to zinc and lead concentrations of 0.03 and 0.01 mg/L experience high mortality rates within 36 hours (Meade 1976). In addition, when water hardness is low (i.e., 12 mg/L), the toxicity of the zinc and lead are intensified (Klauda et al. 1991).

Juvenile Riverine/Estuarine Habitat

Geographical and temporal movement patterns

American shad larvae are transformed into juveniles 3 to 5 weeks after hatching at around 28 mm total length (TL) (Jones et al. 1978; Crecco and Blake 1983; Klauda et al. 1991; McCormick et al. 1996); they disperse at, or downstream of, the spawning grounds, where they spend their first summer in the lower portion of the same river. While most young American shad use freshwater nursery reaches (McCormick et al. 1996), it is thought that their early ability to hypo-osmoregulate allows them to utilize brackish nursery areas during years of high juvenile abundance (Crecco et al. 1983). Juveniles are typically 7 to 15 cm in length before they leave the river and enter the ocean (Talbot and Sykes 1958). For example, in the Hudson River, juvenile American shad and blueback herring were found inshore during the day, while alewives predominated inshore at night (McFadden et al. 1978; Dey and Baumann 1978). Additionally, American shad juveniles use the headpond of the Annapolis River, Nova Scotia, as a nursery area, which has surface water salinities of 25 to 30%; they were observed remaining in the offshore region of the estuary for almost a month before the correct cues triggered emigration (Stokesbury and Dadswell 1989). Farther south, O’Donnell (2000) found that juvenile American shad in the Connecticut River began their seaward emigration at approximately 80 days post-hatch.

In addition, juvenile American shad may demonstrate temporal and latitudinal migration trends. It seems that juveniles in northern rivers emigrate seaward first, and those from southern rivers emigrate progressively later in the year (Leggett 1977a). For example, downstream emigration peaks at night (i.e., at 1800-2300 hours) (O'Leary and Kynard 1986; Stokesbury and Dadswell 1989) in September and October in the Connecticut River, late October in the Hudson River (Schmidt et al. 1988), and late October through late November in the Upper Delaware River and Chesapeake Bay (Krauthamer and Richkus 1987) and the Cape Fear River, North Carolina (Fischer 1980). Interestingly, some researchers (Chittenden 1969; Limburg 1996; O'Donnell 2000) found evidence that juvenile emigration was already underway by mid-summer, indicating that movement may be triggered by cues other than declining fall temperatures.

The combination of factors that trigger juvenile American shad emigration is uncertain, but some researchers suggest that decreased water temperatures, reduced water flow, or a combination of both during autumn appear to be key factors (Sykes and Lehman 1957; Walburg and Nichols 1967; Moss 1970). In the Susquehanna River, an increase in river flow from October through November may actually help push juveniles downstream (R. St. Pierre, U.S. Fish and Wildlife Service, personal communication). Miller et al. (1973) suggest that water temperature is more important than all other factors, because it directly affects the juvenile American shad. The lower lethal temperature limit that triggers the final movement of juveniles from fresh water is approximately 4 to 6°C (Chittenden 1969; Marcy 1976). In addition, Zydlewski and McCormick (1997a) observed changes in osmoregulatory physiology in migrating juvenile American shad, and concluded that these changes were part of a suite of physiological alterations that occur at the time of migration. While these changes are strongly affected by temperature, researchers suggest that other environmental and/or ontogenetic factors may have an influence on timing of migration (Zydlewski and McCormick 1997a).

Another migration theory deals with the age and growth of juvenile American shad. Limburg (1996) suggested that at the population level, temperature may provide the stimulus for fish to emigrate, or it may be a gradual process that is cued by size of fish, with early cohorts leaving first. Several researchers (Chittenden 1969; Miller et al. 1973; Limburg 1996; O'Donnell 2000) have observed younger, smaller young-of-the-year American shad in upstream reaches, while older and larger individuals within the same age cohorts are found downstream earlier in the season. This apparent behavior has lead researchers to hypothesize that as American shad grow and age, they move downstream (Chittenden 1969; Miller et al. 1973; Limburg 1996; O'Donnell 2000). Similarly, both Chittenden (1969) and Marcy (1976) suggest that factors associated with size appear to initiate the earlier stages of seaward emigration.

In contrast, Stokesbury and Dadswell (1989) suggest that size at emigration may not be the important factor that triggers migration, but that environmental stress may reach a point where seaward movement is necessary regardless of a critical size. O'Leary and Kynard (1986) and Stokesbury and Dadswell (1989) found that American shad movement typically occurred during quarter to new moon periods when water temperatures dropped below 19°C and 12°C, respectively. In these cases, decreasing water temperatures and the new moon phase, which provided dark nights, were considered to be more important in providing cues for emigration than increased river flow.

Following downstream migration in late fall, juvenile American shad may spend their first year near the mouths of streams, in estuaries, or in other nearshore waters (Hildebrand 1963; Colette and Klein-MacPhee 2002), or they may move to deeper, higher salinity areas, such as in portions of the lower Chesapeake Bay (Table 7; Hildebrand and Schroeder 1928). In their southern range, some juveniles may stay in the river for up to one full year (Williams and Bruger 1972). In South Carolina, juvenile American shad were found predominantly in deeper, channel habitats of estuarine systems, during fall and winter. Small crustaceans preyed upon by American shad are generally abundant near the bottom in these areas (McCord 2003).

Habitat Type	Location	Citation
sound	Long Island	Savoy 1993
offshore estuary	New Jersey	Milstein 1981; Cameron and Pritchard 1963
brackish/ freshwater	Potomac River	Hammer 1942
estuary	Neuse River, NC	Holland and Yelverton 1973

Table 7. Overwintering habitats for juvenile American shad along the Atlantic coast

Juveniles and the saltwater interface

Early studies of juvenile American shad describe a variety of responses to changes in salinity. When accompanied by temperature changes, juveniles generally adapt to abrupt transfers from freshwater to saltwater, but high mortality results when transferred from saltwater to freshwater (Tagatz 1961). For example, Tagatz (1961) observed 60% mortality for juveniles in isothermal transfers (21°C) from freshwater to 30 ppt saltwater; however, no individuals survived transfers from freshwater (21.1°C) to 33 ppt saltwater (7.2 to 12.8°C). Freshwater transfers to 15 ppt in association with a temperature decrease less than 4°C also resulted in high mortalities (30 to 50%). Conversely, at temperature increases greater than 14°C, all juvenile American shad survived abrupt transfers from saltwater (15 ppt and 33 ppt) to freshwater (Tagatz 1961).

In another study, Chittenden (1973b) observed 0% mortality in isothermal transfers (17°C) from freshwater or 5 ppt to 32 ppt seawater. Additionally, juveniles transferred from 30 ppt seawater to freshwater suffered 100% mortality, but no mortalities resulted when they were transferred from 5 ppt to freshwater. In general, American shad are considered to be capable of surviving a wide range of salinities at early life stages, especially if salinity changes are gradual (Chittenden 1969).

Experiments conducted on American shad and other anadromous fish (Rounsefell and Everhart 1953; Houston 1957; Tagatz 1961; Zydlewski and McCormick 1997a, 1997b) have demonstrated that most fish undergo physiological changes before emigrating to saltwater. This ability to adapt to changes in salinity occurs at the onset of metamorphosis for American shad, between 26 and 45 days post-hatch. Zydlewski and McCormick (1997b) noted that the ability to osmoregulate in full-strength seawater is an important factor that limits American shad early life history stages to freshwater and low-salinity estuaries. The researchers suggested that a decrease and subsequent loss of hyper-osmoregulatory ability may serve as a proximate cue for juveniles to begin their downstream migration (Zydlewski and McCormick 1997b).

Juvenile substrate association

Although juvenile American shad are often most abundant where boulder, cobble, gravel, and sand are present (Walburg and Nichols 1967; Odom 1997), substrate type is not considered to be a critical factor in nursery areas (Krauthamer and Richkus 1987). Ross et al. (1997) found no overall effect of habitat type on juvenile American shad relative abundance in the upper Delaware River, indicating that juveniles use a wide variety of habitat types to their advantage in many nursery areas. These researchers suggest that in contrast to earlier life stages and spawning adults, pre-migratory juveniles may be habitat generalists; however, a positive relationship was found between abundance of juvenile American shad and percent of SAV cover in SAV habitats only. In addition, Odom (1997) found that juvenile American shad favored riffle/run habitat in the James River, especially areas with extensive beds of water stargrass (*Heteranthera dubia*). These areas provided flow-boundary feeding stations where juveniles could feed on drifting macroinvertebrates while reducing their energy costs (Odom 1997).

Estuarine productivity is linked to freshwater detrital nutrient input to the estuary (Biggs and Flemer 1972; Hobbie et al. 1973; Saila 1973; Day et al.1975) and detritus production in the salt marsh (Teal 1962; Odum and Heald 1973; Reimhold et al. 1973; Stevenson et al. 1975). Based on the assumption that the amount of submerged and emergent vegetation will be a qualitative estimate of the estuary's secondary productivity, and therefore, food availability (zooplankton) to juvenile American shad, Stier and Crance (1985) suggest that estuarine habitat with 50% or more vegetation coverage is optimal.

It is important to note that, although no link has been made between the presence of SAV and abundance of alosines, there seems to be a general agreement that there is a correlation between water quality and alosine abundance (B. Sadzinski, Maryland Department of Natural Resources, personal communication). Abundance of SAV is often used as an indirect measure of water quality, with factors such as available light (Livingston et al. 1998), salinity, temperature, water depth, tidal range, grazers, suitable sediment quality, sediment nutrients, wave action, current velocity, and chemical contaminants controlling the distribution of underwater grasses (Koch 2001). Maryland has made it a priority to increase the amount of SAV within the Chesapeake Bay watershed in order to improve water quality. According to B. Sadzinski (Maryland Department of Natural Resources, personal communication), if SAV in a given area increases, this can be used as an indicator of improved water quality, which in turn, will likely benefit alosine species.

Juvenile depth

Juveniles have been observed at depths ranging from 0.9 to 4.9 m in the Connecticut River (Marcy 1976); however, abundance is related to the distance upstream and not to depth (MacKenzie et al. 1985). In the Connecticut River, juveniles were caught primarily at the bottom during the day (87%) and all were caught at the surface at night (Marcy 1976). Chittenden (1969) observed juveniles in the Delaware River most often in deeper, non-tidal pools away from the shoreline during daylight hours; after sunset juveniles scattered and were found at all depths (Miller et al. 1973).

Although data was sparse for depth optima for juveniles, Stier and Crance (1985) developed a suitability index based on input provided by research scientists. They suggest that for all life history stages, including juveniles, the optimum range for river depth is between 1.5 and 6.1 m. Depths less than 0.46 m and greater than 15.24 m are unsuitable habitat according to the model.

Juvenile water temperature associations

Juvenile American shad demonstrate some variability in temperature tolerances and preferences among river systems (Table 8). Leim (1924) found that juveniles captured in the Shubenacadie River, Canada, were usually found where temperatures tended to be the highest compared to other regions of the river. Additionally, temperature appears to have a significant impact on growth of juvenile American shad. Limburg (1996) found that juveniles in the laboratory had higher initial growth rates at 28.5°C than individuals reared at lower temperatures. O'Donnell (2000) concluded that it may be advantageous for eggs to hatch later in the year because temperatures are higher and growth rates are faster; however, competition and predation rates are also higher.

Characterization	**Temperature (^oC)**	**Location**	**Citation**
Optimal range	15.5 - 23.9	N/A	Crance 1985
Optimal range	10 - 25	N/A	Stier and Crance 1985
Range	10 - 30	Connecticut River	Marcy et al. 1972
Critical maximum	34 - 35	Neuse River, NC	Horton and Bridges 1973
Maximum tolerance	35	N/A	Stier and Crance 1985
Minimum preference	8	N/A	MacKenzie et al. 1985
Minimum tolerance	3	N/A	Stier and Crance 1985
Minimum tolerance	31.6	N/A	Ecological Analysts Inc. 1978
Begin migration	19	Connecticut River	Leggett 1976; O'Leary and Kynard 1986
Begin migration	23 - 26	Connecticut River	Marcy 1976
Begin migration	18.3	Connecticut River	Watson 1970
Peak migration	16	Connecticut River	Leggett and Whitney 1972; O'Leary and Kynard 1986
Peak migration	15.1	North Carolina	Neves and Depres 1979; Boreman 1981
End migration	8.3	Delaware River	Chittenden and Westman 1967
End migration	8.3	Chesapeake Bay	Chesapeake Bay Program 1988

Table 8. Temperature tolerances, preferences, and cues for juvenile American shad

Juvenile American shad do not appear to be as tolerant to temperature changes as eggs of the same species. In fact, juveniles are sensitive to water temperature changes, and actively avoid temperature extremes, if possible. Laboratory tests suggest that juveniles can tolerate temperature increases between 1° and 4°C above ambient temperature, but beyond that they will avoid changes if given a choice (Moss 1970). For example, juveniles acclimated to 25° C suffered a 100% mortality rate when the temperature was decreased to 15°C. There was also a 100% mortality rate for juveniles acclimated to 15°C and then subjected to temperatures less than 5°C. Finally, no survival was reported for juveniles acclimated to 5°C and then exposed to 1°C (PSE&G 1982).

Juvenile dissolved oxygen associations

Minimum dissolved oxygen values have a more adverse effect upon fish than average dissolved oxygen values; therefore, minimum dissolved oxygen criteria have been recommended. Dissolved oxygen concentrations less than 5.0 mg/L are considered sub-lethal to juvenile American shad (Miller et al. 1982). As with spawning areas, Bilkovic (2000) assigned a value of greater than 5.0 mg/L dissolved oxygen as optimal for nursery areas.

Seemingly healthy juvenile American shad have been collected in the Hudson River, New York, where dissolved oxygen concentrations were 4 to 5 mg/L (Burdick 1954). Similarly, in headponds above hydroelectric dams on the St. John River, New Brunswick, dissolved oxygen must be at least 4 to 5 mg/L for migrating juveniles to pass through (Jessop 1975). In the Delaware River, dissolved oxygen concentrations less than 3.0 mg/L blocked juvenile migration, and concentrations below 2.0 mg/L were lethal. Emigrating juveniles have historically arrived at the upper tidal section of the Delaware River by mid-October, but do not continue further seaward movement until November or December, when the pollution/low oxygen conditions dissipate (Miller et al. 1982).

Under laboratory conditions, juvenile American shad did not lose equilibrium until dissolved oxygen decreased to 2.5 to 3.5 mg/L (Chittenden 1969, 1973a). Juveniles have been reported to survive brief exposure to dissolved oxygen concentrations of as little as 0.5 mg/L, but survived only if greater than 3 mg/L was available immediately thereafter (Dorfman and Westman 1970).

Juvenile pH associations

Areas that are poorly buffered (low alkalinity) and subject to episodic or chronic acidification may provide less suitable nursery habitat than areas that have higher alkalinities and are less subject to episodic or chronic acidification (Klauda et al. 1991). Once juvenile American shad move downstream to brackish areas with a higher buffering capacity, they may be less impacted by changes in pH (Klauda 1989).

Juvenile water velocity/flow

Ideal water velocity rates are thought to range between 0.06 to 0.75 m/s for the juvenile non-migratory stage of American shad (Klauda et al. 1991). The rate of water velocity is also critical for fish migrating downstream that pass over spillways (MacKenzie et al. 1985). Furthermore, it has been suggested that water flow may serve to orient emigrating juveniles in the downstream direction. Studies conducted on American shad in the St. Johns River, Florida, led researchers to speculate that the lack of water flow as a result of low water levels could result in the inability of juveniles to find their way downstream (Williams and Bruger 1972).

Juveniles and suspended solids

Ross et al. (1997) suggest that optimal turbidity values for premigratory American shad juveniles in tributaries is between 0.75 and 2.2 NTU. While preliminary, these results could be cautiously applied to other river systems, but consideration should be given to the range and diversity of habitat types in the river system under study before applying the models.

Juvenile feeding

Juvenile American shad begin feeding in freshwater and continue into the estuarine environment. They favor zooplankton over phytoplankton (Maxfield 1953; Walburg 1956), and in general, have a wider selection of prey taxa than larvae due to their increased size and the estuaries' higher diversity. Long, closely-spaced gill rakers enable juveniles to effectively filter plankton from the water column during respiratory movements (Leim 1924). Juvenile American shad are opportunistic feeders, whose freshwater diet includes copepods, crustacean zooplankton, cladocerans, aquatic insect larvae, and adult aquatic and terrestrial insects (Leim 1924; Maxfield 1953; Massmann 1963; Levesque and Reed 1972; Marcy 1976). After juveniles leave coastal rivers and estuaries for nearshore waters, they may prey on some fish, such as smelt, sand lance, silver hake, bay anchovy, striped anchovy, and mosquitofish (Leidy 1868; Bowman et al. 2000).

Although juveniles obtain most of their food from the water column (ASMFC 1999), many of the crustaceans that juveniles prey upon are benthic (Krauthamer and Richkus 1987). Leim (1924) speculated that although American shad obtain a minor amount of food near the bottom of the water column, they do not pick it off the bottom, but rather capture items as they are carried up into the water column a short distance by tidal currents (including mollusks).

Walburg (1956) found that juvenile American shad fed primarily on suitable organisms that were readily available. In contrast, Ross et al. (1997) found that juveniles in SAV habitat fed principally on chironomids, while those feeding in tributaries consumed terrestrial insects almost exclusively, despite the fact that insects were less available than other food sources. Researchers did not attribute the differences to developmental limitations, but concluded that there were true feeding differences between habitats. Other studies have noted different selection of organisms along the same river, but at different locations, such as above a dam (Levesque and Reed 1972) or downstream of a dam (Domermuth and Reed 1980).

Feeding of juvenile American shad may also differ along a stream gradient. In waters of Virginia, Massman (1963) found that juvenile American shad upstream consume more food than juveniles that remain downstream near their spawning grounds. The upstream sections of the river have a higher shoreline to open water ratio that may provide a more abundant source of terrestrial insects, a favored prey item (Massman 1963; Levesque and Reed 1972), while the downstream sections contain more autochthonously-derived prey. In contrast, the lower reach of the Hudson River appears to be more productive (as a function of primary productivity and respiration rates) than upper and middle reaches (Sirois and Fredrick 1978; Howarth et al. 1992). This greater productivity may lead to higher fish production in the lower estuary, as well as a higher relative condition of downriver juvenile American shad earlier in the season, compared to upriver and midriver fish (Limburg 1994).

Juvenile American shad also demonstrate diel feeding patterns. Johnson and Dropkin (1995) found that juveniles increase feeding intensity as the day progresses, achieving a maximum feeding rate at 2000 h. Similarly, juveniles in the Mattaponi and Pamunkey rivers in Virginia, feed during the day with stomachs reaching maximum fullness by early evening (Massman 1963).

In addition, at least one non-native species has proven to have an impact on young-of-the-year American shad. In the Hudson River, there is strong evidence that zebra mussel colonization has reduced the planktonic forage base of the species (Waldman and Limburg 2003).

Juvenile competition and predation

Juveniles in freshwater may be preyed upon by American eel, bluefish, weakfish, striped bass, birds, and aquatic mammals (Mansueti and Kolb 1953; Walburg and Nichols 1967; Facey et al. 1986).

With regard to inter-species competition, differences among alosine species in terms of distribution, diel activity patterns, and feeding habits are evident in many systems, and are likely mechanisms that may reduce competition between juveniles of the different species (Schmidt et al. 1988). For example, several researchers have noted that larger American shad (Chittenden 1969; Marcy 1976; Schmidt et al. 1988) and alewife (Loesch et al. 1982; Schmidt et al. 1988) move downstream first, which helps to segregate size classes of the two species.

Secondly, there is the idea of diel, inshore-offshore segregation. Both American shad and blueback herring juveniles occur in shallow nearshore waters during the day. However, competition for prey between American shad and blueback herring is often reduced by: 1) more opportunistic feeding by American shad, 2) differential selection for cladoceran prey, and 3) higher utilization of copepods by blueback herring (Domermuth and Reed 1980). American shad feed most often in the upper water column, the air-water interface (Loesch et al. 1982), and even leap from the water (Massman 1963), feeding on *Chironomidae* larvae, *Formicidae*, and *Cladocera*; they are highly selective for terrestrial insects (Davis and Cheek 1966; Levesque and Reed 1972). Juvenile bluebacks are more planktivorous, feeding on copepods, larval dipterans, and *Cladocera* (Hirschfield et al. 1966), but not the same cladoceran families that alewife feed upon (Domermuth and Reed 1980).

Juveniles and contaminants

Tagatz (1961) found that the 48 h lethal concentrations (LC_{50}) for juvenile American shad range from 2,417 to 91,167 mg/L for gasoline, No. 2 diesel fuel, and bunker oil. The effects of gasoline and diesel fuel are exacerbated when the dissolved oxygen concentration is simultaneously reduced. Gasoline concentrations of 68 mg/L at 21 to 23°C resulted in a lethal time (LT_{50}) of 50 minutes for juveniles when dissolved oxygen was reduced to 2.6 to 3.2 mg/L. Additionally, juveniles that were exposed to 84 mg/L of diesel fuel at 21 to 23°C with dissolved oxygen between 1.9 and 3.1 mg/L experienced an LT_{50} of 270 minutes (Tagatz 1961).

Late Stage Juvenile and Adult Marine Habitat

Geographical and temporal patterns at sea

American shad typically live 5 to 7 years (Leggett 1969) and remain in the ocean for 2 to 6 years before becoming sexually mature, at which point they return to their natal rivers to spawn (Talbot and Sykes 1958; Walburg and Nichols 1967). Both sexes begin to mature at 2 years, with males maturing on average in 4.3 years and females maturing on average in 4.6 years. Fish north of Cape Hatteras are iteroparous and will return to rivers to spawn when temperatures are suitable (Leggett 1969).

Results from 50 years of tagging indicate that discrete, widely separated aggregations of juvenile and adult American shad occur at sea (Talbot and Sykes 1958; Leggett 1977a, 1977b; Dadswell et al. 1987; Melvin et al. 1992). These aggregations are a heterogeneous mixture of individuals from many river systems (Dadswell et al. 1987); it is unknown if American shad from all river systems along the east coast intermingle throughout the entire year (Neves and Depres 1979). Populations that return to rivers to spawn are a relatively homogeneous group (Dadswell et al. 1987), and fish from all river systems can be found entering coastal waters as far south as North Carolina in the winter and spring (Neves and Depres 1979).

Dadswell et al. (1987) presented the following seasonal movement timeline for American shad:

1) *January & February* –found offshore from Florida to Nova Scotia; spawning inshore from Florida to South Carolina;
2) *March & April* –moving onshore and northward from the Mid-Atlantic Bight to Nova Scotia; spawning from North Carolina to the Bay of Fundy;
3) *Late June* – concentrated in the inner Bay of Fundy, inner Gulf of St. Lawrence, Gulf of Maine, and off Newfoundland and Labrador; spawning fish are still upstream from Delaware River to St. Lawrence River;
4) *Autumn* –American shad leaving the St. Lawrence estuary are captured across the southern Gulf of St. Lawrence, while fish leaving the Bay of Fundy are found from Maine to Long Island; some individuals already migrated as far south as Georgia and Florida.

Through an analysis of tag returns, occurrence records, and trawl survey data, Dadswell et al. (1987) found that there are three primary offshore areas where aggregations of American shad overwinter: 1) off the Scotian Shelf/Bay of Fundy, 2) in the Mid-Atlantic Bight, and 3) off the Florida coast. It appears that the majority of American shad that overwinter along the Scotian Shelf spawn in rivers in Canada and New England (Vladykov 1936; Melvin et al. 1985). Fish aggregations that overwinter off the mid-Atlantic coast (from Maryland to North Carolina) are comprised of populations that spawn in rivers from Georgia to Quebec (Talbot and Sykes 1958; Miller et al. 1982; Dadswell et al. 1987).

The regional composition of American shad aggregations overwintering off the Florida coast is unknown. Leggett (1977a) proposed the following estimates for timing and origin of southern migrations for overwintering off Florida based on migration rates and an average departure date of October 1 from the Gulf of Maine/Bay of Fundy region: Rhode Island/Long Island coast in mid-to-late October, off Delaware Bay in early November, and off the coast of North Carolina, Georgia, and Florida in early December. Additionally, early migration studies of American shad found that during mild winters, small aggregations sometimes enter the sounds of North Carolina during November and December, but disappear if the weather becomes cold (Talbot and Sykes 1958).

Most American shad populations that overwinter off the mid-Atlantic coast (between 36° to 40°N) migrate shoreward in the winter and early spring. Pre-spawning adults homing to rivers in the south Atlantic migrate shoreward north of Cape Hatteras, North Carolina, then head south along the coast to their natal rivers. The proximity of the Gulf Stream to North Carolina provides a narrow migration corridor at Cape Hatteras through which individuals may maintain travel in the preferred temperature range of 3 to 15°C. Although pre-spawning adults are not required to follow a coastal route to North Atlantic rivers because temperatures in the Mid-Atlantic Bight are generally well within a tolerable range in the spring, tag returns indicate that most individuals likely enter coastal waters in the lower mid-Atlantic region, and then migrate north along the coast (Dadswell et al. 1987).

South of Cape Cod, pre-spawning American shad migrate close to shore (Leggett and Whitney 1972), but north of that point the migration corridor is less clear (Dadswell et al. 1987). Pre-spawning adults may detour into estuaries during their coastal migration; however, the timing and duration of the stay is unknown (Neves and Depres 1979). Although poorly documented, immature American shad (age 1+) may also enter estuaries and accompany adults to the spawning grounds, more than 150 km upstream (Limburg 1995, 1998). Additionally, non-spawning adults have been recorded in brackish estuaries (Hildebrand 1963; Gabriel et al. 1976). Dadswell et al. (1987) found three primary offshore summer aggregations of American shad: 1) Bay of Fundy/Gulf of Maine, 2) St. Lawrence estuary, and 3) off the coast of Newfound and Labrador. Neves and Depres (1979) also found distinct summer aggregations on Georges Bank and south of Nantucket Shoals. Furthermore, American shad from all river systems, including those from south Atlantic rivers, have been collected at the Gulf of Maine feeding grounds during the summer (Neves and Depres 1979). While individuals from north Atlantic rivers are most abundant in the Bay of Fundy in the early summer, the appearance of American shad from the southern range does not peak until mid-summer (Melvin 1984; Dadswell et al. 1987). These migrating groups are a mixture of juveniles, immature sub-adults, and spent and resting adults that originate from rivers along the entire East Coast (Dadswell et al. 1983). Since there are very few repeat spawners in the southern range, the majority (76%) of American shad that migrate to the Bay of Fundy from areas south of Cape Lookout, North Carolina, are juveniles (Melvin et al. 1992).

American shad enter the Bay of Fundy in early summer and move throughout the inner Bay of Fundy for four months in a counterclockwise direction with the residual current (Dadswell et al. 1987). As water temperatures decline in the fall, American shad begin moving through the Gulf of Maine, and continue to their offshore wintering grounds. This species has been captured in late fall and winter 80 to 95 km offshore of eastern Nova Scotia (Vladykov 1936), 65 to 80 km off the coast of Maine, 40 to 145 km off southern New England, and 175 km from the nearest land of southern Georges Bank (Colette and Klein-MacPhee 2002; Dadswell et al. 1987).

Salinity associations at sea

During their residence in the open ocean, American shad sub-adults and adults will live in seawater that is approximately 33 ppt. During coastal migration periods, pre-spawning adults may detour into estuaries where water is more brackish, but the timing and duration of the stay is unknown (Neves and Depres 1979).

Depth associations at sea

While it is known that adult American shad move offshore to deeper waters during the fall and early winter, information regarding preferred depths is lacking. American shad have been found throughout a broad depth range in the ocean, from surface waters to depths of 340 m (Walburg and Nichols 1967; Facey and Van Den Avyle 1986). Alternatively, catch data analyses showed that this species has been caught at depths ranging from surface waters to 220 m (Walburg and Nichols 1967), but are most commonly found at intermediate depths of 50 to 100 m (Neves and Depres 1979). Seasonal migrations are thought to occur mainly in surface waters (Neves and Depres 1979).

The summer and autumn months are a time of active feeding for American shad, and analyzing stomach contents has served as a means to infer distribution in the water column. Studies by Neves and Depres (1979) suggested that American shad follow diel movements of zooplankton, staying near the bottom during the day and dispersing in the water column at night. Other researchers (Dadswell et al. 1983) have suggested that light intensity may control depth selection by American shad. For example, American shad swim much higher in the water column in the turbid waters of Cumberland Basin, Bay of Fundy, than they do in clear coastal waters, where they are found in deeper water. Both areas are within the same surface light intensity range (Dadswell et al. 1983).

Temperature associations at sea

Early studies by Leggett and Whitney (1972) found that American shad move along the coast via a “migrational corridor” where water temperatures are between 13 and 18°C. Neves and Depres (1979) later modified the near-bottom temperature range from 3 to 15°C, with a preferred range of 7 to 13°C. These researchers also hypothesized that seasonal movements are broadly controlled by climate, and that American shad follow paths along migration corridors or oceanic paths of “preferred” isotherms. Melvin et al. (1985) and Dadswell et al. (1987) revised this theory with data indicating movement of American shad across thermal barriers. It was determined that American shad remain for extended periods in temperatures outside their “preferred” range; this species migrates rapidly between regions regardless of currents and temperatures (Melvin et al. 1985; Dadswell et al. 1987). For example, Dadswell et al. (1987) documented non-reproductive American shad migrating from wintering grounds in the Mid-Atlantic Bight through the Gulf of Maine in May-June, where a constant sub-surface temperature of 6°C prevails, to reach the Bay of Fundy by mid-summer.

Temperature change and some aspect of seasonality (i.e., day length) may initiate migratory behavior, but timing of the behavior by different individuals may be influenced by intrinsic (genetic) factors and life history stage of the individual. Chance may also play a small role in determining which direction a fish will travel, at least within a confined coastal region. Dadswell et al. (1987) concluded that extrinsic factors related to ocean climate, seasonality, and currents may provide cues for portions of non-goal-oriented migration, while intrinsic cues and bi-coordinate navigation appear to be important during goal-oriented migration.

Suspended solid associations at sea

Due to extreme turbidity, the American shad preference zone for light intensity in summer and fall in the Bay of Fundy is limited to surface waters (2 to 10 m). Although this makes the fish more susceptible to fishing gear that operates near surface waters, these waters are highly productive sources of zooplankton. Sight-oriented planktivores may be at a disadvantage in these turbid waters, but American shad, which can use a filter-feeding mechanism, may have a competitive advantage (Dadswell et al. 1983).

Feeding at sea

While offshore, American shad are primarily planktivorous, feeding on the most readily available organisms, such as copepods, mysid shrimps, ostracods, amphipods, isopods, euphausids, larval barnacles, jellyfish, small fish, and fish eggs (Willey 1923; Leim 1924; Maxfield 1953; Massmann 1963; Levesque and Reed 1972; Marcy 1976). Themelis (1986) found that in the Bay of Fundy, American shad mostly consume planktonic and epibenthic crustaceans. Differences in dominant prey items may be attributed to changing availability of zooplankton assemblages and the size of the American shad. Juveniles feed more extensively on copepods than adults and a smaller proportion of their diet is composed of large prey items such as euphausids and mysids (Themelis 1986). In earlier studies, Leim (1924) reported similar observations, with copepods decreasing in importance in the diets of American shad over 400 mm in length. Detritus has also been found in the stomachs of American shad, but it probably provides little nutritional value and is simply ingested during the course of feeding (Themelis 1986).

The Bay of Fundy is regarded as the primary summer feeding grounds for American shad, however, the entire bay does not provide optimal feeding conditions for adults. For example, although both adult and juvenile American shad feed readily in the oceanic lower Bay of Fundy, only juveniles feed to a large extent within the turbid and estuarine waters of the upper bay. This is attributed to the juvenile’s ability to successfully filter smaller prey items that dominate the upper bay (Themelis 1982).

Competition and predation at sea

Once in the ocean, American shad are undoubtedly preyed upon by many species including sharks, tunas, king mackerel, bluefish, striped bass, Atlantic salmon, seals, porpoises, other marine mammals, and seabirds, given their schooling nature and lack of dorsal or opercular spines (Melvin et al. 1985; Weiss-Glanz et al. 1986).

Current laboratory research by Plachta and Popper (2003) has found that American shad can detect ultrasonic signals to at least 180 kHz, which is within the range that echolocating harbour porpoises and bottlenose dolphins use to track alosines. In this laboratory environment, American shad have been observed modifying their behavior in response to echolocation beams, such as turning slowly away from the sound source, forming very compact groups, and displaying a quick “panic” response. Although behavior in a natural environment may be different from that observed in experimental tanks, this study suggests that American shad may have evolved a mechanism to make themselves less “conspicuous” or less easily preyed upon by echolocating odontocetes (Plachta and Popper 2003).

1.3.1.5 Significant Environmental, Temporal and Spatial Factors Affecting Distribution of American shad

Table 9 Significant environmental, temporal, and spatial factors affecting distribution of American shad. Please note that, although there may be subtle variations between systems, the following data include a broad range of values that encompass the different systems that occur along the East Coast. Where a specific range is known to exist, it will be noted. For the sub-adult–estuarine/oceanic environment and non-spawning adult–oceanic environment life history phases, the information is provided as a general reference, not as habitat preferences or optima. NIF = No Information Found.

Life Stage	Time of Year and Location	Depth (m)	Temperature (°C)	Salinity (ppt)	Substrate	Current Velocity (m/sec)	Dissolved Oxygen (mg/L)
Spawning Adult	Mid-November-August (south to north progression) in natal rivers and tributaries from St. Johns River, Florida to St. Lawrence River, Canada	**Tolerable:** 0.46-15.24 **Optimal:** 1.5-6.1 **Reported:** Variable	**Tolerable:** 8-26 **Optimal:** 14-24.5 **Reported:** Varies across range and may vary between years	**Tolerable:** NIF **Optimal:** NIF **Reported:** Mostly freshwater	**Tolerable:** NIF **Optimal:** NIF **Reported:** Sand, silt, gravel, boulder	**Tolerable:** NIF **Optimal:** 0.3-0.9 **Reported:** Avoid pools but prefer slow flow; velocity is an important factor	**Tolerable:** NIF **Optimal:** NIF **Reported:** Minimum 4
Egg	Mid-November-August (south to north progression) at spawning areas or slightly downstream	**Tolerable:** NIF **Optimal:** NIF **Reported:** Settle at bottom in shallow water	**Tolerable:** 8-30 **Optimal:** NIF **Reported:** Variable	**Tolerable:** NIF **Optimal:** NIF **Reported:** Variable	**Tolerable:** NIF **Optimal:** NIF **Reported:** Gravel, rubble, and sand have highest survival	**Tolerable:** NIF **Optimal:** 0.3-0.9 **Reported:** Low flow	**Tolerable:** NIF **Optimal:** NIF **Reported:** Minimum 5
Larvae	2-17 days after fertilization depending on temperature, downstream of spawning areas	**Tolerable:** 0.46-15.24 **Optimal:** 1.5-6.1 **Reported:** Surface and water column	**Tolerable:** 10-30 **Optimal:** 15-25 **Reported:** Variable	**Tolerable:** NIF **Optimal:** NIF **Reported:** Variable	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** 0.3-0.9 **Reported:** Low flow	**Tolerable:** NIF **Optimal:** NIF **Reported:** Minimum 5

Life Stage	Time of Year and Location	Depth (m)	Temperature (°C)	Salinity (ppt)	Substrate	Current Velocity (m/sec)	Dissolved Oxygen (mg/L)
Early Juvenile – Riverine Environment	3-5 weeks after hatching Downstream of spawning areas as far as brackish waters	**Tolerable:** 0.46-15.24 **Optimal:** 1.5-6.1 **Reported:** Variable	**Tolerable:** 3-35 **Optimal:** 10-25 **Reported:** Variable; growth higher at higher temps	**Tolerable:** 0-30 **Optimal:** NIF **Reported:** Gradual change well tolerated	**Tolerable:** NIF **Optimal:** Possibly areas w/50%+ SAV **Reported:** Boulder, cobble, gravel, sand, SAV	**Tolerable:** NIF **Optimal:** 0.1-0.8 **Reported:** Moderate needed for migration	**Tolerable:** NIF **Optimal:** NIF **Reported:** Minimum 5
Subadult & Non-spawning Adult – Estuarine / Oceanic Environment	2-6 years after hatching; 1) Overwinter offshore of Florida, the Mid-Atlantic Bight, and Nova Scotia 2) Spring – migration route is unknown 3) Late June – inner Bay of Fundy, inner Gulf of St. Lawrence, Gulf of Maine, and Newfoundland and Labrador 4) Autumn – moving offshore	**Tolerable:** Surface waters to 340 m **Optimal:** 50-100 m **Reported:** Variable; possible diel migrations with zooplankton	**Tolerable:** Variable **Optimal:** 7-13 **Reported:** Generally travel in preferred isotherm	**Tolerable:** NIF **Optimal:** NIF **Reported:** Brackish to saltwater	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF

Appendix D - Overlapping Habitat and Habitat Areas of Particular Concern for Alosines

Identification and Distribution of Habitat and Habitat Areas of Particular Concern for Alosines

NOTE: Due to the dearth of information on Habitat Areas of Particular Concern (HAPC) for alosine species, this information is applicable to American shad, hickory shad, alewife, and blueback herring combined. Information about one alosine species may be applicable to other alosine species, and is offered for comparison purposes only. Certainly, more information should be obtained at individual HAPCs for each of the four alosine species.

All habitats described in the preceding chapters (spawning adult, egg, larval, juvenile, sub-adult, and adult resident and migratory) are deemed essential to the sustainability of anadromous alosine stocks, as they presently exist (ASMFC 1999). Klauda *et al*. (1991b) concluded that the critical life history stages for American shad, hickory shad, alewife, and blueback herring, are the egg, prolarva (yolk-sac or pre-feeding larva), post-larva (feeding larva), and early juvenile (through the first month after transformation). Nursery habitat for anadromous alosines consists of areas in which the larvae, post-larvae, and juveniles grow and mature (ASMFC 1999). These areas include spawning grounds and areas through which the larvae and post-larvae drift after hatching, as well as the portions of rivers and estuaries in which they feed, grow, and mature. Juvenile alosines, which leave the coastal bays and estuaries prior to reaching adulthood, also use the nearshore Atlantic Ocean as a nursery area (ASMFC 1999).

Sub-adult and adult habitat for alosines consists of: the nearshore Atlantic Ocean from the Bay of Fundy in Canada to Florida; inlets, which provide access to coastal bays and estuaries; and riverine habitat upstream of the spawning grounds (ASMFC 1999). American shad and river herring have similar seasonal distributions, which may be indicative of similar inshore and offshore migratory patterns (Neves 1981). Although the distribution and movements of hickory shad are essentially unknown after they return to the ocean (Richkus and DiNardo 1984), due to harvest along the southern New England coast in the summer and fall (Bigelow and Schroeder 1953) it is assumed that they also follow a migratory pattern similar to American shad (Dadswell *et al*. 1987).

Critical habitat in North Carolina is defined as, “The fragile estuarine and marine areas that support juvenile and adult populations of economically important seafood species, as well as forage species important in the food chain.” Among these critical habitats are anadromous fish spawning and nursery areas in all coastal fishing waters (NCAC 3I.0101 (20) (NCDEHNR 1997). Although most states have not formally designated essential or critical alosine habitat areas, most states have identified spawning habitat, and some have even identified nursery habitat.

Tables in Section II of each alosine species chapter contain significant environmental, temporal, and spatial factors that affect the distribution of American shad, hickory shad, alewife, and blueback herring. Additional tables found on the included DVD contain confirmed, reported, suspected, or historical state habitat for American shad, hickory shad, alewife, and blueback herring. Alosines spend the majority of their life cycle outside of state waters, and the Commission recognizes that all habitats used by these species are essential to their existence.

Present Condition of Riverine Habitats and Habitat Areas of Particular Concern

Fisheries management measures cannot successfully sustain anadromous alosine stocks if the quantity and quality of habitat required by all species are not available. Harvest of fisheries resources is a major factor impacting population status and dynamics, and is subject to control and manipulation. However, without adequate habitat quantity and quality, the population cannot exist (ASMFC 1999).

Habitat Quantity

Thousands of kilometers of historic anadromous alosine habitat have been lost due to development of dams and other obstructions to migration. In the 19th century, organic pollution from factories created zones of hypoxia or anoxia near large cities (Talbot 1954; Chittenden 1969). Gradual loss of spawning and nursery habitat quantity and quality, and overharvesting are thought to be the major causative factors for population declines of American shad, hickory shad, alewife, and blueback herring (ASMFC 1999). Although these threats are considered the major causative factors in the decline of shad and river herring, additional threats are discussed in the Threats chapter.

It is likely that American shad spawned in all rivers and tributaries throughout the species' range on the Atlantic coast prior to dam construction in this country (Colette and Klein-MacPhee 2002). While precise estimates are not possible, it is speculated that at least 130 rivers supported historical runs; now there are fewer than 70 systems that support spawning. Individual spawning runs may have numbered in the hundreds of thousands. It is estimated that runs have been reduced to less than 10% of historic sizes. One recent estimate of river kilometers lost to spawning is 4.36×10^3 compared to the original extent of the runs. This is an increase in available habitat over estimates from earlier years, with losses estimated at 5.28×10^3 in 1898 and 4.49×10^3 in 1960. The increase in available habitat has largely been due to restoration efforts and enforcement of pollutant abatement laws (Limburg *et al*. 2003).

Some states have general characterizations of the degree of habitat loss, but few studies have actually quantified impacts in terms of the area of habitat lost or degraded (ASMFC 1999). It has been noted that dams built during the 1800's and early to mid-1900's on several major tributaries to the Chesapeake Bay have substantially reduced the amount of spawning habitat available to American shad (Atran *et al*. 1983; CEC 1988), and likely contributed to long-term stock declines (Mansueti and Kolb 1953). North Carolina characterized river herring habitat loss as "considerable" from wetland drainage, stream channelization, stream blockage, and oxygen-consuming stream effluent (NCDENR 2000).

Some attempts have been made to quantify existing or historical areas of anadromous alosine habitat, including spawning reaches. For example, Maine estimated that the American shad habitat area in the Androscoggin River is 10,217,391 yd^2. In the Kennebec River, Maine, from Augusta to the lower dam in Madison, including the Sebasticook and Sandy rivers, and Seven Mile and Wesserunsett streams, there is an estimated 31,510,241 yd^2 of American shad habitat and 24,606 surface acres of river herring habitat. Lary (1999) identified an estimated 90,868 units (at 100 yd^2 each) of suitable habitat for American shad and 296,858 units (at 100 yd^2 each) for alewife between Jetty and the Hiram Dam along the Saco River, Maine. Above the Bosher's Dam on the James River, Virginia, habitat availability was estimated in terms of the number of spawning fish that the main-stem area could support annually, which was estimated at 1,000,000 shad and 10,000,000 river herring (Weaver *et al*. 2003).

Although many stock sizes of alosine species are decreasing or remain at historically low levels, some stock sizes are increasing. It has not been determined if adequate spawning, nursery, and adult habitat presently exist to sustain stocks at recovered levels (ASMFC 1999).

Habitat Quality

Concern that the decline in anadromous alosine populations is related to habitat degradation has been alluded to in past evaluations of these stocks (Mansueti and Kolb 1953; Walburg and Nichols 1967). This degradation of alosine habitat is largely the result of human activities. However, it has not been possible to rigorously quantify the magnitude of degradation or its contribution to impacting populations (ASMFC 1999).

Of the habitats used by American shad, spawning habitat has been most affected. Loss due to water quality degradation is evident in the northeast Atlantic coast estuaries. In most alosine spawning and nursery areas, water quality problems have been gradual and poorly defined; it has not been possible to link those declines to changes in alosine stock size. In cases where there have been drastic declines in alosine stocks, such as in the Chesapeake Bay in Maryland, water quality problems have been implicated, but not conclusively demonstrated to have been the single or major causative factor (ASMFC 1999).

Toxic materials, such as heavy metals and various organic chemicals (i.e., insecticides, solvents, herbicides), occur in anadromous alosine spawning and nursery areas and are believed to be potentially harmful to aquatic life, but have been poorly monitored. Similarly, pollution in nearly all of the estuarine waters along the East Coast has certainly increased over the past 30 years, due to industrial, residential, and agricultural development in the watersheds (ASMFC 1999). Specific challenges that currently exist are identified and discussed in greater detail in the Threats Chapter.

Threats to Alosine Species

NOTE: Due to broad geographic ranges, alosine species are susceptible to varied threats throughout different life stages. The threats identified under this section occur during the freshwater and/or estuarine portion of species life histories.

Identification of Threats

THREAT #1: BARRIERS TO UPSTREAM AND DOWNSTREAM MIGRATION

Section 1.1A: Dams and Hydropower Facilities

Issue 1.1A.1: Blocked or restricted upstream access

There has been considerable loss of historic spawning habitat for shad and river herring due to the dams and spillways impeding rivers along the East Coast of the United States. Permanent man-made structures pose an ongoing barrier to fish passage unless fishways are installed or structures are removed. Low-head dams can also pose a problem, as fish are unable to pass over them except when tides or river discharges are exceptionally high (Loesch and Atran 1994). Historically, major dams were often constructed at the site of natural formations conducive to waterpower, such as natural falls. Diversion of water away from rapids at the base of falls can reduce fish habitat, and in some cases cause rivers to run dry at the base for much of the summer (MEOEA 2005).

Many dams have facilities that are designed to provide upstream passage to spawning habitat for migratory species. However, dams without adequate upstream fish passage facilities prevent, or significantly reduce, the numbers of migratory fish that return to available habitat (Quinn 1994). Suboptimal fish passage at a low-head dam on the Neuse River, North Carolina, resulted in limited production of American shad in that system (Beasley and Hightower 2000). Subsequent removal of the dam in 1998 facilitated the return of American shad and striped bass to historic spawning habitats above the dam.

American shad likely spawned in most, if not all, rivers and tributaries in their range prior to dam construction along the Atlantic coast (Colette and Klein-MacPhee 2002). Precise estimates are not possible, but scientists speculate that at least 130 rivers supported historical runs; now there are fewer than 70 spawning systems for American shad. Furthermore, individual spawning runs at one time may have numbered in the hundreds of thousands, but current runs may provide less than 10% of historic spawning habitat (Limburg *et al*. 2003). Dams built from the 19th century through the mid-20th century on several major tributaries to the Chesapeake Bay have substantially reduced the amount of spawning habitat available to American shad (Atran *et al*. 1983; CEC 1988), and likely contributed to long-term stock declines (Mansueti and Kolb 1953).

Issue 1.1A.2: Impacts during downstream migration

Another impact of dams on diadromous species migration is their potential to cause mortality to young fish that pass over sluices and spillways during out-migration. Potential effects to fish passing through spillways or sluices may include injury from turbulence, rapid deceleration, terminal velocity, impact against the base of the spillway, scraping against the rough concrete face of the spillbay, and rapid pressure changes (Ferguson 1992; Heisey *et al*. 1996).

Prior to the early 1990s, it was thought that migrating shad and river herring suffered significant mortality going through turbines during downstream passage (Mathur and Heisey 1992). One study estimated that mortality of adult American shad passing through a Kaplan turbine was approximately 21.5% (Bell and Kynard 1985).

Juvenile shad emigrating from rivers have been found to accumulate in larger numbers near the forebay of hydroelectric facilities, where they become entrained in intake flow areas (Martin *et al*. 1994). Relatively high mortality rates were reported (62% to 82%) at a hydroelectric dam for juvenile American shad and blueback herring, depending on the power generation levels tested (Taylor and Kynard 1984). In contrast, Mathur and Heisey (1992) reported a mortality rate of 0% to 3% for juvenile American shad (55 to 140 mm fork length), and 4% for juvenile blueback herring (77 to 105 mm fork length) through Kaplan turbines. Mortality rate increased to 11% in passage through a low-head Francis turbine (Mathur and Heisey 1992). Other studies reported less than 5% mortality when large Kaplan and fixed-blade, mixed-flow turbines were used at a facility along the Susquehanna River (RMC 1991, 1994). At the same site, using small Kaplan and Francis runners, the mortality rate was as high as 22% (NA 2001). At another site, mortality rate was about 15% where higher revolution, Francis-type runners were used (RMC 1992).

Additional studies reported that changes in pressure had a more pronounced effect on juveniles with thinner and weaker tissues as they moved through turbines (Taylor and Kynard 1984). Furthermore, some fish may die later from stress, or become weakened and more susceptible to predation, so losses may not be immediately apparent to researchers (Gloss 1982).

Issue 1.1A.3: Delayed migration

When juvenile alosines delay out-migration, they may concentrate behind dams, making them more susceptible to actively feeding predators. They may also be more vulnerable to anglers that targ*et al*osines as a source of bait. Delayed out-migration can also make juvenile alosines more susceptible to marine predators that they may have avoided if they had followed their natural migration patterns (McCord 2005a). In open rivers, juvenile alosines gradually move seaward in groups that are likely spaced according to the spatial separation of spawning and nursery grounds (Limburg 1996; J. McCord, South Carolina Department of Natural Resources, personal observation).

Issue 1.1A.4: Changes to the river system

In addition to physically impeding fish migration, dams can have other impacts on anadromous fish habitat. Releasing water from dams and impoundments (or reservoirs) may lead to flow alterations, altered sediment transport, disruption of nutrient availability, changes in water quality downstream (including both reduced and increased changes in temperatures), streambank erosion, concentration of sediment and pollutants, changes in species composition, solubilization of iron and manganese and their absorbed or chelated ions, and hydrogen sulfide in hypolimnetic (release of water at low level outlets) releases (Yeager 1995; Erkan 2002). Many dams spill water over the top of the structure where water temperatures are the warmest, which essentially creates a series of warm water ponds rather than a natural stream channel (Erkan 2002). Conversely, water released from deep reservoirs may be poorly oxygenated, below normal seasonal water temperature, or both, thereby causing loss of suitable spawning or nursery habitat in otherwise habitable areas.

Reducing minimum flows can dehydrate otherwise productive habitats causing increased water temperature or reduced dissolved oxygen levels (ASMFC 1985, 1999; USFWS *et al*. 2001).

Pulsing or "hydropeaking" releases typically produce the most substantial environmental alterations (Yeager 1995), including reduced biotic productivity in tailwaters (Cushman 1985).

During low flow periods (typically summer and fall), gases, dissolved oxygen in particular, may be depleted (Yeager 1995). Storing water at hydropower facilities during times of diminished rainfall can also lead to low dissolved oxygen conditions downstream. Such conditions have occurred along the Susquehanna River at the Conowingo Dam, Maryland, from late spring through early fall, and have historically caused large fish kills below the dam (Krauthamer and Richkus 1987).

Disruption of seasonal flow rates in rivers has the potential to impact upstream and downstream migration patterns for adult and juvenile alosines (ASMFC 1985, 1999; Limburg 1996; USFWS *et al*. 2001). Changes to natural flows can also disrupt natural productivity and availability of zooplankton, which is nourishment for larval and early juvenile alosines (Crecco and Savoy 1987; Limburg 1996).

Although most dams that impact diadromous fish are located along the length of rivers, fish can also be affected by hydroelectric projects at the mouths of rivers, such as the large tidal hydroelectric project at the Annapolis River in the Bay of Fundy, Canada. Dadswell *et al*. (1983) found that this particular basin and other surrounding waters are used as foraging areas during summer months by American shad from all runs along the East Coast of the United States. Because the facilities are tidal hydroelectric projects, fish may move into and out of the impacted areas with each tidal cycle. Although turbine mortality is relatively minor with each passage, the repeated passage into and out of these facilities may cumulatively result in substantial overall mortalities (Scarratt and Dadswell 1983).

Issue 1.1A.5: Secondary impacts

Blocked migratory paths can reduce the diadromous species contribution of nutrients and carbon to riparian systems. Riverine habitats and communities may be strongly influenced by migratory fauna that provide a significant source of energy input (Polis *et al*. 1997). Furthermore, many freshwater mussels are dependent upon migratory fishes as hosts for their parasitic larvae (Neves *et al*. 1997; Vaughn and Taylor 1999); loss of upstream habitat for migratory fish is a major cause of mussel population declines (Williams *et al*. 1993; Watters 1996).

It is estimated that the annual biomass contribution of anadromous alosines to the non-tidal James River, Virginia, was 155 kg/ha (assumes 3.6 million fish with 70% post-spawning mortality) in the 1870s, before dams blocked upstream migration (Garman 1992). Based on the estimated 90% reduction in alosine abundance in the Chesapeake Bay over the past 30 years, Garman and Macko (1998) concluded that, "the ecological roles hypothesized for anadromous *Alosa* spp. may now be greatly diminished compared to historical conditions."

Section 1.1B: Avoiding, Minimizing, and Mitigating Impacts of Dams and Hydropower Facilities

Approach 1.1B.1: Removing dams

Not all projects are detrimental to fish populations, so each site should be evaluated separately to determine if fish populations will be (or are being) negatively impacted (Yeager 1995). Wherever practicable, tributary blockages should be removed, dams should be notched, and bypassing dams or installing fish lifts, fish locks, fishways, or navigation locks should be considered. Full dam removal will likely provide the best chance for restoration; however, it is not always practicable to remove large dams along mainstem rivers. Removing dams on smaller, high-order tributaries is more likely to benefit ascending river herring than shad, which spawn in the larger mainstem portions of rivers (Waldman and Limburg 2003).

Example: Successful Dam Removals

Along the large, lower-river tributaries of the Susquehanna River, Pennsylvania, at least 25 dams have either been removed or fitted with fishways, which has provided a total of 350 additional stream kilometers for anadromous fish (St. Pierre 2003). In addition, some dams within the Atlantic sturgeon's range have been removed, including the Treat Falls Dam on the Penobscot River, Maine, and the Enfield Dam on the Connecticut River, Connecticut. In 1999, the Edwards Dam at the head-of-tide on the Kennebec River was removed, which restored 18 miles of Atlantic sturgeon spawning and nursery habitat and resulted in numerous sightings of large Atlantic sturgeon from Augusta to Waterville (Squires 2001).

Unfortunately, many waterways along the Atlantic coast host impoundments constructed during the Industrial Revolution that originally were a source of inexpensive power; many of these structures are no longer in use and should be removed (Erkan 2002).

Approach 1.1B.2: Installing or modifying fish passage facilities

1. For Upstream Passage

a) Fishways

Fish passage facilities, or fishways, allow fish to pass around an impoundment they would otherwise be unable to negotiate. Vertical slot fishways are commonly used to provide upstream access around dam structures. They are designed to draw fish away from the turbulent waters at the base of the dam toward the smooth flowing waters at the entrance of the fishway. Once fish enter the fishway, they negotiate openings, or vertical slots, in the baffle walls. Fish move from pool to pool as they advance up the fishway, using the pools as rest areas (VDGIF 2006).

Another type of fishway is the fish ladder. Fish ladders consist of a series of baffles, or weirs, that interrupt the flow of water through the passage structure. As with vertical slot fishways, a series of ascending pools is created.

A third type of fishway, the Denil fishway, is the most common type in the northeast and reliably passes shad and river herring. In fact, construction of fish ladders in coastal streams of Maine resulted in rapid and noticeable increases in the number of adult alewife returning to these streams (Rounsefell and Stringer 1943).

It is important to note that although fish passage facilities are instrumental in restoring fish to historical habitat, they are not 100% efficient because some percentage of target fish will not find and successfully use the fishway (Weaver *et al*. 2003). At sites where bypass facilities are in place, but are inadequate, efficiency of upstream and downstream fish passage should be improved. Furthermore, passage facilities should be designed specifically for passing target species; some facilities constructed for species such as Atlantic salmon, have proven unsuitable for passing shad (Aprahamian *et al*. 2003).

In 1999, a vertical slot fishway was opened at Bosher's Dam on the James River, Virginia, ending nearly 200 years of blocked access to upstream areas. As a result, 221.4 km of historical spawning habitat on the main stem of the river and 321.9 km on tributaries was restored. By 2001, an increasing trend of relative abundance of American shad in the fall zone was strongly correlated with an increasing trend of American shad passage (Weaver *et al*. 2003). (Note: This increase was dominated by hatchery-raised fish, thus, fish passage may have had little to do with the increased population in this situation; M. Hendricks, Pennsylvania Fish and Boat Commission, pers., comm.)

b) Pipe passes

Pipe passes consist of a pipe below the water level that passes through a barrier. Substrate is provided in the pipe to decrease water velocity and to allow American eel to crawl through the pipe. Although this design creates a direct passage, it is flawed because the pipe often becomes blocked with debris, rendering it ineffective. Pipe passes are most efficient at the outflow of large impoundments that act as a sediment trap for debris so that water entering the pipe is clear of material that might cause a blockage (Solomon and Beach 2004).

c) Locks and lifts

For locks, fish swim into a lock chamber with an open lower gate. The gate periodically closes and the chamber is filled with water, bringing it up to level with the headpond. The upper gate is then opened and the fish swim out. This type of fish passage involves a great deal of engineering and can be expensive. This solution is ideal for very high head situations where conventional passes are impractical (Solomon and Beach 2004).

Alternatively, a fishlift involves a chamber that fish swim into. A steel bucket recessed in the chamber floor is lifted up to or above the head pond level, a gate is opened and the fish are dumped out. Moffitt *et al*. (1982) noted that blueback herring responded quite favorably to improved lift facilities at the Holyoke Dam on the Connecticut River, with passage increasing tremendously. Despite these improvements, stocks have declined considerably in recent years (R. St. Pierre, United States Fish and Wildlife Service, pers. comm.).

2. For Downstream Passage

Fish migrating downstream may pass through turbines, spillage, bypass facilities, or a combination of the three. One comparison between spillways and efficiently operated turbines found that the two systems were comparable in reducing fish mortality (Heisey *et al*. 1996).

Downstream passage of spent adult American shad through large turbines at the Safe Harbor project along the Susquehanna River, Pennsylvania, found that survival rate was 86% (NA and Skalski 1998). Survival rates would likely not be as favorable at facilities that employ smaller, high-speed turbines. Additional measures to help facilitate survival rates include controlled spills during peak migration months (St. Pierre 2003).

At some sites it is not desirable to move fish through turbines, alternatively, they can be moved through a bypass facility. Creating a strong attraction flow helps guide fish to the bypass system and away from the intake flow areas of the turbines (Knights and White 1998; Verdon *et al*. 2003). Additionally, barrier devices can help deter fish away from flow intake areas. Barrier devices used to deter fish include lights, high-frequency sound, air bubble curtains, electrical screens, water jet curtains, and chemicals. Mechanical barrier devices include hanging chains, louvers, angled bars, and screens (Martin *et al*. 1994; Richkus and Whalen 1999; Richkus and Dixon 2003). Submerged strobe lights were found to be quite effective at directing fish away from turbines and through a sluiceway (Martin *et al*. 1994).

Approach 1.1B.3: Operational modifications

Hydroprojects operate more closely to the natural flow patterns of a stream when water moves through them with a fairly constant flow. Consequently, storage-release projects are more likely to alter both daily and seasonal flow patterns (Yeager 1995). Adjusting in-stream flows to more closely reflect natural flow regimes may help increase productivity of alosines, especially during summer to early fall when large, deep reservoirs stratify, and anoxic water releases are possible (McCord 2003).

Power generation can also be reduced, or ceased altogether, during prime downstream migration periods. This option might be cost-effective if migratory behavior coincides with off-peak rate schedules (Gilbert and Wenger 1996). Flows can be re-regulated at dams downstream of the primary dam to stabilize flows further downstream (Cushman 1985). Additionally, some studies have found that the most efficient operating flows for small turbines may not result in the best fish survival rates, but that operation at higher flows may pass fish more safely (Fisher *et al*. 1997).

Where hydrological conditions have been modified, additional measures can be implemented to help mitigate impacts on the river. For example, operational changes can be made to accomplish a number of improvements, such as reducing the upper limit of variability of one or more of the physical or chemical characteristics of the river. For example, incorporating turbine venting into major dams has proven useful for increasing dissolved oxygen concentrations. Alternatively, aerating reservoirs upstream of hydroelectric plants (Mobley and Brock 1996), as well as aerating flows downstream from the plants using labyrinth weirs and infuser weirs have also proven reliable for increasing the dissolved oxygen concentration in the water (Hauser and Brock 1994).

For alosines that migrate downstream during early evening hours, maintaining peak efficiency flows through selected turbines during these hours, as well as employing turbines that reduce mortality, may be effective (St. Pierre 2003).

Approach 1.1B.4: Streambank stabilization

States that have significant problems with streambank erosion have turned to stabilization to help further prevent erosion. Projects should maintain vegetated riparian buffers, making use of native vegetation wherever possible (MEOEA 2005). Habitat modification, including manipulating the cross-sectional geometry of the stream channel, may also serve to mitigate effects (Cushman 1985).

Loesch (1987) found that blueback herring responded favorably to changes in physical and hydrological conditions, becoming re-established and even increasing in abundance once favorable conditions were established or restored.

Approach 1.1B.5: Fish transfers

When populations have been extirpated from their habitat due to dam blockage, it may be necessary to transfer sexually mature pre-spawning adults or hatchery-reared fry and fingerlings above obstructed areas.

Transplanting of fertilized alosine eggs has had limited success; eggs are now collected mostly for use in culture operations. Culture operations have focused primarily on American shad, and to a lesser degree blueback herring, alewife, and hickory shad (Hendricks 2003). Transplanting adult American shad, blueback herring, and alewife has been highly successful. Adult gravid shad can be trapped in the river where they originate, or other rivers, and trucked to upstream sites where they can be expected to spawn in areas that are otherwise not accessible. This may be an effective means for supplementing the river population until fish passage facilities are improved (both in the upstream and downstream direction), or fish passage facilities are constructed where they currently do not exist. As the return populations grow, further modifications may be necessary to accommodate larger runs (St. Pierre 1994).

For example, the release of hatchery-reared American shad in the James River, Virginia, in the mid-1990's, resulted in greater than 40% of hatchery-reared fish spawning several years later. This percentage greatly exceeded the percentage of the hatchery contribution (3 to 8%). If the offspring of hatchery-reared fish survive to reproduce, this should provide a significant boost to this severely depressed population (Olney *et al*. 2003).

At the Conowingo Dam on the Susquehanna River, Pennsylvania, 70 to 85% of the adult American shad returning from 1991 through 1995 were hatchery-reared. By 2003, the hatchery-to-wild ratio had been reversed, and naturally produced adults comprised 40 to 60% of returning fish (St. Pierre 2003).

Additionally, Maryland reported that over 80% of the 142 adults captured in the Patuxent and Choptank rivers in 2000 were of hatchery origin. It appears that shad stock enhancement, through the release of hatchery-reared fish, has proven to be beneficial when accompanied by other management measures including habitat restoration and water quality protection (Hendricks 2003).

Finally, pre-spawning adult American shad were taken from the Connecticut River and transplanted in the Pawcatuck River, Rhode Island, where they had been absent for 100 years. Six years later, in 1985, a population of over 4,000 fish existed (Gibson 1987).

Section 1.2: Road Culverts and Other Sources of Blockage

Issue 1.2A: Road culverts

While dams are the most common obstructions to fish migration, road culverts are also a significant source of blockage. Culverts are popular, low-cost alternatives to bridges when roads must cross small streams and creeks. Although the amount of habitat affected by an individual culvert may be small, the cumulative impact of multiple culverts within a watershed can be substantial (Collier and Odom 1989).

Roads and culverts can also impose significant changes in water quality. Winter runoff in some states includes high concentrations of road salt, while stormwater flows in the summer cause thermal stress and bring high concentrations of other pollutants (MEOEA 2005).

Sampled sites in North Carolina revealed river herring upstream and downstream of bridge crossings, but no herring were found in upstream sections of streams with culverts. Additional study is underway to determine if culverts are the cause for the absence of river herring in these areas (NCDENR 2000). Even structures only 20 to 30 cm above the water can block shad and river herring migration (ASMFC 1999).

Issue 1.2B: Other man-made structures

Additional man-made structures that may obstruct upstream passage include: tidal and amenity barrages; tidal flaps; mill, gauging, amenity, navigation, diversion, and water intake weirs; fish counting structures; and earthen berms (Durkas 1992; Solomon and Beach 2004). The impact of these structures is site-specific and will vary with a number of conditions including head drop, form of the structure, hydrodynamic conditions upstream and downstream, condition of the structure, and presence of edge effects (Solomon and Beach 2004).

Issue 1.2C: Natural barriers

Rivers can also be blocked by non-anthropogenic barriers, such as beaver dams, waterfalls, log piles, and vegetative debris. These blockages may be a hindrance to migration, but they can also be beneficial since they provide adhesion sites for eggs, protective cover, and feeding sites (Klauda *et al*. 1991b). Successful passage at these natural barriers is often dependent on individual stream flow characteristics during the fish migration season.

THREAT #2: WATER WITHDRAWAL FACILITIES

Section 2.1A: Hydropower, Drinking Water, Irrigation, and Snow-making Facilities

Issue 2.1A.1: Impingement and entrainment

Large volume water withdrawals (e.g., drinking water, pumped-storage hydroelectric projects, irrigation, and snow-making), especially at pumped-storage facilities, can drastically alter local current characteristics (e.g., reverse river flow). This can cause delayed movement past the facility, or entrainment where the intakes occur (Layzer and O'Leary 1978). Planktonic eggs and larvae entrained at water withdrawal projects experience high mortality rates due to pressure changes, shear and mechanical stresses, and heat shock (Carlson and McCann 1969; Marcy 1973; Morgan *et al*. 1976). Well-screened facilities are unlikely to cause serious mortality to juveniles; however, large volume withdrawals can entrain significant numbers (Hauck and Edson 1976; Robbins and Mathur 1976).

Impingement of fish can trap them against water filtration screens, leading to asphyxiation, exhaustion, removal from the water for prolonged periods of time, or removal of protective mucous and descaling (DBC 1980).

Studies conducted along the Connecticut River found that larvae and early juveniles of alewife, blueback herring, and American shad suffered 100% mortality when temperatures in the cooling system of a power plant were elevated above 28°C; 80% of the total mortality was caused by mechanical damage and 20% was due to heat shock (Marcy 1976b). Ninety-five percent of the fish near the intake were not captured by the screen, and Marcy (1976b) concluded that it did not seem possible to screen fish larvae effectively. Results from earlier years led Marcy (1976c) to conclude that although mortality rates for eggs and larvae entrained in the intake system were very high, given the high natural mortality rate and the number of eggs produced by one adult shad, the equivalent of only one adult shad was lost during that study year as a result of egg and larval entrainment. Furthermore, there was no evidence that adult shad had changed the location of their spawning areas in the river as a result of plant operation (Marcy 1976c).

Another study of juvenile American shad emigrating from the Hudson River found that impingement at power plants was an inconsequential source of mortality; however, when added to other more serious stresses, it may possibly contribute to increased mortality rates (Barnthouse and Van Winkle 1988).

Issue 2.1A.2: Alteration of stream physical characteristics

Water withdrawals can also alter physical characteristics of streams, including: decreased stream width, depth, and current velocity; altered substrate; and temperature fluctuations (Zale *et al*. 1993). In rivers that are drawn upon for water supply, water is often released downstream during times of decreased river flow (usually summer). Additionally, failure to release water during times of low river flow and higher than normal water temperatures can cause thermal stress, leading to fish mortality. Consequently, water flow disruption can result in less freshwater input to estuaries (Rulifson 1994), which are important nursery areas for many anadromous species.

Cold water releases often decrease the water temperature of the river downstream, which has been shown to cause juvenile American shad to abandon their nursery areas (Chittenden 1969; 1972). At the Cannonsville Reservoir on the West Branch of the Delaware River, cold-water releases from the dam resulted in the elimination of nursery grounds below the dam for American shad (DBC 1980).

Section 2.1B: Avoiding, Minimizing, and Mitigating Impacts of Water Withdrawal Facilities

Approach 2.1B.1: Use of technology and water velocity modification

Impacts resulting from entrainment can be mitigated to some degree through the use of the best available intake screen technology (ASMFC 1999), or through modifying water withdrawal rates or water intake velocities (Lofton 1978; Miller *et al*. 1982). Devices have also been used at hydroelectric projects to deter fish from intake flows, including: electrical screens, air bubble curtains, hanging chains, lights, high-frequency sound, water jet curtains, chemicals, visual keys, or a combination of these approaches (Martin *et al*. 1994). Promoting measures among industry that use reclaimed water, instead of freshwater from natural areas, can help reduce the amount of freshwater needed (FFWCC 2005). Location along the river was also found to be a significant factor affecting impingement rates in the Delaware River (Lofton 1978).

THREAT #3: TOXIC AND THERMAL DISCHARGES

Section 3.1A: Industrial Discharge Contamination

Issue 3.1A.1: Chemical effects on fish

Industrial discharges may contain toxic chemicals, such as heavy metals and various organic chemicals (e.g., insecticides, solvents, herbicides) that are harmful to aquatic life (ASMFC 1999). Many contaminants have been identified as having deleterious effects on fish, particularly reproductive impairment (Safe 1990; Longwell *et al*. 1992; Mac and Edsall 1991). Chemicals and heavy metals can be assimilated through the food chain, producing sub-lethal effects such as behavioral and reproductive abnormalities (Matthews *et al*. 1980). In fish, exposure to polychlorinated biphenyls (PCBs) can cause fin erosion, epidermal lesions, blood anemia, altered immune response, and egg mortality (Post 1987;

Kennish *et al*. 1992). Furthermore, PCBs are known to have health effects in humans and are considered to be human carcinogens (Budavari *et al*. 1989).

A number of common pollutants have been found to disturb the thyroid gland in fish, which plays a role in the maturation of oocytes. These chemicals include: lindane (organochlorine) (Yadav and Singh 1987); malathion (organophosphorus compound) (Lal and Singh 1987; Singh 1992); endosulfan (organochlorine) (Murty and Devi 1982); 2,3,7,8-PCDD and –PCDF (dioxin and halogenated furane); some PCBs (particularly 2,3,7,8-TCDD *para* and *meta* forms) (Safe 1990); and PAHs (polycyclic aromatic hydrocarbons) (Leatherland and Sunstegard 1977, 1978, 1980).

Steam power plants that use chlorine to prevent bacterial, fungal, and algal growth present a hazard to all aquatic life in the receiving stream, even at low concentrations (Miller *et al*. 1982). Pulp mill effluent and other oxygen-consuming wastes are discharged into a number of streams.

Lack of dissolved oxygen from industrial pollution and sewage discharge can greatly affect abundance of shad and prevent migration upriver or prevent adults from emigrating to sea and returning again to spawn. Everett (1983) found that during times of low water flow when pulp mill effluent comprised a large percentage of the flow, river herring avoided the effluent. Pollution may be diluted in the fall when water flow increases, but fish that reach the polluted waters downriver before the water has flushed the area will typically succumb to suffocation (Miller *et al*. 1982).

Effluent may also pose a greater threat during times of drought. Such conditions were suspected of interfering with the herring migration along the Chowan River, North Carolina, in 1981. In past years, the effluent from the pulp mill had passed prior to the river herring run, but drought conditions caused the effluent to remain in the system longer. Toxic effects were indicated, and researchers suggested that growth and reproduction might have been disrupted as a result of eutrophication and other factors (Winslow *et al*. 1983).

Even thermal effluent from power plants can have a profound effect on fish, causing disruption of schooling behavior, disorientation, and death. Researchers concluded that 30°C was the upper natural temperature limit for juvenile alosines (Marcy *et al*. 1972).

Issue 3.1.2: Sewage effects on fish

Sewage can have direct and indirect effects on anadromous fish. Minimally effective sewage treatment during the 1960s and early 1970s may have been responsible for major phytoplankton and algal blooms in tidal freshwater areas of the Chesapeake Bay, which reduced light penetration (Dixon 1996), and ultimately reduced SAV abundance (Orth *et al*. 1991). Some of Massachusetts' large to mid-sized rivers receive raw sewerage into their waters, and during summer low flows, are composed primarily of sewerage treatment effluent (MEOEA 2005).

Section 3.1B: Avoiding, Minimizing, and Mitigating Impacts of Toxic and Thermal Discharges

Approach 3.1B.1: Proper treatment of facility discharge

Although there has been a general degradation of water quality coastwide, the levels of sewage nutrients discharged into coastal waters during the past 30 years have decreased as a result of the Clean Water Act, passed in 1972. This has led to a decrease in organic enrichment, which has benefited water quality conditions. A reduction of other types of pollutant discharges into these waters, such as heavy metals and organic compounds, would not be expected (ASMFC 1999).

In many northern rivers, such as the Kennebec, Penobscot, Connecticut, Hudson, and Delaware Rivers, dissolved oxygen levels approached zero parts per million in the 1960s and 1970s. Since then, water quality has greatly improved as a result of better point-source treatment of municipal and industrial waste (USFWS-NMFS 1998). In 1974, secondary and tertiary sewage treatment was initiated in the Hudson River, which led to conditions where dissolved oxygen was greater than 60% saturation. There was a return of many fish species to this habitat (Leslie 1988), including a high abundance of juvenile shortnose sturgeon (Carlson and Simpson 1987; Dovel *et al*. 1992).

Additionally, although poor water quality is often identified as a barrier to fish migration, it should be noted that poor water quality can be caused by both point and non-point sources of pollution. In fact, it may be difficult, if not impossible, for water quality standards to be achieved in some regions due to the effects of non-point sources of pollution (Roseboom *et al*. 1982).

The estimated lost spawning habitat for American shad in 1898 was 5.28 x 10^3 river km, and in 1960 it was estimated at 4.49 x 10^3 km. The most recent estimate is now 4.36 x 10^3 river km. This increase in available habitat has been largely attributed to restoration efforts and enforcement of pollutant abatement laws (Limburg *et al*. 2003).

In compliance with the Clean Water Act, proper treatment of large city domestic sewage at treatment plants has dramatically improved the poor water quality conditions that persisted in the Delaware River for many years. Water quality problems were dramatically manifested in a “pollution block,” including severely depressed levels of dissolved oxygen in the early 1900s in the Philadelphia/Camden area. There were very few repeat American shad spawners in this river, compared with other mid-Atlantic rivers (Miller *et al*. 1982). The situation had greatly improved by the late 1950s, due to a reduction in point-source pollution entering tidal waters, which led to an increase in dissolved oxygen by the 1980s (Maurice *et al*. 1987). This has led to a large enhancement of the American shad population in this river (Ellis *et al*. 1947; Chittenden 1969; Miller *et al*. 1982).

Similarly, improvements to water quality in the Potomac River in the 1970s led to increased water clarity and subsequently an increase in SAV abundance in 1983 (Dennison *et al*. 1993). In addition, pulp mill effluent was thought to have limited American shad survival in the Roanoke River (Walburg and Nichols 1967), but compliance with water quality standards in recent years has resulted in improved spawning habitat in this system (Hightower and Sparks 2003). Additional measures to improve habitat include reducing the amount of thermal effluent into rivers and streams, and discharging earlier in the year to reduce impacts to migrating fish (ASMFC 1999).

THREAT #4: CHANNELIZATION AND DREDGING

Section 4.1A: Impacts of Dredging on Fish Habitat

Issue 4.1A.1: Primary environmental impacts of channelization

Channelization has the potential to cause significant environmental impacts (Simpson *et al*. 1982; Brookes 1988), including bank erosion, elevated water velocity, reduced habitat diversity, increased drainage, and poor water quality (Hubbard 1993). Dredging and disposal of spoils along the shoreline can also create spoil banks, which block access to sloughs, pools, adjacent vegetated areas, and backwater swamps (Frankensteen 1976). Dredging may also release contaminants resulting in bioaccumulation, direct toxicity to aquatic organisms, or reduced dissolved oxygen levels (Morton 1977). Furthermore, careless land use practices may lead to erosion, which can lead to high concentrations of suspended solids (turbidity) and substrate (siltation) in the water following normal and intense rainfall events. This can displace larvae and juveniles to less desirable areas downstream and cause osmotic stress (Klauda *et al*. 1991b).

Spoil banks are often unsuitable habitat for fishes. Sand areas are an important nursery habitat to YOY striped bass. This habitat is often lost when dredge disposal material is placed on natural sand bars and/or point bars. The spoil is too unstable to provide good habitat for the food chain. Mesing and Ager (1987) found that electrofishing CPUE for gamefish was significantly greater on natural habitat than on “new (75%),” recent (66%),” or “old (50%)” disposal sites. Old sites that had not been disposed on for 5 to –10 or more years had not recovered to their natural state in terms of relative abundance of gamefish populations. The researchers also found that placement of rock material on degraded sand disposal sites had significantly greater electrofishing CPUE for sportfish than these sites had prior to placement of the rock material (Mesing and Ager 1987).

Draining and filling, or both, of wetlands adjacent to rivers and creeks in which alosines spawn has eliminated spawning areas in North Carolina (NCDENR 2000).

Issue 4.1A.2: Secondary environmental impacts of channelization

Secondary impacts from channel formation include loss of vegetation and debris, which can reduce habitat for invertebrates and result in reduced quantity and diversity of prey for juveniles (Frankensteen 1976). Additionally, stream channelization often leads to altered substrate in the riverbed and increased sedimentation (Hubbard 1993), which in turn can reduce the diversity, density, and species richness of aquatic insects (Chutter 1969; Gammon 1970; Taylor 1977). Suspended sediments can reduce feeding success in larval or juvenile fishes that rely on visual cues for plankton feeding (Kortschal *et al*. 1991). Fish species that rely on benthic invertebrates within sediments may also experience decreased food availability if prey numbers are reduced. Sediment re-suspension from dredging can also deplete dissolved oxygen, and increase bioavailability of any contaminants that may be bound to the sediments (Clark and Wilber 2000).

Issue 4.1A.3: Impacts of channelization on fish physiology and behavior

Migrating adult river herring have been found to avoid channelized areas with increased water velocities. Several channelized creeks in the Neuse River basin in North Carolina have reduced river herring distribution and spawning areas (Hawkins 1979). Frankensteen (1976) found that the channelization of Grindle Creek, North Carolina removed in-creek vegetation and woody debris, which served as substrate for fertilized eggs.

Channelization can also reduce the amount of pool and riffle habitat (Hubbard 1993), which is an important food-producing area for larvae (Keller 1978; Wesche 1985). American shad postlarvae have been found concentrated in riffle-pool habitat (Ross *et al*. 1993).

Dredging can negatively affect alosine populations by producing suspended sediments (Reine *et al*. 1998), and migrating alosines are known to avoid waters of high sediment load (ASMFC 1985; Reine *et al*. 1998). It is also possible that fish may avoid areas where there is ongoing dredging due to suspended sediment in the water column. This was believed to have been the cause of a diminished return of adult spawning shad in a Rhode Island river, although no causal mechanism could be established (Gibson 1987). Filter-feeding fishes, such as alosines, can be negatively impacted by suspended sediments on gill tissues (Cronin *et al*. 1970). Suspended sediments can clog gills that provide oxygen, resulting in lethal and sub-lethal effects to fish (Sherk *et al*. 1974, 1975).

Nursery areas along the shorelines of the rivers in North Carolina have been affected by dredging and filling, as well as by erection of bulkheads; however, the degree of impact has not been measured. In some areas, juvenile alosines were unable to enter channelized sections of a stream due to high water velocities caused by dredging (ASMFC 2000). Despite findings by Miller *et al*. (1982) that the effects of river dredging on fish populations were insignificant, they suspected that migrating juvenile shad could potentially be impacted by increased suspended solids, lowered dissolved oxygen concentration, and release of toxic materials.

Section 4.1B: Avoiding, Minimizing, and Mitigating Impacts of Channelization

Approach 4.1B.1: Seasonal restrictions and proper material disposal

Dredging restrictions are already in place in many rivers including the Kennebec, Connecticut, Cape Fear, Cooper, and Savannah Rivers (USFWS-NMFS 1998), to help curtail the impacts of dredging to anadromous fish. Seasonal restrictions on dredging in areas where anadromous fish are known to occur should be established until there is irrefutable evidence that dredging does not restrict the movement of fish (Gibson 1987). It is recommended that dredge material be disposed of in the most ecologically beneficial way possible that will prevent harm to existing natural habitats (FFWCC 2005).

THREAT #5: LAND USE CHANGE

The effects of land use and land cover on water quality, stream morphology, and flow regimes are numerous, and may be the most important factors determining quantity and quality of aquatic habitats (Boger 2002). Studies have shown that land use influences dissolved oxygen (Limburg and Schmidt 1990), sediments and turbidity (Basnyat *et al*. 1999; Comeleo *et al*. 1996), water temperature (Hartman *et al*. 1996; Mitchell 1999), pH (Osborne and Wiley 1988; Schofield 1992), nutrients (Basnyat *et al*. 1999; Osborne and Wiley 1988; Peterjohn and Correll 1984), and flow regime (Johnston *et al*. 1990; Webster *et al*. 1992).

Siltation, caused by erosion due to land use practices, can kill submerged aquatic vegetation (SAV). SAV can be adversely affected by suspended sediment concentrations of less than 15 mg/L (Funderburk *et al*. 1991) and by deposition of excessive sediments (Valdes-Murtha and Price 1998). SAV is important because it improves water quality (Rybicki and Hammerschlag 1991), and provides refuge habitat for migratory fish and planktonic prey items (Maldeis 1978; Killgore *et al*. 1989; Monk 1988).

Section 5.1A: Agriculture

Issue 5.1A.1: Sedimentation and irrigation

Decreased water quality from sedimentation became a problem with the advent of land-clearing agriculture in the late 18th century (McBride 2006). Agricultural practices can lead to sedimentation in streams, riparian vegetation loss, influx of nutrients (e.g., inorganic fertilizers and animal wastes), and flow modification (Fajen and Layzer 1993). Agriculture, silviculture, and other land use practices can lead to sedimentation, which reduces the ability of semi-buoyant eggs and adhesive eggs to adhere to substrates (Mansueti 1962).

In addition, excessive nutrient enrichment stimulates heavy growth of phytoplankton that consume large quantities of oxygen when they decay, which can lead to low dissolved oxygen during the growing season (Correll 1987; Tuttle *et al*. 1987). Such conditions can lead to fish kills during hot summer months (Klauda *et al*. 1991b).

Another factor, chemical contamination from agricultural pesticides, has a significant potential to impact stream biota, especially aquatic insects, but is difficult to detect (Ramade *et al*. 1984).

Furthermore, irrigation can cause dewatering of freshwater streams, which can decrease the quantity of both spawning and nursery habitat for anadromous fish. Dewatering can cause reduced water quality as a result of more concentrated pollutants and/or increased water temperature (ASMFC 1985).

Uzee and Angermeier (1993) found that in some Virginia streams, there was an inverse relationship between the proportion of a stream's watershed that was agriculturally developed and the overall tendency of the stream to support river herring runs. In North Carolina, cropland alteration along several creeks and rivers has significantly reduced river herring distribution and spawning areas in the Neuse River basin (Hawkins 1979).

Issue 5.1A.2: Nutrient loading

Atmospheric nitrogen deposition in coastal estuaries of states such as North Carolina, has had an increasingly negative effect on coastal waters, leading to accelerated algal production (or eutrophication) and water quality declines (e.g., hypoxia, toxicity, and fish kills). The primary source of atmospheric nitrogen in these areas comes from livestock operations and their associated nitrogen-rich (ammonia) wastes, and to a lesser degree, urbanization, agriculture, and industrial sources (Paerl *et al*. 1999). Animal production farms have greatly contributed to deteriorating water quality in other areas, including the Savannah, Ogeechee, and Altamaha Rivers (Georgia), and the Chesapeake Bay (USFWS-NMFS 1998; Collins *et al*. 2000; McBride 2006).

From the 1950s to the present, increased nutrient loading has made hypoxic conditions more prevalent (Officer *et al*. 1984; Mackiernan 1987; Jordan *et al*. 1992; Kemp *et al*. 1992; Cooper and Brush 1993; Secor and Gunderson 1998). Hypoxia is most likely caused by eutrophication, due mostly to non-point source pollution (e.g., industrial fertilizers used in agriculture) and point source pollution (e.g., urban sewage).

Section 5.1B: Avoiding, Minimizing, and Mitigating Agricultural Impacts

Approach 5.1B.1: Erosion control and best management practices

Erosion control measures and best management practices (BMPs) can reduce sediment input into streams, which can reduce the impact on aquatic fauna (Lenat 1984; Quinn *et al*. 1992). Agricultural BMPs may include: vegetated buffer strips at the edge of crop fields, conservation tillage, strip cropping, diversion channels and grassed waterways, soil conservation and water quality planning, nutrient management planning, and installing stream bank fencing and forest buffers. Animal waste management includes: manure storage structures, runoff control for barnyards, guttering, and nutrient management (ASMFC 1999). Programs to upgrade wastewater treatment at hog and chicken farms should be promoted (NC WRC 2005). Additionally, restoring natural stream channels and reclaiming floodplains in areas where the channel or shoreline has been altered by agricultural practices can help mitigate impacts (VDGIF 2005).

Section 5.2A: Logging/Forestry

Issue 5.2A.1: Logging

Logging activities can modify hydrologic balances and in-stream flow patterns, create obstructions, modify temperature regimes, and input additional nutrients, sediments, and toxic substances into river systems. Loss of riparian vegetation can result in fewer refuge areas for fish from fallen trees, fewer insects for fish to feed on, and reduced shade along the river, which can lead to increased water temperatures and reduced dissolved oxygen (EDF 2003). Potential threats from deforestation of swamp forests include: siltation from increased erosion and runoff; decreased dissolved oxygen (Lockaby et al. 1997); and disturbance of food-web relationships in adjacent and downstream waterways (Batzer et al. 2005).

In South Carolina, forestry BMPs for bottomland forests are voluntary. When BMPs are not exercised, plant material and disturbed soils may obstruct streams, excessive ruts may force channel-eroded sediments into streams, and partially stagnated waters may become nutrient-rich, which can lead to algal growth. These factors contribute to increased water temperature and reduced dissolved oxygen (McCord 2005b).

Section 5.2B: Avoiding, Minimizing, and Mitigating Logging Impacts

Approach 5.2B.1: Best management practices

Virginia advocates working with private, small foresters to implement forestry BMPs along rivers to reduce the impacts of forestry practices (VDGIF 2005). Florida discourages new bedding on public lands where there is healthy groundcover (FFWCC 2005).

Section 5.3A: Urbanization and Non-Point Source Pollution

Issue 5.3A.1: Pollution impacts on fish and fish habitat

Urbanization can cause elevated concentrations of nutrients, organics, or sediment metals in streams (Wilber and Hunter 1977; Kelly and Hite 1984; Lenat and Crawford 1994). Recent studies conducted in Charleston Harbor, South Carolina, found that crustacean prey of estuarine fishes are directly affected by urbanization and related water quality parameters, including concentrations of a variety of toxicants (especially petroleum-related materials) (EDF 2003). Furthermore, the amount of developed land may influence use of a habitat, but other factors such as size, elevation, and habitat complexity are important as well, and in some cases may outweigh the negative effects of development (Boger 2002). More research is needed on how urbanization affects diadromous fish populations.

One study found that when the percent of land in areas increased to about 10% of the watershed, the number of alewife egg and larvae decreased significantly in tributaries of the Hudson River, New York (Limburg and Schmidt 1990).

Section 5.3B: Avoiding, Minimizing, and Mitigating Impacts of Urbanization and Non-Point Source Pollution

Approach 5.3B.1: Best management practices

Urban BMPs include: erosion and sediment control; stormwater management; septic system maintenance; and forest buffers (ASMFC 1999). Siting stormwater treatment facilities on upland areas is recommended where possible (FFWCC 2005). Wooded buffers and conservation easements should be established along streams to protect critical shoreline areas (ASMFC 1999), and low impact development should be implemented, where practicable (NCWRC 2005).

Since the abundance of SAV is often used as an indirect measure of water quality, and there is a correlation between water quality and alosine abundance, steps should be taken to halt further reduction of underwater sea grasses (especially important in the Chesapeake Bay) (B. Sadzinski, Maryland Department of Natural Resources, pers. comm.).

Regarding cumulative effects on river herring spawning habitat, Boger (2002) suggested that land use and morphology within the entire watershed should be considered, and that the cumulative effects within the entire watershed may be as important as the type of land use within buffer zones. This is an important point to consider when establishing required widths of buffer zones in an effort to balance anthropogenic activities in the watershed and maintain biological integrity of streams (Boger 2002).

THREAT #6: ATMOSPHERIC DEPOSITION

Section 6.1A: Atmospheric Deposition

Issue 6.1A.1: Acid rain and low pH

Atmospheric deposition occurs when pollutants are transferred from the air to the earth's surface. This occurrence inputs a significant source of pollutants to many water bodies. Pollutants can get from the air into the water through rain and snow, falling particles, and absorption of the gas form of the pollutants into the water. Atmospheric deposition that causes low pH and elevated aluminum (acid rain) can contribute to changes in fish stocks. When pH declines, the normal ionic salt balance of the fish is compromised and fish lose body salts to the surrounding water (Southerland *et al*. 1997).

American shad stocks that spawn in poorly buffered Eastern Shore Maryland rivers, like the Nanticoke and Choptank, were found to be vulnerable to storm-induced, toxic pulses of low pH and elevated aluminum. These stocks, therefore, may recover at a much slower rate than well-buffered Western Shore stocks, even if all other anthropogenic stressors are removed (Klauda 1994; ASMFC 1999). Streams often experience their highest levels of acidity in the spring, when adult shad are returning to spawn (Southerland *et al*. 1997).

There is speculation that recent precipitous declines in American shad populations may partly be due to acid rain (Southerland *et al*. 1997). Fertilized eggs, yolk-sac larvae, and to a lesser degree, young feeding (post yolk-sac) larvae of American shad have the highest probability for exposure to temporary episodes of pH depressions and elevated aluminum levels in, or near, freshwater spawning sites (Klauda 1994). Klauda (1994) suggests that even infrequent and temporary episodes of critical or lethal pH and aluminum exposures in the spawning and nursery areas could contribute to significant reductions in egg or larval survival of American shad and thereby slow stock recovery. High mortalities of hatchery-reared American shad larvae in 2006 and 2007 were thought to be due to pH depression and elevated aluminum (M. Hendricks, Pennsylvania Fish and Boat Commission, pers. comm.). In 2008, treatment of raw hatchery water with limestone sand raised pH from 6.0 to above 7.0, and resulted in high survival and healthy larvae. Juvenile fish are more susceptible to the effects of low pH, which may effectively prevent reproduction (Klauda 1994).

Threats may be seasonal, ongoing, or even sporadic, all of which can have long-term effects on the recovery of stocks. For example, Hurricane Agnes in 1972 is suspected of causing the 1972 year-class failure for American shad, hickory shad, alewife, and blueback herring, as well as altering many spawning habitat areas in the Chesapeake Bay. Almost twenty years later, these impacts were suggested to be contributing to the slow recovery of stocks in this area (Klauda *et al*. 1991b).

Section 6.1B: Avoiding, Minimizing, and Mitigating Impacts of Atmospheric Deposition

Approach 6.1B.1: Reduction of airborne chemicals

Supporting the reduction of airborne chemical releases from power plants, paper mills, and refineries is one way to decrease the levels of toxins in the air that eventually settle into riverine habitat. Incentives can be promoted at the state level and through cooperative interstate agreements (FFWCC 2005).

Effects of Habitat Degradation on Harvesting/Marketability

Effects of habitat degradation that result in non-natural mortality can affect the size of the population and ultimately the size of the allowable harvest. Some threats may not increase mortality, but can reduce or eliminate marketability. These threats include non-lethal limits of contaminants that may render fish unfit for human consumption, or changes in water quality that may reduce fish condition or appearance to a point where they are unmarketable (ASMFC 1999).

The following table lists threats that have been identified for shad and river herring habitat. Because the magnitude of an impact may vary locally or regionally, the degree to which each impact may occur is not specified. Instead, the likelihood to which each impact may occur within each geographical area (riverine waters, territorial waters, or EEZ) is provided.

Table 1. Threats identified for shad and river herring. The categories are as follows: Present (P) denotes a threat that has been specifically identified in the literature; No Information Found (NIF) indicates that no information regarding this threat was found within the literature, but there is a possibility that this threat could occur within the specified geographical area; and Not Present (NP) indicates that the threat could not possibly occur within that geographical area (e.g., dam blockage in the EEZ).

THREAT	**Riverine Waters**	**Territorial Waters**	**EEZ**
Chemical			
Acid/aluminum pulses	P	NIF	NIF
Sedimentation	P	NIF	NIF
Suspended particles	P	NIF	NIF
Inorganic inputs	P	P	NIF
Organic chemicals	P	P	NIF
Thermal effluent	P	P	NP
Urban stormwater pollution	P	P	NIF
Sewage/animal waste	P	P	NIF
Non-point source pollution	P	P	NIF
Physical			
Dams/spillways	*P*	NP	NP
Other man-made blockages (e.g., tide gates)	P	P	NP
Non-anthropogenic blockages (e.g., vegetative debris)	P	NP	NP
Culverts	P	NP	NP
Inadequate fishways/fish-lifts	P	NP	NP
Water releases from reservoirs	P	P	NP
Non-hydropower water withdrawal facilities (e.g., irrigation, cooling)	P	P	NP
Channelization	P	NIF	NP
Dredge and fill	P	P	NP
Urban and suburban sprawl	P	NIF	NP
Land-based disturbances (e.g., de-forestation)	P	NIF	NP
Jetties	NP	P	NP
Overharvesting	P	*P*	P
Biological			
Excessive striped bass predation	P	P	NIF
Nuisance/toxic algae	P	NIF	NIF

Appendix E - Protected Species Considerations

Marine Mammals

In October 1995, Commission member states, NMFS and USFWS began discussing ways to improve implementation of the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA) in state waters. Historically, these policies have been only minimally implemented and enforced in state waters (0-3 miles). It was agreed that the Commission's plans describe impacts of state fisheries on certain marine mammals and endangered species—collectively termed protected species—and recommend ways to minimize these impacts. Section 117 of the MMPA requires that NMFS and the U.S. Fisher and Wildlife Service (USFWS) develop stock assessment reports (Reports) for all marine mammal stocks within U.S. waters or that enter U.S. waters (e.g., stocks for which only the margins of the range extends into U.S. waters or that enter U.S. waters only during anomalous current or temperature shifts). Each Report is required to estimate the annual human-caused mortality and serious injury of the stock, by source, and, for a strategic stock, other factors that may be causing a decline or impeding recovery of the stock, including effects on marine mammal habitat and prey, and commercial fisheries that interact with the stock.

Section 3(20) of the MMPA defines a strategic stock as a stock: (1) for which the level of direct human-caused mortality exceeds the potential biological removal (PBR) level; (2) which is declining and is likely to be listed under the Endangered Species Act (ESA) within the foreseeable future; or (3) which is listed as a threatened or endangered species under the ESA or as a depleted species under the MMPA.

Section 3(20) of the MMPA defines the term *potential biological removal* (PBR) as:

> [T]he maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population.

For strategic stocks interacting with Category I and II fisheries, Section 118(f) of the MMPA requires NMFS to appoint a Take Reduction Team (TRT), which must develop a Take Reduction Plan (TRP) designed to assist in the recovery of or to prevent the depletion of the strategic stock that interacts with a commercial fishery. Section 118(f)(2) of the MMPA states that the immediate goal of a TRP for a strategic stock shall be to reduce, within six months of its implementation, the incidental mortality or serious injury of marine mammals incidentally taken in the course of commercial fishing operations to levels less than the PBR level established for that stock under Section 117.

Upon the completion of draft stock assessment reviews developed under Section 117 of the MMPA, NMFS recognized the need to establish TRTs to reduce serious injury and mortality of coastal bottlenose dolphins, harbor porpoises and large whales in several coastal gillnet fisheries along the Atlantic coast.

Harbor Porpise and coastal bottlenose dolphin are taken by gillnets in coastal state waters at the time alosine fisheries occur, designated as the Mid-Atlantic gillnet fishery under the MMPA's List of Fishery process. The Mid-Atlantic gillnet fishery operates year-round west of a line drawn at 72° 30' W. long. south to 36° 33.03' N. lat. and east to the eastern edge of the EEZ and north of the North Carolina/South Carolina border, not including waters where Category II and Category III inshore gillnet fisheries operate in bays, estuaries and rivers (72 FR 66048; November 27, 2007). Both Harbor Porpoise and bottlenose dolphins are known to enter tidal estuaries.

Harbor Porpoise

Harbor porpoises that are found along the eastern United States are considered to be one stock or population: the Gulf of Maine/Bay of Fundy stock. This population is dispersed in the Gulf of Maine and Mid-Atlantic in the winter and spring, and then is more concentrated in the Bay of Fundy/upper Gulf of Maine in the summer. The Harbor Porpoise Take Reduction Plan (HPTRP) became effective in January 1999 and implemented regulations in New England and the Mid-Atlantic to reduce the serious injury and mortality of harbor porpoises in commercial gillnet fisheries. The timing and location of the HPTRP management areas coincide with the temporal and seasonal distribution of harbor porpoises.

In July 1993, the Northeast Fisheries Science Center's Sea Sampling (Observer) program initiated an observer program in the Mid-Atlantic coastal gillnet fishery. From 1995 to 2000, 114 harbor porpoises were observed taken (Waring *et al.* 2002). During that time, observed fishing effort was scattered between New York and North Carolina from the beach to 50 miles from shore. Most of the animals taken in state waters are taken in the months of March, April and May, from North Carolina to New Jersey. After 1995, documented bycatch was observed from December to May. The timing and location of stranding data in Mid-Atlantic States follow the timing and location(s) of the ocean-intercept shad fishery as it moves north along the coastline. It is important to note that the East Coast American shad ocean-intercept fishery closed in 2005.

Annual average estimated harbor porpoise mortality and serious injury from the Mid-Atlantic coastal gillnet fishery between 1995 and 1998, before implementation of the Harbor Porpoise Take Reduction Plan, (63 FR 66464, December 2, 1998), was 358 animals (Waring *et al.* 2002). Subsequently, between 2000 and 2004, the average annual harbor porpoise mortality and serious injury in this fishery was 65 animals (Waring *et al.* 2006). However, NMFS has observed an increase in harbor porpoise takes in commercial gillnet fisheries in recent years, due to a lack of compliance with the HPTRP requirements and takes occurring outside HPTRP management areas. The most recent Report estimates that between 2001 and 2005, the total annual estimated average human-caused mortality was 734 harbor porpoises per year (652 from U.S. fisheries), which is higher than the current PBR of 610 (Waring *et al.* 2007).

NMFS reconvened the Harbor Porpoise Take Reduction Team (HPTRT) in December 2007 to discuss updated harbor porpoise abundance and bycatch information. An additional HPTRT meeting was held in January 2008 via teleconference. The HPTRT made recommendations for modifying the HPTRP to address the recent increases in harbor porpoise takes in both the New England and Mid-Atlantic regions.

Bottlenose Dolphin

There are at least two morphologically and genetically distinct stocks of bottlenose dolphin along the eastern coast of the United States: (1) a coastal migratory stock that occurs in coastal waters from Long Island, New York to as far south as central Florida; and (2) an offshore stock primarily distributed along the outer continental shelf and slope in the Northwest Atlantic Ocean. The coastal morphotype is comprised of a complex mosaic of 7 spatial and temporal management units. Resident estuarine stocks are likely demographically distinct from the coastal management units; however, they are currently included in the coastal management unit definitions (Waring *et al.* 2007). Although the estuarine stocks are currently reported with the management units, abundance, mortality and PBR estimates do not include estuarine stocks. Research continues to further define the coastal stock management units and the degree of movement of estuarine dolphins into nearshore, coastal waters, as the spatial overlap remains unclear.

The coastal bottlenose stock was designated as depleted under the Marine Mammal Protection Act due to a large-scale, natural die-off in 1987-1988. Therefore, the coastal stock is listed as strategic because of this die-off and exceeding PBR from serious injuries and mortalities incidental to commercial fisheries. Because one or more of the management units may be depleted, all of the management units currently retain the depleted status.

Estimated annual mortality previously exceeded PBR in at least one management unit. From 2001-2005, the total estimated average annual fishery-related mortality was 61 dolphins attributed to the Mid-Atlantic gillnet fishery. These takes occurred in the Northern Migratory, Northern North Carolina and Southern North Carolina Management Units during both summer and winter months. From 2001-2005, an annual estimate of at least 5 (CV= 0.53) mortalities occurred in the shark drift gillnet fishery off the coast of Florida, affecting the Central Florida Management Unit. Currently, there are no observer data for other fisheries interacting with the coastal stock. However, stranding data indicate interactions with the Virginia Pound Net Fishery and the Atlantic Blue Crab Trap/Pot Fishery. Therefore, the total average annual mortality estimate is a lower bound of the actual annual human-caused mortality for each coastal management unit (Waring *et al*. 2007).

The Bottlenose Dolphin Take Reduction Team (BDTRT) was convened in 2001, and the Bottlenose Dolphin Take Reduction Plan was implemented in May 26, 2006 (71 FR 24776) to address the serious injuries and mortalities incidental to nine Category I and II fisheries. Estimated fishery mortality currently does not exceed PBR for any of the management units due to recent declines in fishery efforts (Waring *et al*. 2007).

Sea Turtles

Sea turtles that occur in U.S. waters are listed as either endangered or threatened under the ESA. Five species occur along the Atlantic coast of the United States: loggerhead (*Caretta caretta*), Kemps ridley (*Lepidochelys kempii*), green (*Chelonia mydas*), leatherback (*Dermochelys coriacea*), and hawksbill (*Eretmochelys imbricata*).

Shad and river herring are harvested primarily with anchored, staked and drift gillnets; however, there is also a pound net, trawl, and hook and line component to these fisheries. All of these gear types are documented to impact sea turtles. Because these fisheries occur inshore, it is likely to interact with sea turtles depending on the location and season.

A. Gillnets

Stranded loggerhead and Kemp's ridley sea turtles have been partially or completely entangled in gillnet material, and are most likely to come in contact with the gear in shallow coastal waters. Loggerheads and leatherbacks have been captured in the Mid-Atlantic gillnet fishery. Green sea turtles are present in small numbers in these areas and could also be taken in this fishery. Leatherbacks are also present, especially when warmer waters bring jellyfish, their preferred prey, into coastal areas. Hawksbill sea turtles are only rare visitors to the areas where fishing effort occurs, preferring coral reefs with sponges for forage, so interaction would be limited; however, entanglement in gillnets has been identified as a serious problem for hawksbills in the Caribbean (NMFS and USFWS 1993).

Spring and fall gillnet operations have been strongly implicated in coincident sea turtle stranding events from North Carolina through New Jersey. On average, the highest numbers of interactions occurred in spring, followed by summer and fall. The southern states appear to have had more spring interactions, while the northern states had more summer interactions, probably due to the northern migration of sea turtles in the warmer months.

Netting gear found on stranded turtles varied widely, from 2-11.5-inch (5-29-cm) stretch mesh, and ranged from small, cut pieces of net, to lengths of abandoned net (up to 1200 feet (365 m)). Net gear was of various materials including nylon, cotton, and propylene, and in various colors including blue, black and green. Gear type included flounder, sturgeon, and mullet nets, monofilament, twine, gillnets, pound nets, trammel nets, seines, sink nets, and nets attached to anchors, cork floats and buoys.

B. Pound Nets

Most of pound net fishery interactions result in live releases and are documented primarily from North Carolina, Virginia, Long Island and Rhode Island. In Chesapeake Bay, Virginia, turtles become entangled in pound nets starting in mid-May with increasing numbers of entanglements until late June. The construction of leaders in pound nets was found to be a significant factor in these entanglements (Musick *et al*. 1987). Entanglement was found to be insignificant for small mesh (8-12 inch mesh = small; >12-16 inch mesh = large). Large-mesh nets and nets with stringers spaced 16-18 inches apart entangled a large number of turtles. Therefore, the potential to entangle sea turtles in pound nets could be alleviated by decreasing the mesh size in the leaders (Musick *et al*. 1987). The pound net component of the shad and river herring fishery for North Carolina occurs in Albemarle Sound, which is not frequented by turtles due to the relatively low salinities found there.,

C. Hook-and-Line

From 1991 through 1995, a total of 112 stranded turtles had fishing hooks associated with some part of their bodies. Sea turtles have also been caught on recreational hook and line gear. For example, from May 24 to June 21, 2003, five live Kemp's ridleys were reported as being taken by recreational fishermen on the Little Island Fishing Pier near the mouth of the Chesapeake Bay. Many other similar anecdotal reports exist. These animals are typically alive and, while the hooks should be removed whenever possible and when it would not further injure the turtle, NOAA fisheries suspects that the turtles are probably often released without hooks being removed. It is unlikely that hook and line fishing for shad impact sea turtles because most shad angling occurs in inland waters not frequented by seaturtles.

D. Recommendations for Sea Turtle Protection

1. A conservation plan and application for a Section 10 ESA incidental take permit should be developed for those states where the fishery occurs when sea turtles are present.
2. Research into gear development/deployment for gillnets should be conducted to minimize the impact on sea turtles.
3. Pound net leaders should be no larger than 12-inch mesh.
4. Public outreach material should be developed to improve awareness of sea turtle entanglement with hooks and monofilament line.

Migratory Coastal Birds

An unknown, but possibly significant, number of migratory birds are drowned each year in anchored gillnets in the nearshore marine waters of the mid-Atlantic region. Preliminary estimates, based on a study underway by the U.S. Fish and Wildlife Service and incidental mortality data from the Services Madison Wildlife Health Laboratory, indicate that many thousands of loons and sea ducks are killed each year. Before the ocean-intercept shad fishery closure, most shad/bird interactions occur during January through March from North Carolina to New Jersey. South Carolina banned anchored gillnets in their coastal fishery because of excessive bird mortalities.

All of the species listed in Table 2 are diving birds which pursue fish underwater or feed on benthic invertebrates. Fish eating birds are especially vulnerable to drowning in gillnets because they pursue prey underwater. Additionally, fish eating birds may be attracted to the vicinity of nets that are anchored for days at a time to feed on forage fish feeding near the nets. All of the birds listed are present along the Atlantic coast from October through April, depending on weather and timing of migration. Double-crested cormorants are present throughout the year but are most abundant in the middle and northern Atlantic states during the summer.

The actual populations of most migratory coastal birds are largely unknown. Except for some diving ducks (*Aythya*), current surveys sample only a small portion of the populations of sea ducks and do not survey for non-game birds such as loons and grebes. The U.S. Migratory Bird Treaty Act prohibits the take and possession of protected migratory birds, except as may be permitted by regulations. Take means to pursue, hunt, shoot, wound, kill, trap, capture or collect. Possession means to detain and control.

A list of protected bird species most likely to interact with shad herring fisheries along the Atlantic coast are listed in Table 2 and their status can be found in Table 3.

Table 1 List of protected birds in nearshore marine coastal waters most likely to interact with gillnets.

Common Name	**Species Name**
Common Loon	*Gavia immer*
Red-throated Loon	*Gavia stellata*
Horned Grebe	*Podiceps auritus*
Red-necked Grebe	*Podiceps grisegena*
Double-crested Cormorant	*Phalacrocorax auritus*
Northern Gannet	*Sula bassanus*
Oldsquaw	*Clangula byemalis*
Black Scoter	*Melanitta nigra*
Surf Scoter	*Melanitta perspicillata*
Red-breasted Merganser	*Mergus serrator*

Table 2. Protected birds in coastal bays most likely to interact with gillnets and their East Coast population status.

Species		**Status**
Common Name	**Species Name**	
Common Loon	*Gavia immer*	Unknown
Red-throated Loon	*Gavia stellata*	Unknown, 50,000+ winter south of NJ
Horned Grebe	*Podiceps auritus*	Unknown
Red-necked Grebe	*Podiceps grisegena*	Unknown
Double-crested Cormorant	*Phalacrocorax auritus*	Abundant and increasing
Redhead	*Aythya americana*	Depressed but increasing slightly
Canvasback	*Aythya valisineria*	Slightly increasing
Greater Scaup	*Aythya marila*	Decreasing
Lesser Scaup	*Aythya affinis*	Stable
Ring-necked Duck	*Aythya collaris*	Unknown
Red-breasted Merganser	*Mergus serrator*	Stable
Common Goldeneye	*Bucephala clangula*	Stable
Bufflehead	*Bucephala albcola*	Increasing
Oldsquaw	*Clangula hyemalis*	Stable
Black Scoter	*Melanitta nigra*	Probably declining
White-winged Scoter	*Melanitta fusca*	Probably declining
Surf Scoter	*Melanitta perspicillata*	Probably declining
Ruddy Duck	*Oxyura jamaiccasis*	Stable

Shortnose Sturgeon

The shad gillnet fishery has long been known to capture large numbers of sturgeon (Leland 1968), including adult shortnose sturgeon (Collins and Smith 1995). In the southeast, the shad fishery is likely the primary source of injury and direct mortality of shortnose sturgeon (Collins *et al*. 1996). Existing data indicate that in the southeastern U.S., this species occurs in the shad gillnet bycatch in every river system that supports both a shad gillnet fishery and a shortnose sturgeon population.

The riverine shad gillnet season and the shortnose sturgeon spawning migration normally coincide in the southeastern U.S., resulting in capture of individuals intending to spawn (females apparently spawn only once every 2-3 years). Preliminary data suggest that non-lethal encounters of migrating sturgeon with gillnets may result in fallback (i.e., individuals abort the migration, move back downriver, and presumably resorb their gametes) (unpublished data; pers. comm., M. Moser, UNC Wilmington). Thus, in addition to causing injury and direct mortality of spawners, the non-lethal capture of sturgeon in the shad gillnet fishery may cause reduced spawning success and low year class strength.

A. Recommendation for Shortnose Sturgeon Protection

A conservation plan and application for a Section 10 ESA incidental take permit should be developed for those states where the fishery occurs when shortnose sturgeons are present and shortnose sturgeon are a documented bycatch..